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Economic, biodiversity, resource protection and social values of orchards: A study of six orchards by the Herefordshire Orchards Community Evaluation Project

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

This report describes the results of a partnership project, which ran from 2006-2010, to investigate the values of orchards beyond value generated by the economic enterprise of orchard management. Uncertainty in markets for orchard produce, development pressure, neglect and land use change all pose threats to the continued existence of orchards, making a full understanding of the values of orchards an urgent need.

The project was set up by the Herefordshire Orchard Topic Group, an independent association of individuals and organizations working to support all aspects of orchards and orcharding in Herefordshire.

Project objectives were:

- To investigate the range of values of orchards in Herefordshire from economic, environmental and social perspectives.
- To attempt to apply monetary value to these values.
- To engage local communities and disseminate the results of the project as widely as possible.
- To use the project to inspire further action that would increase knowledge and awareness of the values of orchards.

Orchard values were investigated by looking in detail at six orchards selected as case studies to represent the different types and characteristics of orchards found in Herefordshire. All the orchards had multiple values, although not all orchards had all the values assessed and values differed in importance across orchards. The project found that local communities cared about the orchards in their locality, and welcomed engagement about their worth.

Each of the chapters about orchard values in the report has been peer-reviewed but the findings are the responsibility of the authors alone and do not necessarily represent the views of any of the partnership organisations. Monetary evaluation is a particularly difficult topic. The approach chosen by the authors is one of many and is of interest, but should not be regarded as being Natural England's preferred approach. Natural England is using the results of the project to strengthen the evidence base relating to orchards.

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Further information
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Economic, biodiversity, resource protection and social values of orchards: a study of six orchards by the Herefordshire Orchards Community Evaluation Project

Edited by
H. Robertson, D. Marshall, E. Slingsby and G. Newman

2012

ECHO's Orchard

This project was part-financed by the European Union (EAGGF) and DEFRA through the Herefordshire Rivers LEADER+ Programme.

This project has been supported by the Sustainable Development Fund, a Defra initiative in the Wye Valley Area of Outstanding Natural Beauty (AONB).

ECHO's Orchard: The cover photograph shows a collage made by a group from ECHO of themselves in an orchard. The collage was made for the Orchard Art competition, a project arising from the Herefordshire Orchards Community Evaluation Project. ECHO for Extra Choices in Herefordshire is a registered charity providing opportunities for adults with learning disabilities. The image is reproduced with the permission of ECHO.

Summary

Orchards in Herefordshire form an important element of the economic activity, landscape and culture of the county. Uncertainty in markets for orchard produce, development pressure, neglect and land use change all pose threats to the continued existence of orchards. Such threats spurred the Herefordshire Orchard Topic Group to find out what the full value of orchards might be, beyond value generated by the economic enterprise of orchard management. In addition to economic value, values may relate to environmental features such as biodiversity and social attributes such as appreciation by local communities. Little was known about these wider orchard values by orchard managers, policy makers, conservationists, scientists and local communities in Herefordshire and elsewhere and a partnership project was set up to try to fill these knowledge gaps. The project is the first known attempt to investigate the multiple values of orchards in the UK.

The Herefordshire Orchard Topic Group is an independent association of individuals and organizations working to support all aspects of orchards and orcharding in Herefordshire. The project was managed on behalf of the Orchard Topic Group by The Bulmer Foundation, a registered charity which seeks to enable and demonstrate sustainable development, focused in Herefordshire. Forum for the Future, a UK-based sustainable development charity, was commissioned to work with the Bulmer Foundation to develop and implement the methodology for the valuation process. A particularly important element of the project was the involvement of orchard owners, local communities, visitors to Herefordshire and local naturalists in exploring the values of orchards. Many people volunteered their time to participate in the project and their contribution was an essential part of the partnership that delivered the project.

The project was named the Herefordshire Orchards Community Evaluation Project and had the following objectives:

- To investigate the range of values of orchards in Herefordshire from economic, environmental and social perspectives.
- To attempt to apply monetary value to these values.
- To engage local communities and disseminate the results of the project as widely as possible.
- To use the project to inspire further action that would increase knowledge and awareness of the values of orchards.

Economic and environmental values considered to be of key importance by the Topic Group were selected for investigation. Economic values chosen were orchard profitability, benefit to the local economy by expenditure on orchard management by orchard owners and spending by tourists. Environmental values selected were biodiversity and resource protection, the latter in terms of climate regulation by net carbon sequestration, soil quality and protection from diffuse pollution. Social values were identified by the local communities living in the vicinity of the study orchards, and were specific to each community. Monetary valuation was made through a ‘triple bottom line’ accounting process to encompass environmental and social valuations in addition to the economic valuation.

The project was led by David Marshall of the Bulmer Foundation. The project began in 2006 and most of the work was done by 2008, but further data collection and analysis went on into 2009 and 2010. Orchard values were investigated by looking in detail at six orchards selected as case studies to represent the different types and characteristics of orchards found in Herefordshire. The orchards selected could be assigned to two main types, namely traditional and intensive orchards. Traditional orchards have low-intensity management, without use of inorganic fertilisers or pesticides, in contrast to intensive orchards, where inorganic fertilisers and pesticides are used. Within these types, the case study sites had varying attributes:

- Henhope Orchard: Traditional, certified organic, cider apples, machine-harvested, livestock enterprise (sheep), very low visibility in the landscape, no public access.
- Tidnor Wood Orchards: Traditional but previously intensive, certified organic, cider apples, machine-harvested, livestock enterprise (sheep), Community Interest Company, cider apple heritage collection, above medium visibility in the landscape, public access by arrangement.
- Lady Close Orchard: Traditional, recently restored from old remnant orchard, dessert and culinary apples, not harvested, livestock enterprise (sheep), in nature reserve, above medium visibility in the landscape, public ownership and access, close to village.
- Half Hyde Orchard: Traditional, cider apples, machine-harvested, livestock enterprise (cattle), quite high visibility in the landscape, no public access.
- Salt Box Orchard: Intensive, cider apples, machine-harvested, medium visibility in the landscape, no adjacent settlement, public footpath.
- Village Plum Orchard: Intensive, plum, manual-harvested, medium visibility in the landscape, edge of village location, public footpath.

Some biodiversity and carbon storage information was collected for a seventh orchard, Romulus Orchard, as it lay adjacent to Half Hyde Orchard and provided a useful comparison to this orchard.

Details about management, land use history and fruit varieties were collected from the orchard owners, along with estimates of income and costs associated with orchard production for 2006 or 2007. No account was taken of 'irregular' costs or long-term costs, such as the cost of replacing the orchard at the end of its productive life. Factors such as depreciation in the value of machinery were not taken into account. The income and cost estimates enabled orchard profitability to be calculated. Purchases by the orchard owner from local suppliers or wages spent locally by orchard employees were identified in order to estimate the benefit to the local economy through applying a factor of 1.0 to represent the local multiplier effect of 're-spending' of this money in Herefordshire.

All the orchards generated income, even Lady Close Orchard where no fruit was harvested, although income here was small. Nevertheless, the low management costs for Lady Close meant that a small net profit was recorded for the orchard. The fruit crop dominated earnings in the other 5 orchards. The plum harvest was worth over three times that of the cider apple crops but was more costly to pick and pack. The densely planted apple trees in Salt Box Orchard yielded the largest profit per hectare (ha) but Village Plum Orchard made the largest contribution to local expenditure / ha, primarily because of the money paid to the plum pickers and their spending in the local economy. The profit / ha made by Salt Box Orchard, an intensive cider apple orchard, was greater than the profit / ha from the traditional cider orchards such as Henhope Orchard. However, Henhope Orchard was more profitable / ha than the intensive plum orchard. Tidnor Wood Orchards was a special case as it was the only orchard to have a negative net profit, although it contributed the most to the local economy after Village Plum Orchard. Labour costs at Tidnor were high because of significant work being undertaken by the owner to develop the orchard in several ways. These included the establishment of the site as a registered National Collection of cider apples. Tourism values were estimated from an average for each orchard, related to total tourism spend in the county, weighted by visibility of each orchard and by whether the orchard had traditional or intensive management. Three of the traditional orchards had higher tourism value than the intensive orchards but Henhope Orchard had lower visibility and lower tourism value than the intensive orchards.

The biodiversity of the study orchards was investigated through a habitat survey and species surveys. The report concentrates on bryophytes (mosses and liverworts), lichens, fungi and myxomycetes, because these groups have been relatively little studied in orchards. A brief review was also made of the potential value of the orchard habitats for invertebrates and birds. The habitat survey covered the orchard habitat mosaic of the fruit trees, the orchard floor and the orchard boundaries. Orchard management played a major role in determining the features of these habitats. The traditional orchards qualified as priority habitats for conservation under the UK

Biodiversity Action Plan (BAP). The traditional orchards contained larger and older fruit trees with a greater abundance of veteran tree features than the intensive orchards, which were managed for high fruit productivity, and which utilised densely-planted bush trees. The traditional orchards contained larger numbers of fruit varieties than the intensive orchards. Orchard floors in the traditional orchards were fully grassed while those in the intensive orchards had bare ground under the tree rows, due to management by herbicides. The species-richness of the grasslands varied among the orchards, but most of the grassland was species-poor, probably because of past re-seeding or treatment with inorganic fertilisers and herbicides. All the orchards had hedgerows, most of which were dominated by native woody species and which were priority BAP habitats. The majority of the hedgerows were not in favourable condition, particularly because of gaps in the woody structure of the hedgerows and the abundance of herbaceous plants indicating nutrient enrichment and disturbance. The brief review of habitat and management effects on invertebrates and birds concluded that these two species groups were likely to be favoured by the veteran tree features in the traditional orchards and by the lack of pesticide use.

The bryophyte, lichen, fungus and myxomycete surveys showed that the traditional orchards all had species of special interest, ranging from nationally endangered, rare and scarce species to species uncommon in Herefordshire. No species of special interest were found in the intensive orchards. The traditional orchards had a good variety of epiphytic bryophytes although no rarities were found. Few species were found in the intensive orchards, probably because younger trees predominated, compared to the traditional orchards, rather than because of intensity of management. The lichen survey found 45 species that were epiphytic on fruit trees. One Critically Endangered lichen, *Teloschistes chrysophthalmus*, golden-eye lichen, and two nationally scarce species were recorded in the traditional orchards. The largest number of species was found in the traditional orchard with the oldest trees. Intensive management with pesticide sprays, either during the project period or in the past, of four of the seven orchards, might have played a role in reducing their lichen species complement. The survey provided the first known published lists of fungi in intensively managed orchards in Britain, other than fungi causing diseases of fruit trees, and the first myxomycete lists for orchards in Britain. Frequency of fungus and myxomycete survey visits and lack of bark sampling in some sites most probably affected the numbers of such species found across the orchards. Of those orchards receiving several visits, woody habitats contributed most species to the list in traditional orchards while in the intensive orchard surveyed, Salt Box, herbaceous vegetation produced the most fungus species. Compared with live wood and dead wood still attached to trees, fallen dead wood contributed most species in all the orchards analysed. Grassland fungi from the waxcap group were only found at Henhope Orchard. Grassland here may become richer in fungi over time with continuation of the current low-intensity management.

The way that orchards are managed has implications for the protection of air, water and soil resources. Climate regulation, in terms of carbon storage and net annual carbon sequestration was assessed, as well as impacts of orchard management in relation to potential effects of diffuse pollution of adjacent habitats and on soil quality. In addition, an attempt was made to estimate carbon storage and net annual carbon sequestration by orchard hedgerows. Soil sampling provided estimates of carbon amounts in the soil and measurements for samples of fruit trees were used to estimate storage and accumulation of carbon in fruit trees. Soil carbon storage predominated over storage in fruit trees but amounts of carbon in soil were generally not high compared to soil carbon storage in other habitats, such as woodland and permanent grassland. Soil carbon levels appeared to be significantly affected by land use history. Orchard sites that had been disturbed in the recent past, for example, by arable cultivation, had lower soil carbon levels than orchards that had remained undisturbed. Annual carbon accumulation rates per hectare by fruit trees were estimated to be larger in intensive orchards, which had higher densities of trees, than in traditional orchards. However, amounts of carbon accumulated in the semi-permanent form of wood in fruit trees each year were less than carbon amounts removed each year through fruit harvesting. Comparisons of carbon accumulation per year against carbon emissions, calculated from orchard management details and standard emission factors, revealed that the intensive orchards and one of the traditional orchards were carbon sinks, while the remaining traditional orchards were small sources of carbon emitted to the atmosphere, largely due to emissions from livestock grazing the orchards. Orchard hedgerows were estimated to make a positive contribution to carbon sequestration by the orchards.

The traditional orchards were judged to have had a greater potential to maintain higher soil organic matter status than the intensive orchards, as in these orchards bare ground was maintained along tree rows. Based on existing literature, management with pesticides in the intensive orchards might have possibly resulted in soil biota being less effective in provision of soil-based ecosystem services than in the traditional orchards. The literature suggests that use of pesticides in intensive orchards poses greater potential diffuse pollution risks than their use in other agricultural land uses, due to the total toxicity and amounts of pesticides applied and the need to apply pesticides by air-assisted sprayers. Risk of diffuse pollution of adjacent habitats by nutrients or sediment was judged to be likely to have been relatively low for the study orchards compared to other agricultural land uses. However, the presence of bare ground along tree rows in the intensive orchards and high stocking rates in two of the traditional orchard sites could have exacerbated any loss of nutrients or sediment from these orchards.

The Herefordshire Orchards Community Evaluation Project appears to be the first to undertake structured, direct, interaction with visitors and local communities to ascertain the importance of orchards for people who are not necessarily directly engaged in managing orchards. The assessment of the social value of orchards was carried out by seeking the views of a range of different groups, including general visitors to Herefordshire, visitors to Lady Close Nature Reserve and local communities living around each of the six study orchards. Local people living around these orchards had overwhelming positive responses to the presence of the orchards. Opportunities to enjoy nature and visual attractiveness of orchards were the most important social values, followed by access for walking. Local people were also asked to rank the social values they identified against the key economic and environmental values chosen by the project. Although enjoyment of nature and the natural beauty of orchards were the predominant social values identified by local people, they generally did not highly value the environmental values, such as biodiversity, relative to social values. This could indicate that more needs to be done to relate topics such as climate change and the importance of biodiversity, healthy soil and clean water to the lives of ordinary people. Economic values were rated highly by people living locally, in the case of three orchards more highly overall than social value. General visitors to Herefordshire considered the contribution of orchards to the local economy was very important. General visitors and visitors to Lady Close identified traditional orchards as deserving most financial support, rather than intensive orchards. However, people living near orchards valued orchards highly whether they were traditional or intensive orchards.

The monetary valuation used triple bottom line accounting and was built on the assessment of economic, environmental and social values described in preceding chapters of the report. The values identified in the orchards could be broadly equated to a categorisation of ecosystem services provided by orchards. Triple bottom line accounting proved to be a useful, structured, way of assessing monetary value and costs, although the project could only partially cover the estimation of costs. The advantage of using triple bottom line accounting was as much about the focus that it contributed to the process of investigation as the absolute numbers that the accounts contained. There is no doubt that the analysis was simplistic and imperfect, not only because of some of the assumptions that have been made in the calculations, but also because the interrelationships between values were not taken into account. Biodiversity valuation was particularly challenging but the decision was made to use the fixed cost for favourable habitat management rather than leave biodiversity out of the calculation on the grounds of immeasurability. While the limitations of the measures used to arrive at monetary valuations must be kept in mind, the valuations indicated that each orchard had overall monetary values at least double that of profit alone, based on aggregate figures for each type of value.

The two intensive orchards had the greatest monetary economic value including on a per unit area basis. Orchard profitability to the owner was not always the highest economic value, it was exceeded either by value to the local economy or by tourism value in four out of the six orchards. Climate regulation was the sole monetary environmental value attached to the intensive orchards while biodiversity was the main contributor to the environmental value of traditional orchards. Even though the orchards were clearly important to local communities, monetary social valuation was problematic and the experimental monetary values that were calculated were very influenced by the aggregate economic values of the orchards.

The project was a catalyst for further community activity. Though not part of the formal valuations made by the project, these activities demonstrated a high degree of public interest in other community values of orchards, for example as inspiration for art and drama, which helped to take the message of the value of orchards to new audiences.

Although the project was confined to six case study orchards, it provided pointers to likely values attached to other orchards in the UK, which could be investigated by further research. For example, more survey of bryophytes, lichens and fungi would be helpful, including surveys of species in intensive orchards. A better understanding of the impact of intensive orchard management on these species groups is needed. Examples of resource protection research are the investigation of the contribution of orchards to carbon storage, accumulation and emissions across an orchard landscape and the potential for soil erosion and nitrate loses from orchards.

Acknowledgements

First and foremost we owe a great debt of thanks to the orchard owners for their enthusiastic participation in the project and their endless patience in answering our questions. The project would not have been possible without their support. The commitment of the orchard owners underpins all the values examined in this report. Many other people also volunteered their time to participate in the project and we thank especially the local people who took the time to give us their views about their local orchard and all the local naturalists for their willingness to gather information about the biodiversity of the orchards. Sadly, Stephanie Thomson, who was a keen local naturalist and one of the authors of the biodiversity chapter of the report, has since died. The smooth running of the community evenings was a tribute to the facilitators: Peter Norton, Nicky Davies, Jackie Denman, Helen Forster, Rachel Price, Rob Garner, Shirley Garner, Richard Heathcote, Loraine Boddington, and Claire Skinner. We are grateful to Rebecca Roseff for recording orchard stories and to the people who gave them to Rebecca. Many specialists provided reviews, comments, information and advice and we thank them all: Simon Barker, Alastair Burn, Anita Burrough, Chris Cheffings, Adrian Dawson, Chris Fairs, Vince Giavarini, Emma Goldberg, John Hopkins, Keith Kirby, Richard Jefferson, Peter Lambley, Emily Ledder, Chris Mainstone, Gavin Measures, David Mitchell, Sarah Olney, David Reedy, Robin Stevenson, Dave Stone, Malcolm Storey, Mike Sutcliffe, Ian Taylor, Chris Wedge, Pat Wolesley, Doug Warner, and Rob Wolton. Sarah Hammonds (Natural England Geographic Information Unit) kindly provided essential map data and drew the maps in the report. Morag Daines and Brigid Newland of Natural England's Library Service tirelessly sought out references for us and Malcolm Rush did sterling translations of the foreign language references. Angela Chapple (East Malling Research), Mike Fordon (New York State Agricultural Experiment Station, Cornell University) and David Nowak (USDA Forest Service, Syracuse) were very helpful in tracking down references for us. A special thank you goes to Lindsey Newland for assisting Elizabeth Slingsby with the habitat survey and to Ann Marshall for undertaking surveys with visitors and much other support throughout the project. We are very grateful to Charlie Bower who inspired us to set up the project, together with members of the Herefordshire Orchard Topic Group. The Group provided solid support to the project and the organisations which supplied the essential funding were the Herefordshire Rivers Leader+ Programme, financed by the EU and the UK Government's Department for Food Farming and Rural Affairs (Defra), The Bulmer Foundation, Bulmers, the National Association of Cider Makers, Herefordshire Council, Natural England, and the Sustainable Development Fund, a Defra initiative in the Wye Valley Area of Outstanding Natural Beauty (AONB).

Photograph credits: The cover photograph of ECHO's Orchard was taken by the Hereford Cider Museum. Elizabeth Slingsby took the photographs shown in Plates 2.1, 2.3, 2.4, 2.7, 2.11 - 2.15. The photograph used for Plate 6.7 was taken by Jim Jenkins. All the other photographs were taken by David Marshall.

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1 Introduction

Authors: H. Robertson, D. Marshall, E. Slingsby and G. Newman

Project partnership and background

1.1 Orchards in Herefordshire form an important element of the economic activity, landscape and culture of the county. Uncertainty in markets for orchard produce, development pressure, neglect and land use change all pose threats to the continued existence of orchards. Such threats spurred the Herefordshire Orchard Topic Group to find out what the full value of orchards might be, beyond value generated by the economic enterprise of orchard management. In addition to economic value, values may relate to environmental features such as biodiversity and social attributes such as appreciation by local communities. Little was known about these wider orchard values by orchard managers, policy makers, conservationists, scientists and local communities in Herefordshire and elsewhere and a partnership project was set up to try to fill these knowledge gaps. The project is the first known attempt to investigate the multiple values of orchards in the UK.

1.2 The Herefordshire Orchard Topic Group is an independent association of individuals and organizations working to support all aspects of orchards and orcharding in Herefordshire. It was formed as part of the Herefordshire Sustain Project initiative supported by Small Woods. Membership includes representatives from The Bulmer Foundation, Bulmers, Business Link, the Big Apple, Campaign for the Protection of Rural England, Colwall Orchard Group, Co-operative Wholesale Society, Country Land and Business Association, the Diocese of Hereford, the Duchy of Cornwall, the Forestry Commission, Government Office West Midlands, Herefordshire Biodiversity Partnership, Hereford Cider Museum, Herefordshire Council, Herefordshire Farming and Wildlife Advisory Group, Herefordshire Nature Trust, Herefordshire Partnership, Holme Lacy College, Marcher Apple Network, National Association of Cider Makers, National Farmers Union, National Trust, Natural England, Pryor and Rickett Silviculture, the Tourism Company, Westons Cider and the Woodland Trust.

1.3 The project, called the Herefordshire Orchards Community Evaluation Project, was developed with funding from Leader+, the European Union initiative for assisting rural communities in improving quality of life and economic prosperity in disadvantaged areas. Herefordshire is a relatively disadvantaged, farming-dependant, county and average earnings in Herefordshire are some 20% below the national average according to Herefordshire Council. The specific Leader+ funds came from the Herefordshire Rivers Leader+ Programme, financed by the EU and the UK Government's Department for Food Farming and Rural Affairs (Defra). Other funders were the Bulmer Foundation, Bulmers, the National Association of Cider Makers, Herefordshire Council, Natural England, and the Sustainable Development Fund, a Defra initiative in the Wye Valley Area of Outstanding Natural Beauty *(*AONB*)*.

1.4 The project was managed on behalf of the Orchard Topic Group by The Bulmer Foundation, a registered charity which seeks to enable and demonstrate sustainable development, focused in Herefordshire. Forum for the Future, a UK-based sustainable development charity, was commissioned to work with the Bulmer Foundation to develop and implement the methodology for the valuation process. A particularly important element of the project was the involvement of orchard owners, local communities, visitors to Herefordshire and local naturalists in exploring the values of orchards. Many people volunteered their time to participate in the project and their contribution was an essential part of the partnership that delivered the project.

Project objectives

1.5 The project had the following objectives:

- To investigate the range of values of orchards in Herefordshire from economic, environmental and social perspectives.
- To attempt to apply monetary value to these values.
- To engage local communities and disseminate the results of the project as widely as possible.
- To use the project to inspire further action that would increase knowledge and awareness of the values of orchards.

Implementation of the project

1.6 The project was led by David Marshall of the Bulmer Foundation. The project began in 2006 and most of the work was done by 2008, but further data collection and analysis went on into 2009 and 2010. Orchard values were investigated by looking in detail at six orchards which were selected as case studies to represent the different types and characteristics of orchards found in Herefordshire.

1.7 The orchard project was constrained by funding and time, so could only select some of the possible orchard values. However, the values included were those considered to be of key importance by the Herefordshire Orchard Topic Group. Economic values chosen were orchard profitability, benefits to the local economy by expenditure on orchard management by orchard owners and spending by tourists. Environmental values selected were biodiversity and resource protection, the latter in terms of climate regulation by carbon storage and net carbon sequestration, soil quality and protection from diffuse pollution. Social values were identified by the local communities living in the vicinity of the study orchards, and were specific to each community.

1.8 Monetary valuation was made through a 'triple bottom line' accounting process to encompass environmental and social valuations in addition to the economic valuation. Preliminary estimates of the monetary social, economic and environmental values for the six orchards studied were produced in 2008. Since that time, additional data collection and analyses have been undertaken and assumptions refined, and the results in the current report supersede those of 2008.

1.9 The project is seen as a pilot in the sense that because of its small scale it had to take a case study approach. While features and values of the orchards are compared in the report, a much larger study would be required to reach firm conclusions applicable to all orchards of these types. Nevertheless the project was able to identify topics deserving further work, for consideration by anyone interested in orchards, including environmental organisations, University researchers and their students, natural history societies and individual naturalists.

Structure of the report

1.10 The report takes the form of more or less stand-alone chapters on the selected types of orchard value, each chapter written by a particular group of authors. Cross-references are made to other chapters where necessary to reduce repetition. The report tries to provide adequate detail about methods and findings, with transparency taking precedence over brevity. This approach is taken to safeguard the data and results into the future, to allow comparison with future research. A problem noted during the discussions of the findings of the project in relation to past research was the sometimes inadequate published descriptions of research projects, which significantly reduced the usefulness of such projects.

1.11 Chapter 2 of the report sets the scene for the investigation of the different orchard values and describes the general character and environment of the 6 study orchards. Orchard management and the economic values of the orchards are described in Chapter 3 while biodiversity and resource protection are covered in Chapter 4 and 5 respectively. Social values are examined in Chapter 6. These 4 chapters provide the platform for the monetary valuation of orchards in Chapter 7. The triple bottom line accounts for the 6 orchards are described in Chapter 7 along with an indication of links between values recognised by the project and features that might be valued in ecosystem services assessments.

2 Orchard selection, character and environment

Authors: H. Robertson, E. Slingsby and D. Marshall

Introduction

2.1 The rationale for the choice of study orchards and their principal characteristics are described in this chapter, which sets the scene for the following chapters that deal in detail with economics, biodiversity, resource protection and social aspects of the orchards. First, the general picture of orchards in Herefordshire is briefly described to provide context for the project's study orchards. Next, the selection process for the study orchards is explained, followed by descriptions of the orchards themselves. Information on the characteristics of individual orchards was compiled from maps, aerial photographs, historical and management details provided by orchard owners, habitat survey and soil sampling. The project covered 6 orchards in detail and also collected some biodiversity and carbon storage information about a seventh orchard, Romulus Orchard. Romulus Orchard was adjacent to Half Hyde Orchard, one of the 6 main orchards in the study, and provided a useful comparison to this orchard.

Orchards in Herefordshire

2.2 Herefordshire is a predominantly rural county in the west of England. Stevens and Associates (2010) reported that over 95% of Herefordshire is green space, meaning that the urban area only occupies about 4% of the county area of 217,973 hectares (ha). Most of the countryside is farmed, and is a mix of arable and lowland permanent grassland, with upland grassland occurring in the western fringes of the county. Orchards occupy only about 2.7% of the countryside area of 209,254 ha, although they are highlighted in descriptions of Herefordshire landscapes in Natural England's identification of national character areas (Natural England undated). Herefordshire has been divided into several of these character areas, three of which, the Herefordshire Lowlands (number 100), the Herefordshire Plateau and Teme Valley (101/102) and South Herefordshire and Over Severn (104) cover the bulk of Herefordshire. In these character areas, orchards are identified as one of the key landscape characteristics. The other character areas have stronger upland or woodland characteristics and the descriptions generally make little mention of orchards. All the study orchards lay in the part of Herefordshire covered by the 3 main character areas, 100, 101/102 and 104.

2.3 The character area descriptions for those areas of Herefordshire which are significant for orchards also make reference to the long history of orchards in the county. Orchards were a significant part of the Herefordshire economy since at least the 14th century, and this was reinforced by the development of large scale cider making in the late 19th century and in the 20th century. However, the descriptions also note the more recent losses of orchards and the switch from traditional orchards to bush orchards (Natural England undated).

2.4 The growing of apples for cider and pears for perry features strongly among current Herefordshire orchards, for beverage production by large companies but also by small-scale artisan producers (The Three Counties Cider and Perry Association 2011). Other fruit is also grown in Herefordshire's orchards, indeed growers of dessert apples and cherries have recently won national awards for top-fruit production (Hereford Times 2010, 2011).

2.5 The area of orchards in Herefordshire at the current time is composed of traditional and intensive orchards, which are defined in more detail in the orchard selection section below. The national inventory of traditional orchards in England recently reported that the area in Herefordshire amounted to 2,481.5 ha, the largest of any county in England (Burrough and others 2011). It should be noted that a slightly larger estimate of 2,555 ha was made in 2010, while the inventory was still in progress, for the purposes of orchard valuation (Chapter 7). An approximate estimate of the area of intensive orchards can be made using the Agricultural Census figures for commercial top fruit orchards (Defra, Foss House, York, pers. comm.) and an adjustment factor produced by the Food and Environment Research Agency (FERA), formerly known as the Central Science Laboratory. This factor was derived from a Pesticide Usage Survey in the year 2000 for England and Wales. The latest figure for commercial orchard area available to the project was for 2006, and was 3,582 ha. In the Pesticide Usage Survey, 16% of the total area of commercial orchards had fully grassed orchard floors, rather than herbicide-treated bare strips along the tree rows, which are a sign of intensive management (Dr Joe Crocker, FERA pers. comm.). Thus 16% of the orchard area could be assumed to be of the traditional orchard type. By applying this 16% reduction to the area of commercial orchards, the area of intensive orchards is estimated to be 3,009 ha. The total orchard area in Herefordshire is therefore estimated to be 5,490.5 ha.

Orchard selection

Selection objectives

2.6 The key aim for orchard selection was to include a wide variety of orchards, in terms of characteristics and appearance of fruit trees, landscape setting, management, business enterprise, wildlife habitat, resource protection issues, public access and location in relation to local communities. The project was small scale, meaning only a few orchards could be examined. The 6 orchards chosen were intended as case studies, to explore and illustrate the different values that orchards might possess. The selection did not emphasise the uniformity and replication that would underlie any statistical analysis of orchard values but was very much a pilot exercise, which could be followed by more quantitative investigations in the future. However, the orchards selected could be assigned to one of two broad orchard types, namely traditional and intensive orchards, which are defined below. This division allowed some structured comparisons to be made, and topics to be identified which would be worth further research.

Orchard type definitions

2.7 The main division among the group of study orchards is the categorisation into ‘traditional’ and ‘intensive’ types. The definition of these types follows that used in the UK Biodiversity Action Plan (BAP) (Maddock 2010). Traditional orchards have low-intensity management, without use of inorganic fertilisers or pesticides, in contrast to intensive orchards, where inorganic fertilisers and pesticides are used. Other management features are associated with these differences. Traditional orchards are usually composed of larger, more widely-spaced trees compared to the frequently dense plantings in intensive orchards. Traditional orchards are often grazed by livestock and sometimes cut for hay. The orchard floor in intensive orchards is generally mown and managed with herbicides rather than grazed by livestock.

2.8 There are other terms which are used to categorise orchards in the existing literature referred to in this report and which could cause confusion, so they are briefly defined in relation to the BAP definition here. ‘Conventional’ orchards are in fact intensive orchards, rather than traditional orchards (Fleutsch and Sparling 1994), being managed with synthetic pesticides. ‘Modern’ can be used for orchards where the tree form is ‘bush’ type, as compared with orchards with standard trees, which are defined as ‘traditional’ in this more limited way, compared to the BAP definition. However modern orchards are not always sprayed while some of the ‘traditional’ ones are sprayed (Crocker and others 1998). ‘Organic’ orchards may mean orchards that are sprayed but not with synthetic pesticides (Genghini and others 2006) or orchards certified as meeting particular management standards defined by the European Union (Defra 2006) and inspected by organisations such as the Soil Association.

Restrictions on choice of study sites

2.9 The project received funding from the European Union Leader+ fund which covered projects within 97 parishes in Herefordshire, adjoining the Rivers Wye, Lugg, Arrow and Frome. This area amounted to 41% of the county and was known as the Herefordshire Rivers’ Leader+ area (Watson 2008). Orchard sites were therefore chosen from within this area. However, as mentioned above, the sites were all located in one or other of the 3 Herefordshire character areas that are most significant for orchards in the Herefordshire landscape. A size limit was imposed on prospective orchards, which had to have at least 5 fruit-bearing trees growing together in a land parcel. Owners of candidate orchards were identified with help from Bulmers and the Herefordshire Orchard Topic Group. Some owners declined to be involved while others were enthusiastic. It is recognised that there may be some unknown bias in the findings as they came from orchards managed by outward-looking owners.

Location and economic, environmental and social attributes of the study sites

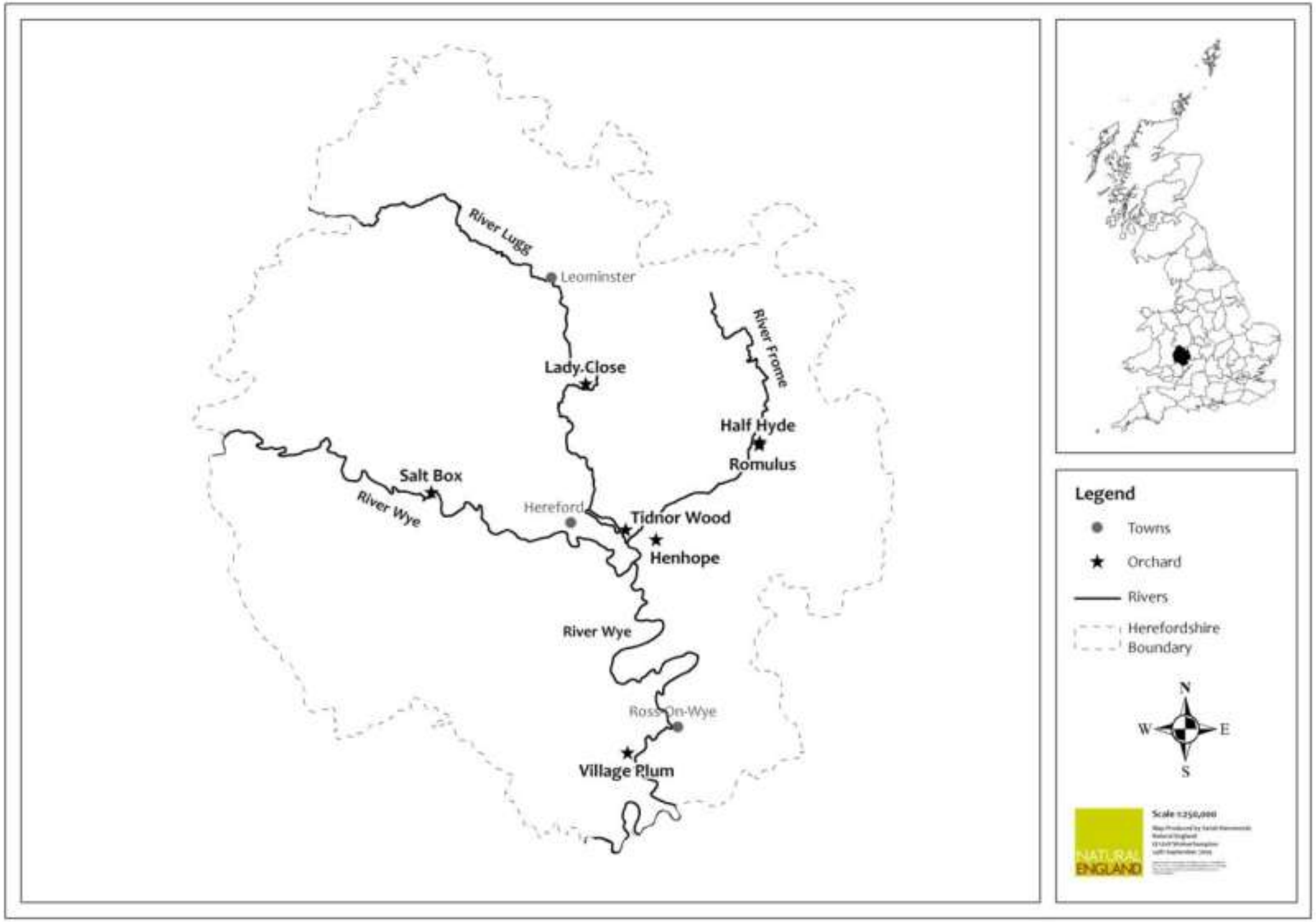
2.10 The selected orchards were chosen from across the county in the Herefordshire Rivers area, and their locations are shown on Map 2.1. Ordnance Survey Grid references are given in Table 2.1, along with site area, fruit type and summary orchard attributes. These attributes are covered in detail in the descriptions of sites later in Chapter 2 or in relevant following chapters.

Table 2.1 Location, size, and summary of economic, environmental and social attributes of the orchards selected for survey

Orchard	OS Grid Reference	Site area (ha)	Summary of economic, environmental and social attributes
Henhope Orchard	SO584389	4.5	Traditional, certified organic, cider apples, machine-harvested, livestock enterprise (sheep), very low visibility in the landscape, no public access
Tidnor Wood Orchards	SO558398	10.3	Traditional but previously intensive, certified organic, cider apples, machine-harvested, livestock enterprise (sheep), Community Interest Company, cider apple heritage collection, above medium visibility in the landscape, public access by arrangement
Lady Close Orchard	SO528512	1.8	Traditional, recently restored from old remnant orchard, dessert and culinary apples, not harvested, livestock enterprise (sheep), in nature reserve, above medium visibility in the landscape, public ownership and access, close to village
Half Hyde Orchard	SO664466	2.5	Traditional, cider apples, machine-harvested, livestock enterprise (cattle), quite high visibility in the landscape, no public access
Romulus* Orchard	SO664464	6.6	Intensive, cider apples, machine-harvested
Salt Box Orchard	SO406427	5.4	Intensive, cider apples, machine-harvested, medium visibility in the landscape, no adjacent settlement, public footpath
Village Plum Orchard	SO560222	6.2	Intensive, plum, manual-harvested, medium visibility in the landscape, edge of village location, public footpath

Notes: *Romulus Orchard was not part of the selection process but was added later and only partially recorded

2.11 For easy reference, tables of data collected for the study sites in the rest of the report show the main type of each orchard by the letters T (for traditional) and I (for intensive), after the name of each orchard.



Map 2.1 Location of the study orchards in Herefordshire

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Topography, hydrology and soils of the study orchards

Topography and hydrology

2.12 The topography of each site was taken from Ordnance Survey (OS) contours from Natural England's copies of OS map data on its Geographic Information System (GIS). The aspect of the sites was also taken from the maps, based on the topographic position of each site in relation to the points of the compass. For example if a site sloped downwards towards the south, this meant that it had a south-facing aspect. Two of the sites had variable aspects, with slopes facing several divergent directions (Table 2.2). Henhope Orchard occupied a shallow valley, with opposite north-east and south-west facing slopes, while the valley bottom sloped towards the north-west. Village Plum Orchard was on a broad ridge that sloped down on the east and west edges of the orchard. Slopes were calculated using the contours and distances between them on the GIS. The steepest and shallowest slopes were measured, ie where contours were closest and widest apart in the site, and the range and average are given in Table 2.2. Examples of sites with topographic variety were Henhope Orchard and Salt Box Orchard. Henhope Orchard was largely on moderate slopes, the steepest slopes were small areas fringing the adjacent woodland. Salt Box Orchard had a steep bank running east-west through the centre of the orchard.

2.13 The only hydrological features described were the distance from the edge of the site to the nearest open water shown on the OS MasterMap and the distance to the main river closest to each site. Two sites were in the River Wye catchment, two were in the River Lugg catchment and three in the catchment of the River Frome (Table 2.2). Salt Box Orchard was adjacent to the River Wye and the owner reported that the lower part of the orchard was sometimes flooded by the river. No rainfall data was collected but the average annual rainfall across Herefordshire is around 700-850 mm according to Met Office recording stations at Ross-on-Wye (706mm) in the south-east of the county and Lyonshall (846mm) at the north-west edge of the county (Met Office 1971-2000a and b).

Table 2.2 Altitude, topography, aspect and landscape position in relation to open water of each orchard

Site	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Romulus (I)**	**Salt Box (I)**	**Village Plum (I)**
Altitude m from OS contours	115-165	50-85	65-75	85-115	80-100	55-70	70-75
Aspect (compass points)	SW-NW-NE	S-SSW-WSW	SSW	WSW	WSW	S-SSE	WNW-NW-NE-ENE
General slope across site (%)	13	12	9	15	7	5	c. 0 (ridge)
Range of slopes (%)	9-80	2-27	5-17	7-46	6-15	3-22	west-facing slope 5-16; east-facing slope 5-12
Distance to nearest mapped open water, m	345	90	45	145	200	0	10
Distance to river, m (river name)	1200 (R. Frome)	260 (R. Lugg)	350 (R. Lugg)	480 (R. Frome)	400 (R. Frome)	0 (R. Wye)	450 (R. Wye)

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Orchard soils

2.14 Soil samples were collected from each orchard by David Marshall in the period 2006-2007. Sampling was done with a soil auger and separate samples were taken from the top 0cm -

15cm layer and the 15cm - 30cm layer of soil. Live vegetation was discarded if any was removed by the auger from the soil surface. Twenty samples from each layer were taken at regular intervals across a site, following a ‘W’ pattern. The samples from the 0cm - 15cm layer were pooled and a sample of the pooled soil taken for analysis. The same procedure was followed for the 15cm – 30cm layer. The texture of soil in the 15cm - 30cm layer was then hand-tested and assigned to a texture class (Table 2.3).

2.15 Soils were analysed for chemical elements and pH by Yara Analytical Services using techniques based on standard procedures (ADAS 1986). Details of methods were provided by Adrian Dawson of Yara Analytical Services. Samples were dried in cabinets at 30^0C, then pulverized and passed through a 2mm sieve. Soil pH was tested on the dry soil in distilled water with a pH meter. Magnesium and potassium were extracted with 1 M ammonium nitrate and measured using an inductively coupled plasma instrument (ICP). Phosphorus was extracted with Olsen (sodium hydrogen carbonate) reagent and measured by solution spectrophotometry after complexing with ammonium molydate. Soil carbon was analysed by the Dumas combustion technique, and carbon given off in gases was measured by spectrophotometry. Results are shown in Table 2.3. The levels of phosphorus, potassium and magnesium can be related to the ADAS index system (Yara Analytical Services undated), which indicates fertility levels, from very low, index 0, to very high, index 9. The relevant index classes for the soil results are shown in the notes below Table 2.3.

Table 2.3 Soil analysis results for each orchard

Soil attribute	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
0-15 cm layer							
pH	6.2	6.3	5.9	6.7	6.9	6.3	6.6
Phosphorus ppm	9	29	20	22	19	15	28
Potassium ppm	97	237	142	214	143	99	167
Magnesium ppm	114	201	135	101	103	214	196
Soil carbon %	3.07	2.49	2.49	3.83	1.39	2.15	1.80
15-30 cm layer							
pH	6	6.1	6.1	7.3	7	6.4	6.4
Phosphorus ppm	6	17	14	15	18	14	22
Potassium ppm	94	166	124	207	111	71	115
Magnesium ppm	107	188	119	88	97	170	148
Soil carbon %	1.80	1.62	1.39	2.78	1.51	1.80	1.04
Texture 15-30 cm layer							
Sandy loam							✓
Silty clay loam			✓				
Sandy clay loam	✓						
Silty clay		✓		✓	✓	✓	

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details. Relevant ADAS index classes:

Phosphorus	0-9ppm, ADAS index 0, very low; 10-15ppm, ADAS index 1, low; 16-25ppm, ADAS index 2, slightly low to medium; 26-45ppm, ADAS index 3, medium to high
Potassium	61-120ppm, ADAS index 1, low; 121-240ppm, ADAS index 2, slightly low to medium
Magnesium	51-100, ADAS index 2, slightly low to medium; 101-175ppm, ADAS index 3, medium to high; 176-250ppm, ADAS index 4, high

2.16 As well as analysis of the orchard soils, the location of each orchard in units in the soil landscape shown on the National Soil Map was recorded (Table 2.4). These units are generalized and cannot be interpreted as the soil types in individual sites, but show the general soil conditions in the areas in which the orchards occurred.

Table 2.4 Location of each orchard in relation to landscape soil unit

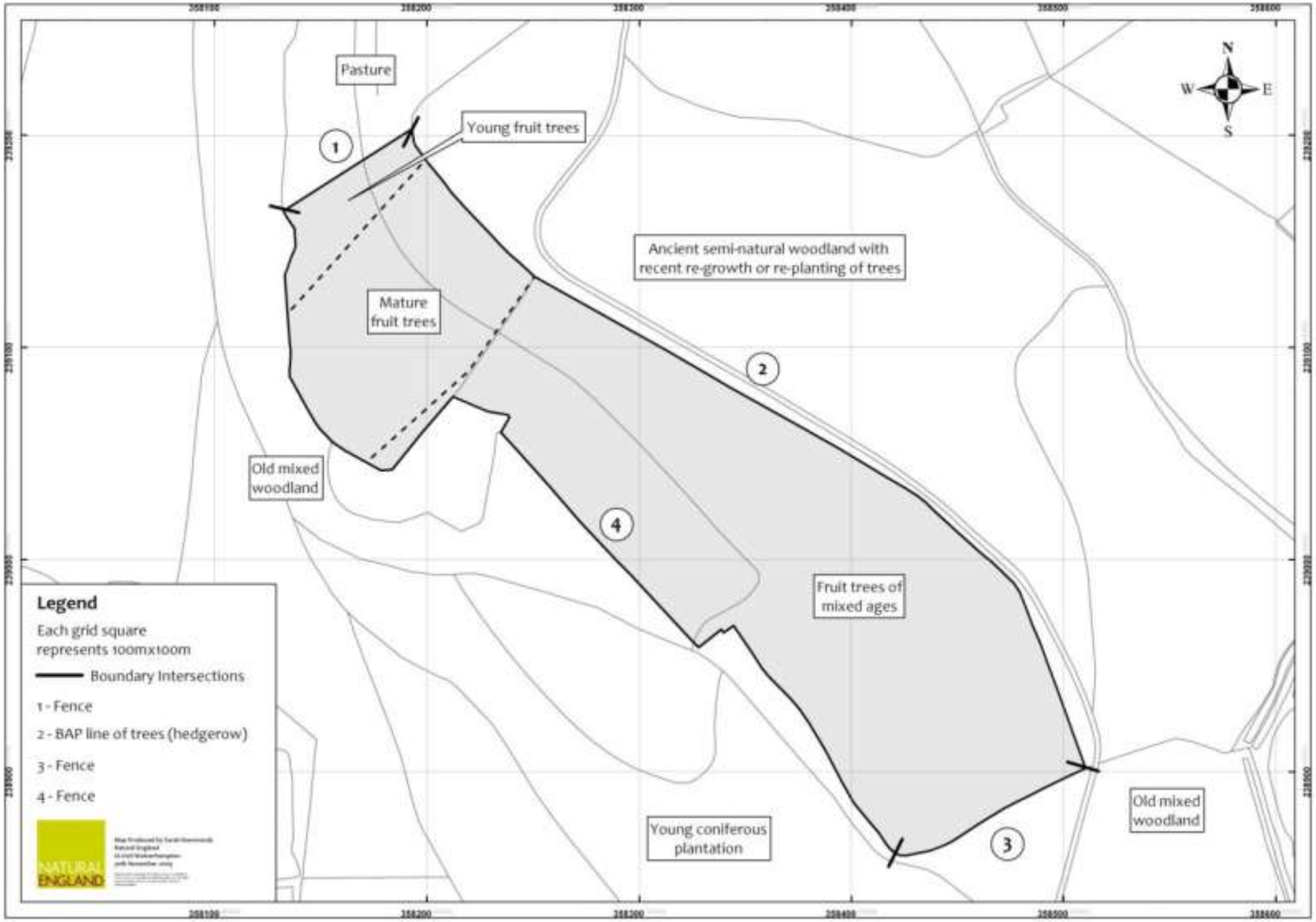
Orchard	Landscape soil unit
Henhope (T)	Unit 8: Slightly acid loamy and clayey soils with slightly impeded drainage, moderate to high fertility
Tidnor (T)	Upper slopes Unit 8: Slightly acid loamy and clayey soils with slightly impeded drainage, moderate to high fertility Lower slopes Unit 12: Freely draining, loamy floodplain soils, moderate to high fertility
Lady Close (T)	Unit 8: Slightly acid loamy and clayey soils with slightly impeded drainage, moderate to high fertility
Half Hyde (T)	Unit 8: Slightly acid loamy and clayey soils with slightly impeded drainage, moderate to high fertility
Romulus (I)	Unit 8: Slightly acid loamy and clayey soils with slightly impeded drainage, moderate to high fertility
Salt Box (I)	Upper slopes Unit 6: Freely draining slightly acid loams, low fertility Lower slopes Unit 12: Freely draining, loamy floodplain soils, moderate to high fertility
Village Plum (I)	Unit 6: Freely draining slightly acid loams, low fertility

Notes: Landscape soil units from National Soil Map, provided by Natural England. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Landscape setting, history, character and accessibility of the study orchards

Orchard landscape setting and site maps

2.17 The adjacent land use around each orchard was mapped by Elizabeth Slingsby as part of the habitat survey carried out in 2008 and 2009. The surrounding land use is shown on Maps 2.2 to 2.8, together with the type of boundaries around each orchard. The individual boundaries, most of which were hedgerows, are described in detail in Chapter 4. Several of the sites adjoin woodland. The statuses of these woodlands were checked against the ancient woodland inventory for Herefordshire (Freeman and Smith 1988). Woodland adjacent to the north side of Henhope Orchard and east side of Romulus Orchard was designated as ancient woodland. Ancient woodland is defined as woodland that, from evidence of old maps, has been known to be in existence since AD 1600 (Marren 1992). Sometimes the site of an ancient woodland is still woodland in the present day, although the trees include non-native trees that have been recently planted. This was the case at Tidnor Wood Orchards, where the woodland was a mixture of conifer and broadleaved tree species (see Chapter 4). Features of the orchards themselves are also shown on the maps and are described in more detail below and in Chapter 4.



Map 2.2 Landscape setting, boundary type and orchard features of Henhope Orchard

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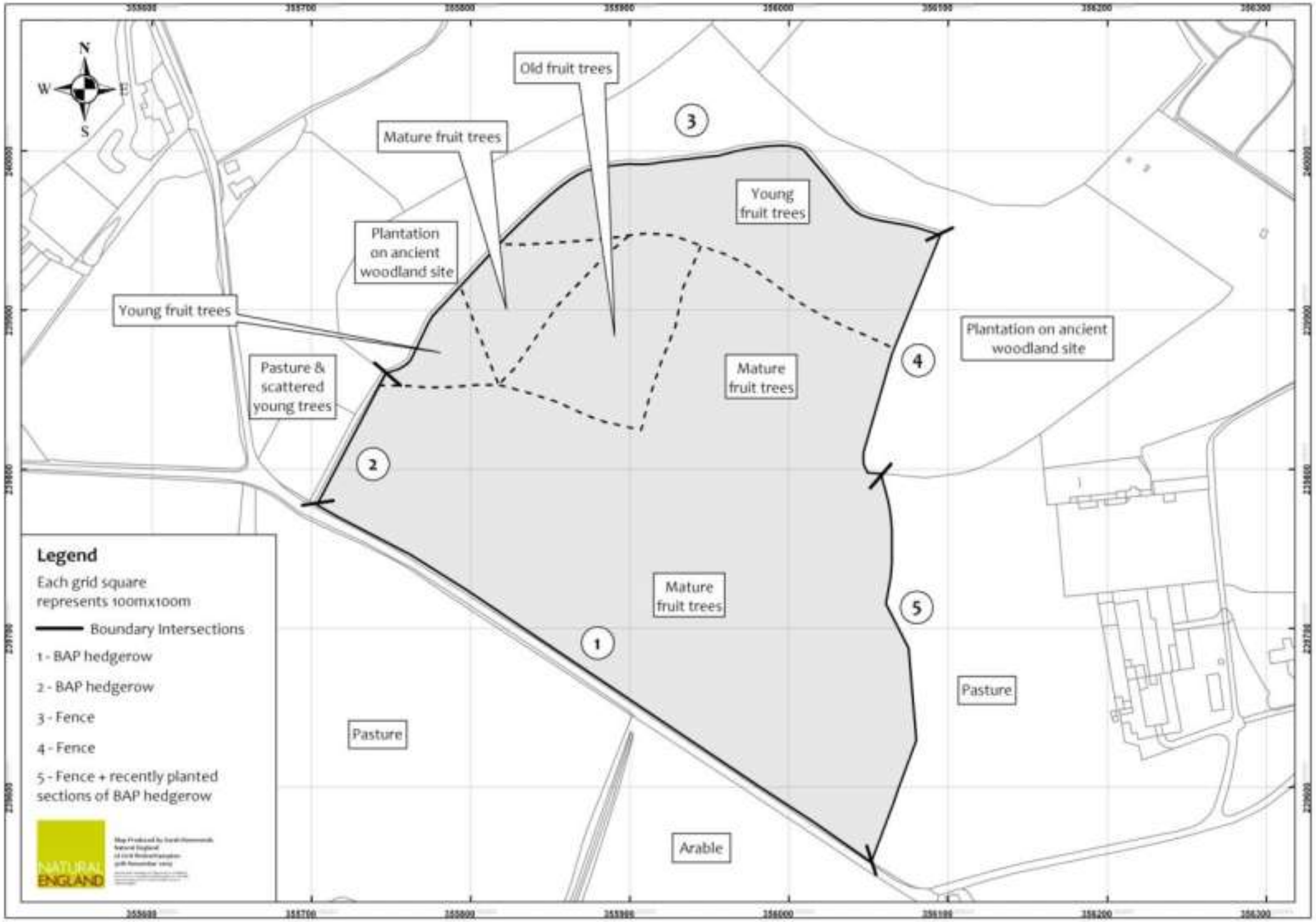

Map 2.3 Landscape setting, boundary type and orchard features of Tidnor Wood Orchards

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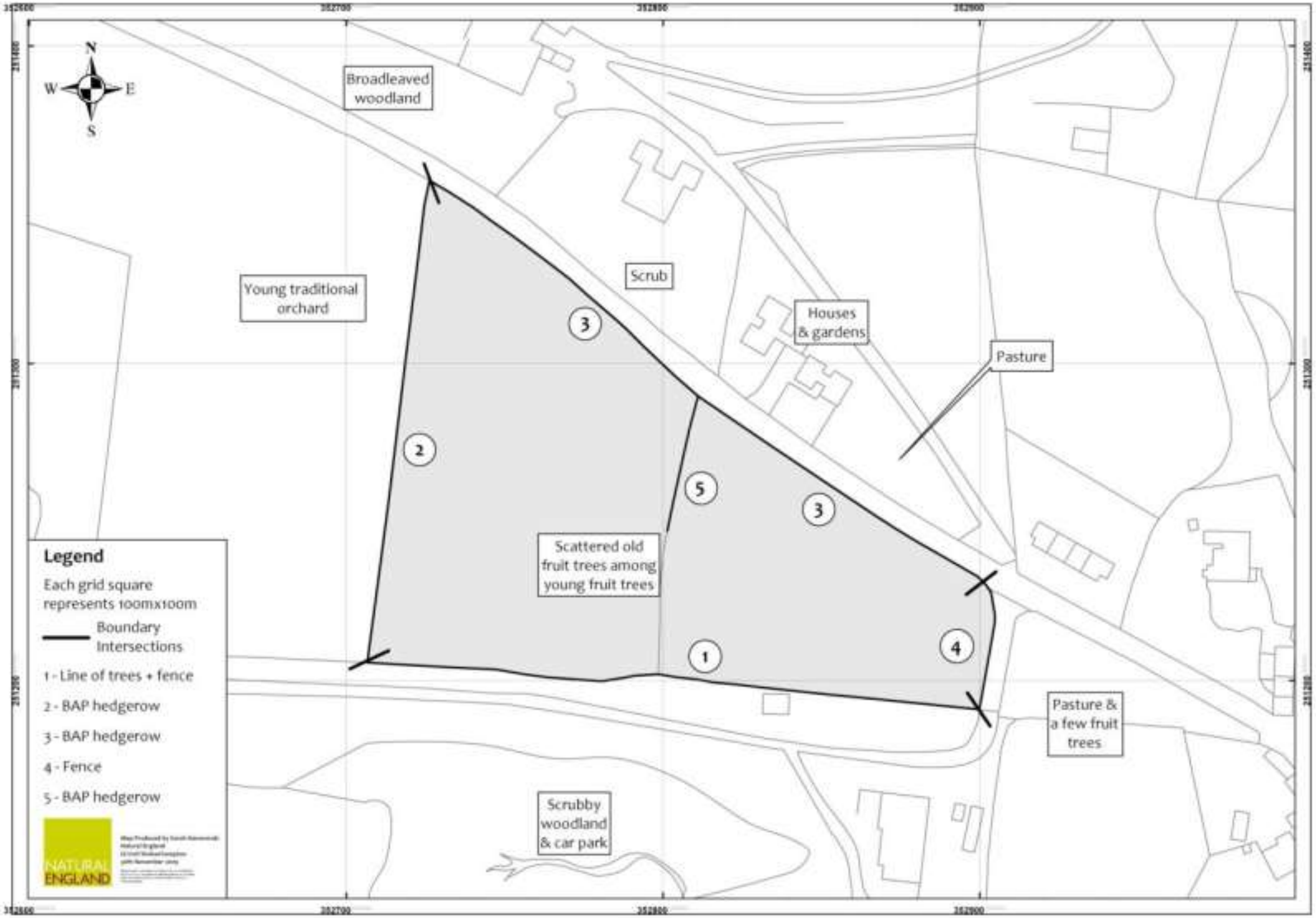

Map 2.4 Landscape setting, boundary type and orchard features of Lady Close Orchard

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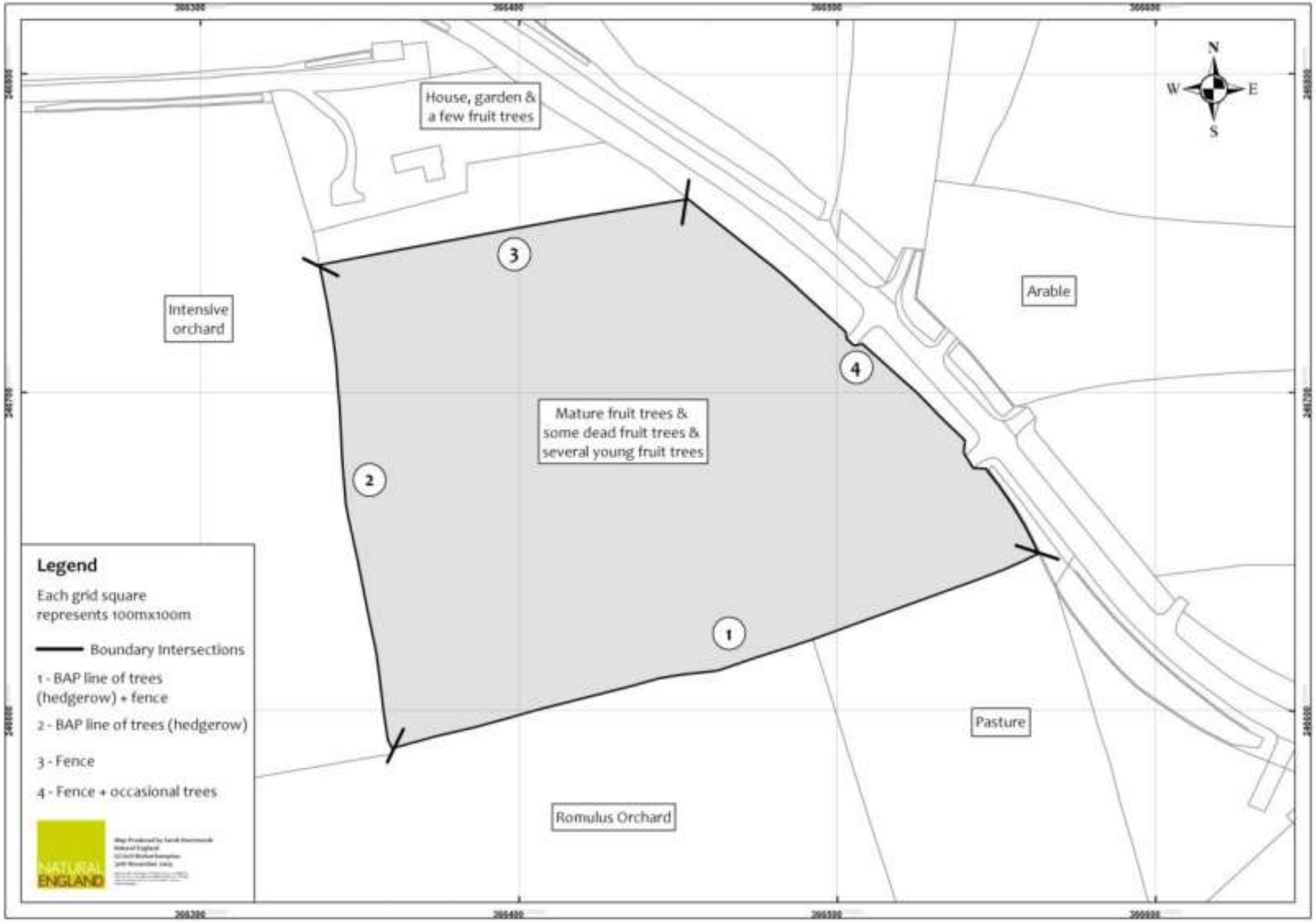
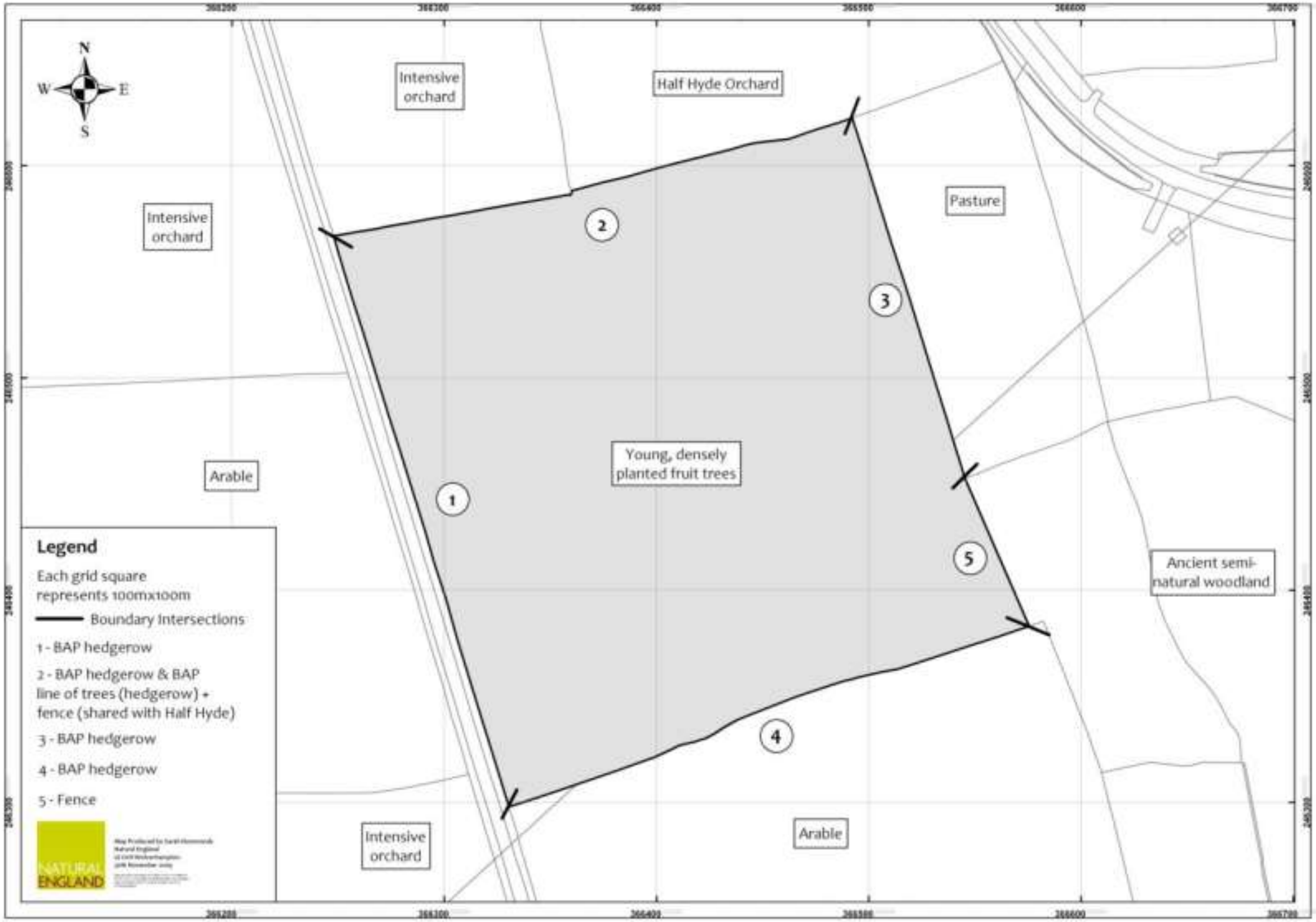


Map 2.5 Landscape setting, boundary type and orchard features of Half Hyde Orchard



Map 2.6 Landscape setting, boundary type and orchard features of Romulus Orchard

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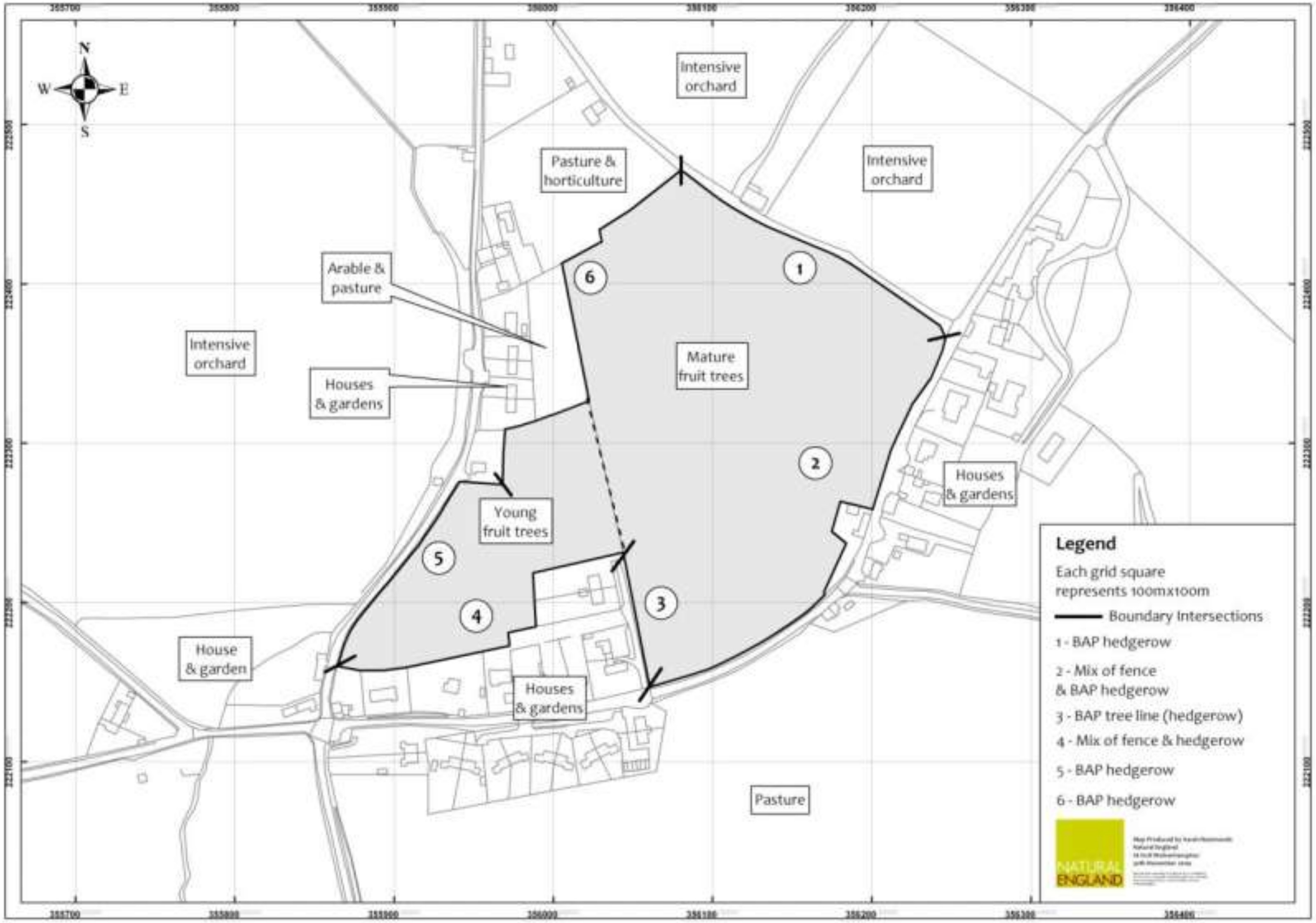
Map 2.7 Landscape setting, boundary type and orchard features of Salt Box Orchard



Map 2.8 Landscape setting, boundary type and orchard features of Village Plum Orchard

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Orchard character, history, visibility and accessibility

2.18 The character of each orchard comprises the fruit type (apple, plum), the physical appearance of the fruit trees (tree form), their density and arrangement. These features were recorded in the habitat survey and the method of recording is explained in Chapter 4 (Table 4.1). Tree density was the average across a site. The actual density may have varied across a site as some areas had no trees, for instance the wide grassland strips between the fruit trees and the orchard boundaries at Salt Box Orchard. The tree form types were 'project-specific' categories, describing the height of tree trunks below the fork of the first branch. A standard tree trunk was around 2m / 6 feet (ft) in height, a half-standard trunk around 1m / 4ft, and the trunk of a bush tree was less than 1m / 4ft in height below the first branch. The intensive orchards had a much stronger pattern of tree rows and grass alleys between rows, whereas the trees in the traditional orchards were more evenly spaced. The planting dates were obtained from the orchard owners. The photographs of each site included below give a flavour of the variable visual character of the orchards (Plates 2.1 to 2.15).

Table 2.5 Character and planting history of each orchard

Site	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Romulus (I)**	**Salt Box (I)**	**Village Plum (I)**
Site area (ha)	4.5	10.3	1.8	2.5	6.6	5.4	6.2
Fruit type	Cider apple	Cider apple	Dessert & culinary apple	Cider apple	Cider apple	Cider apple	Plum
Tree numbers	352	2480	100	187	4407	2966	4073
Tree density / ha	78.2	240.8	55.6	74.8	667.7	549.3	656.9
Tree form	Standard	Half-standard = 2420; standard = 60	Standard	Standard	Bush	Bush	Half-standard
Tree canopy cover	Open	Open & closed*	Open	Open	Closed along rows, open between rows	Closed along rows, open between rows	Closed along rows, open between rows
Average distance between trees (m)	10.5	5.7 / 5.9*	11.1	10.7	In rows: 2.4 Between rows: 5.5	In rows: 2.4 Between rows: 5.8	In rows: 2.1 Between rows: 5.5
Planting dates and numbers of trees	1938-1942 = 228; 1986-1987 = 60; 1988-2000 = 51; 2001-2006 = 13	1930s = 60 (standard trees); 1960s = 1900; 2003-2007 = 520	c1906-1926 = 30; 2000 = 70	1958-1959 = 167 (52 dead in 2008); 1997-2007 = 20 (10 dead in 2008)	1994 = 4407**	1997-1998 = 2966	1987 = 3063; 2001 = 860; 2006 = 150

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details. *One part of the site (Museum Orchard) was recently planted and had an open canopy, with trees at 5.7 m spacing, the remainder of the site had a closed tree canopy with trees 5.9 m apart on average. ** Total includes very rare, more recent, replacements.

Plate 2.1 Henhope Orchard: looking towards the ancient semi-natural woodland on the northern side of the orchard

Plate 2.2 Henhope Orchard: looking towards the orchard from the north-west

Plate 2.3 Tidnor Wood Orchards: recently planted trees in the area known as Museum Orchard

Plate 2.4 Tidnor Wood Orchards: some of the remaining mature trees in the area known as Museum Orchard, looking south

Plate 2.5 Tidnor Wood orchards: sheep and trees in the area known as Bottom Orchard

Plate 2.6 Lady Close Orchard: looking south east, old trees and recently planted trees, hedgerow boundary 5 on left, tree line hedgerow boundary 1 across middle distance

Plate 2.7 Lady Close Orchard: recently planted trees, tree line hedgerow, boundary 1, on left, hedgerow boundary 5 on right

Plate 2.8 Half Hyde Orchard: looking downslope towards the west

Plate 2.9 Half Hyde Orchard: cattle grazing in orchard

Plate 2.10 Romulus Orchard: looking east

Plate 2.11 Romulus Orchard: looking west along hedgerow, boundary 2

Plate 2.12 Salt Box Orchard: looking south

Plate 2.13 Salt Box Orchard: looking northwards along River Wye and the tall herb vegetation of the river bank (boundary 3 of the orchard)

Plate 2.14 Village Plum Orchard: looking east in area of mature fruit trees

Plate 2.15 Village Plum Orchard: looking west across area of younger trees, towards neighbouring intensive orchard

Land use history, visibility and accessibility of Henhope Orchard

2.19 Henhope Orchard was not shown as orchard on the Ordnance Survey (OS) 1:10560 1st Edition map of 1890 apart from a narrow enclosed strip on the south-western border of the orchard. This area appeared to have been incorporated into the subsequent orchard and the inner boundary of the enclosure was no longer present in 2008. According to the orchard owner, Henhope was permanent pasture before the current orchard was planted in the late 1930s / early 1940s.

2.20 Henhope had no public rights of way and, tucked in the head of a valley beneath the slopes of Backbury Hill, was hidden from general view. The nearest village was Prior's Frome, on the other side of Backbury Hill, some 0.5km distance away.

Land use history, visibility and accessibility of Tidnor Wood Orchards

2.21 The OS 1:10560 1st Edition map of 1889 shows the upper slopes of Tidnor Wood Orchards to be orchard, the lower slopes as scattered trees, which were part of the parkland of Longworth Hall according to the orchard owner. The woodland that surrounded the upper part of the orchard was more extensive in 1889 than in 2008. It occupied land subsequently cleared and planted as orchard, probably in the 1960s. The woodland is shown as broad-leaved trees in 1889, rather than mixed broad-leaved and coniferous trees, which made up the composition of the woodland in 2008. The Second Edition OS 1:10560 map of 1905 shows that the woodland had the same extent as in 1889, but the orchard is shown as scattered trees, similar in appearance to the lower slopes.

2.22 The orchard owner related that the current orchard area was pasture before the 1960s, which was when most of the existing orchard trees were planted, apart from a small area planted in the 1930s. The former owner planted arable crops between the trees when they were young and removed any remaining parkland trees. The current owner replaced the mature fruit trees on the upper slopes of the orchard with a collection of 452 cider apple varieties in the period 2003-2007. An aerial photograph taken in 1999 shows that there were bare strips along the tree rows, except under the stand of old trees (Map 2.3), indicating that the orchard was managed intensively. This status was corroborated by the current owner, who said that before his acquisition of the orchard in 2002 it was managed with pesticides. Since 2002 the orchard had been managed without pesticides and fertilisers and had been converted to certified organic status.

2.23 There were no public footpaths through the orchard though some locals did walk there and a few houses had views of the orchard. There was a tall hedge (boundary 1, Map 2.3) on the road side of the orchard which meant that it was not very visible from the small road immediately adjacent to the orchard. The nearest village was Bartestree, about 0.9km away, and it was separated from the orchard by the hill which was crowned by Tidnor Wood. However, Tidnor Wood Orchards Community Interest Company encouraged public participation including tree sponsorship and volunteer activity.

Land use history, visibility and accessibility of Lady Close Orchard

2.24 The orchard was owned by Herefordshire Council and was covered by their Countryside Ranger Service. According to the Council, the land had been church land since 12th century and was referred to as "Our Lady Close" in 1540. Later the orchard site became part of the Hampton Court estate until it was sold at the beginning of the 20th century. Church records show that the site had been cultivated as orchard since 1799, and an 1853 map also shows orchard on this site. There was also a reference to Lady Close Orchard in a record from 1838 in the Herefordshire Record Office (National Archives undated). The OS 1:10560 1st Edition map of 1890 / 1891 and the Second Edition OS 1:10560 map of 1904 / 1905 both show the land east of boundary 5, which was complete at those dates and connected boundary 1 to boundary 3 (Map 2.4), as orchard, and separated by a road from a larger block of orchards which extended northwards.

2.25 The site was acquired by Leominster District Council in 1994 and passed to Herefordshire Council in 1998. The site had been grazed but was then unmanaged for a few years. A 1999 aerial photograph shows that only a few old trees remained in a grassland field. Active management resumed in the late 1990s and a restoration programme begun with the help of the Countryside Stewardship Scheme. In 2000, 70 young trees were planted, with varieties that maintained the character of the orchard as a dessert and culinary apple orchard, rather than cider apple orchard. The old trees were estimated by the Council to be about 80-100 years of age in 2007. The old trees in the part of the site west of boundary 5 must date from after 1905, as they are not shown on the historical OS map of this date.

2.26 Lady Close Orchard was managed as a public amenity by Herefordshire Council at the time of the project. It was part of Bodenham Lake Nature Reserve, and had a car park and information boards. The Nature Reserve, whilst noted on Herefordshire Council's website, was not heavily publicised due to its difficult road access along a narrow lane. The orchard was visited by the public, mainly by people from Bodenham village, which was adjacent to the orchard.

Land use history, visibility and accessibility of Half Hyde Orchard

2.27 The OS 1:10560 1st Edition map of 1886 shows that orchard occupied three-quarters of Half Hyde Orchard at that time, in 4 of 5 sub-divisions of the current orchard site. The Second Edition OS 1:10560 map of 1905 shows that just less than half of the site was orchard at that time. Land use since that time is unknown until 1958-1959 when the existing orchard was planted. The owner recalled that the grassland in the orchard, in the lower, flatter, part of the orchard, was re-seeded in 1977. Around 2002, sheep damaged some of the trees, which died. Many were left in situ and were still present in 2008. Some young trees were planted in the period 1997-2007.

2.28 Half Hyde was located alongside the A4103 main road from Worcester to Hereford, as it drops down the valley side above the River Frome floodplain. The orchard was set against the backdrop of the Wye Plain with the Black Mountains in the far distance. Its tall standard trees were visible to traffic passing in both directions. There were no public footpaths through the orchard and there were few houses close to the orchard. The nearest village was Bishop's Frome, about 1.5km away.

Land use history of Romulus Orchard

2.29 Romulus Orchard lay adjacent to Half Hyde Orchard (Maps 2.5, 2.6). The OS 1:10560 1st Edition map of 1886 and the Second Edition OS 1:10560 map of 1905 show that the southern quarter of the site was orchard at that time. The owner said that the site was an arable field before the fruit trees present in 2008 were planted in 1994.

Land use history, visibility and accessibility of Salt Box Orchard

2.30 The OS 1:10560 1st Edition map of 1891 and the Second Edition OS 1:10560 map of 1905 show that the area was not orchard at those times. An old gravel pit is marked at the eastern edge of the orchard on these maps. The woodland and scrub adjoining boundary 2 (Map 2.7) in 2008 was not marked as woodland in 1891 or 1905 and must have grown up since those times. The owner recounted that the site was under grass and then arable cultivation before the orchard was planted in 1997-1998.

2.31 Salt Box Orchard lay alongside the A438 main road from Brecon to Hereford. However, the bush trees in the orchard were relatively short and were partially hidden by the roadside hedgerow. The site had a public footpath running through it. There were few houses near to the orchard, the closest were about 0.4km away, while the hamlet of Byford was about 0.7km away.

Land use history, visibility and accessibility of Village Plum Orchard

2.32 The OS 1:10560 1st Edition map of 1891 and the Second Edition OS 1:10560 map of 1905 show that the south-eastern third of the area covered by mature fruit trees in 2008 (see Map 2.8) was orchard at those earlier dates and about half of the area occupied by young fruit trees in 2008 (Map 2.8) was orchard at those dates. The owner recalled that the mature trees were planted in 1987, replacing 1967 plantings, while the younger trees were planted in a former grassland area in 2001.

2.33 Village Plum Orchard was adjacent to the village of Glewstone, some of the gardens of houses in the village abutted the orchard boundary (see Map 2.8). A public footpath crossed the orchard. There were only restricted views from the small roads which ran alongside parts of the orchard.

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3 Orchard management and economics

Authors: D. Marshall and H. Robertson

Introduction

3.1 The way that orchards are managed has a major impact on their economic value. This chapter describes the management regime in each study orchard, followed by description and analysis of income and expenditure associated with this management regime. In addition, the influence of the economics of orchard management on the local economy is assessed in this chapter. While the information on orchard management is of critical importance to the orchard economics section in this chapter, it also is referred to in other chapters, in particular Chapter 4 on orchard biodiversity and Chapter 5 on resource protection.

Orchard management

Data collection and presentation

3.2 Information on the management of each orchard site was gathered primarily through a structured set of questions put to each orchard owner. Supplementary information was gathered from owners as required during subsequent work on other project topics such as carbon sequestration. Management information is presented below in the form of a summary description for each orchard and tables displaying management details across all the main six study orchards to facilitate comparisons. One exception to the inclusion of management information in these tables is that concerning hedgerow management, which is more conveniently located in Chapter 4, along with details of the individual hedgerows to which the management was applied. Romulus Orchard was an extra site included in the project to provide useful additional information on some project topics, although it was excluded from the economic assessment. A general description of its management regime is given at the end of the section. The management information applies to the year 2006 for Henhope, Tidnor Wood, Lady Close and Salt Box orchards and to the year 2007 for Half Hyde and Village Plum orchards.

Orchard management summaries

Henhope Orchard

3.3 Henhope Orchard is a traditional cider apple orchard which is organically managed and certified. Since the orchard was originally planted around 70 years ago there has been significant replanting. Over recent years, trees have been replaced at a rate of about five trees a year. The orchard is lightly pruned, only about 10% of the trees are pruned in any one year. Some deadwood is left standing or fallen, some is used for firewood. The trees exhibit biennial cropping, which means that the trees have very different yields every other year. The orchard produced 75 metric tonnes (75,000 kg) of cider apples in 2006, but the crop in the following year was only about 8 tonnes. The fruit is harvested by a contractor using a mechanical tree shaker and harvester, and the apples are sold under contract to the cider industry. The orchard floor is managed by sheep grazing, plus topping of the vegetation to control weeds like nettles and to facilitate fruit harvesting. No organic or inorganic fertilizers are applied and no pesticides are used.

Tidnor Wood Orchards

3.4 Tidnor Wood Orchards encompass four adjacent orchards, which are mainly composed of cider apples. The orchards were undergoing conversion to certified organic status at the time when the management was first described in 2006. Organic status was achieved in 2008. The oldest fruit trees are about 80 years of age but the bulk of the trees are about 50 years old. However, one orchard, Museum Orchard, was replanted between 2002 and 2006 and contains over four hundred different cider apple varieties. This collection has been recognised as a National Collection® (*Malus*-Cider making) by the National Council for the Conservation of Plants and Gardens (NCCPG). Up to 20% of the trees are pruned per year although more pruning and thinning occurred in 2006, in particular thinning of trees in Bottom Orchard to allow more sunlight into the closely spaced half-standard trees in this Orchard. Some dead trees are left standing and log piles for wildlife made at the orchard edges. Other wood is sold as firewood. The orchard trees have variable cropping, with harvests of 215 tonnes in 2006, 330 tonnes in 2005, 140 tonnes in 2007 and 270 tonnes in 2008. Fruit is sold to the cider industry under contract and harvested mechanically by contractors. The orchard floors of all orchards except Museum Orchard are managed by sheep grazing and topping of grassland weeds. Museum Orchard is managed by mowing. There are no inputs of fertilizers or pesticides in the orchards.

Lady Close Orchard

3.5 Lady Close Orchard is a small traditional orchard composed of dessert and culinary apples. The orchard is now managed by the Rangers of Herefordshire Council as part of Bodenham Lake Nature Reserve and it is open to the public. Until the time that 70 new trees were planted in 2000, this was a remnant orchard containing only 30 veteran trees, which were probably 80 to 100 years old. The trees are not pruned apart from removal of branches for safety reasons, and dead wood is left in the orchard. The fruit is currently not harvested, although the orchard's Ranger noted that yield is variable, and the old trees appear to be on a biennial cycle of cropping. The orchard floor is managed primarily by sheep grazing but is also mown twice a year. No fertilizers or pesticides are used in the orchard.

Half Hyde Orchard

3.6 Half Hyde Orchard is a traditional cider apple orchard. Most of the trees are about 50 years old but in the years 1997-2007 20 new trees were planted. Part of the orchard is on a very steep slope, which poses considerable management problems. Pruning is infrequent, in the past 35 years the trees have been pruned twice, the last occasion being in 1999. Standing dead trees and other dead wood are left in the orchard. Fruit yield is variable, 18 tonnes were harvested in 2007 but yields can be up to about 50 tonnes. The cider fruit is shaken from the trees and collected mechanically but the slope is too steep for machinery in places and wet conditions can hamper harvesting. For example, no fruit was harvested in 2008 because of the wetness of the ground. The fruit is sold under contract to the cider industry. The orchard floor is grazed by beef cattle, and the lower parts of the orchard slope are topped by a mower once a year. No fertilizer or pesticide inputs are made to the orchard.

Salt Box Orchard

3.7 Salt Box Orchard is an intensively managed cider apple orchard, planted in 1997. About half the trees are pruned each year and most dead wood as well as prunings on the orchard floor are removed to facilitate access by machines. Salt Box produced 230 tonnes of cider fruit in 2006. Yields do not vary greatly year to year, variability is around 10%-15%. The fruit is harvested mechanically with tree shakers, blower and harvester. The blower produces a jet of air to push the fallen fruit together so that it can be easily picked up by the harvester. The fruit is sold under contract to the cider industry. The orchard floor grassland between the tree rows is mown, and the ground beneath the trees is treated with herbicide to remove ground vegetation which could compete with the trees. Solid inorganic fertilisers are applied to the ground under the tree rows and liquid foliar fertilizer is sprayed onto the tree canopies each year. Occasionally lime is applied to the ground beneath the trees. The tree canopies are also treated with fungicide and insecticide sprays.

Village Plum Orchard

3.8 Village Plum orchard is an intensively managed plum orchard. Most of the orchard trees are about 20 years old, although some are only 6 years old and 150 replacement trees were planted in the older block in 2006. All the trees are pruned every year and in 2008 the upper canopy of each tree was pruned down considerably. The prunings and most dead wood are collected and some is chipped to make a mulch which is applied to the tree rows. The remainder is burnt. In 2007 66 tonnes of fruit was produced and sold to the supermarkets and wholesale trade. Yields can be very variable as trees are vulnerable to frost and hail damage. For example, a late frost in the spring of 2008 damaged the blossom and yield that year was less than 10 tonnes. Fruit is thinned and picked by hand and the high manual labour requirement is largely met by migrant labour. Fruit must be picked as it ripens, meaning that the tree rows have to be picked-over 4 to 5 times during the picking period. Around 5,000 hours a year of manual labour is needed to undertake thinning, pruning, picking and other management in the orchard. The plums are sold fresh to supermarkets and wholesalers. The grassland between the tree rows is managed by mowing, while herbicides are used on the ground under the tree rows to remove ground vegetation. Solid inorganic fertilizers are spread beneath the tree rows each year and the tree canopies are also fertilized by liquid foliar fertilizer every year. Occasionally lime is applied to the ground beneath the trees. Fungicides and insecticides are sprayed on to the tree canopies.

Orchard management tables

3.9 Each table comprises a related group of management activities. Three of the tables cover all 6 orchards (Tables 3.1-3.3). Only Salt Box Orchard and Village Plum Orchard are managed with inorganic fertilizers, herbicide, fungicides and insecticides, details are shown in Table 3.4. Herbicide use is also noted in Table 3.2. The main distinguishing characteristic among the group of study orchards is the categorisation into ‘traditional’ and ‘intensive’ types, as discussed in Chapter 2. The management information in the summaries and tables underlies this categorisation. The traditional orchards have low-intensity management, without use of inorganic fertilisers or pesticides, in contrast to the intensive orchards, where inorganic fertilisers and pesticides are used. Other management features are associated with these differences. The traditional orchards are grazed by livestock and are composed of larger, more widely-spaced trees compared to the intensive orchards. The orchard floor in the intensive orchards is mown and managed with herbicides rather than grazed by livestock. For easy reference, the type of orchard is shown in each table below by the letters T (for traditional) and I (for intensive), after the name of each orchard.

Table 3.1 Pruning management and fruit yields in each orchard

Management	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Area of orchard, ha	4.5	10.3	1.8	2.5	5.4	6.2
Proportion of trees pruned per year	10%	20%**	0%	0%	50%	100%
Treatment of prunings and dead wood	Firewood + burnt in open + retained	Firewood + burnt in open + retained	None	None	Burnt in open	Burnt in open + mulched
Fruit picking method	Mechanical	Mechanical	None	Mechanical	Mechanical	By hand
Total fruit yield, tonnes (year)	75 (2006)	215 (2006)	0 (2006)	18 (2007)	230 (2006)	66 (2007)
Fruit yield, tonnes / ha, calendar year as for total yield	16.7	20.9	0	7.2	42.6	10.6
Number of productive trees*	352	1960	-	125	2966	4073
Number of productive trees / ha	78.2	190.3	-	50	549.3	656.9
Fruit yield per tree, tonnes, calendar year as for total yield	0.21	0.11	0	0.14	0.08	0.02

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. *Young trees in Museum Orchard in Tidnor Wood Orchards and dead trees at Half Hyde Orchard were excluded from the number of productive trees. No fruit was harvested at Lady Close Orchard so number of productive trees was not known. ** Pruning was unusually extensive in this year.

Table 3.2 Orchard floor management in each orchard

Management	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Livestock grazing	Sheep	Sheep	Sheep	Cattle	None	None
Livestock numbers	60	40	75	109	0	0
Livestock age / type	Adult	Adult	Adult	52 cows, 1 bull, 7 heifers (young cows), 49 calves	None	None
Number of days in year grazed	119	84**	98	14	0	0
Grazing period in year*	January to August	February to August	April to August	April to September	None	None
Mowing or topping frequency / year	3	2	2	1	5	1
Herbicide frequency of use along tree rows / year	0	0	0	0	2	1

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. *Grazing may not have been continuous during this period. **Museum Orchard in Tidnor Wood Orchards was not grazed. Further details of herbicide use are in Table 3.4 below.

Table 3.3 Machinery use in each orchard

Management	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Machinery types used	Tractor, tree shaker, apple harvester, pasture topper	Tractors, tree shaker, apple harvester, pasture topper	Tractor and pasture topper	Tractors, tree shaker, apple harvester, pasture topper.	Tractor, mower, fertilizer spreader, sprayers, tree shaker, blower, apple harvester	Tractors, mower, fertilizer spreader, sprayers, wood-mulcher
Tractor use, hours / year*	74	111	1.9	11	138.5	62
Fuel use, litres / year**	592	888	15	88	1108	496
Fuel use litres / ha / year	131.6	86.2	8.3	35.2	205.2	80

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. *Apple harvester may have been self-propelled but most machinery was tractor-driven. **An overall average fuel consumption of 8 litres / hour per tractor hour, including self-propelled machinery, was used. See paragraph 5.65 for more detail on this choice of figure.

Table 3.4 Inorganic fertilizer, herbicide, fungicide and insecticide use in Salt Box and Village Plum orchards

	Total application amount	Application area within the orchard, ha	Rate of application / ha *	Frequency of application / year
Salt Box				
Ammonium nitrate solid fertilizer	211 kg	1.69 (R)	124.9 kg	1
Muriate of potash (potassium chloride) solid fertilizer	422 kg	1.69 (R)	249.7 kg	1
Kieserite (magnesium sulphate) solid fertilizer	211 kg	1.69 (R)	124.9 kg	1
Magnesium sulphate liquid foliar fertilizer	190 kg	5.06 (C)	37.5 kg	5
Croplift liquid foliar fertilizer (20-8-14, nitrogen – phosphorus – potassium)	13 kg	5.06 (C)	2.6 kg	1
Fungicide (Radspor L)	7.6 litres	5.06 (C)	1.5 litres	3
Fungicide (Alpha Captan)	53.1 litres	5.06 (C)	10.5 litres	7
Fungicide (Systhane)	12.4 litres	5.06 (C)	2.5 litres	7
Insecticide (Alpha Chlorpyrifos)	5.1 litres	5.06 (C)	1.0 litres	1
Herbicide (Harvest)	16.9 litres	1.69 (R)	10.0 litres	2
Village Plum				
Ammonium nitrate solid fertilizer (®Nitram)	209 kg	1.67 (R)	125.1 kg	1
Potassium nitrate solid fertilizer	8.4 kg	1.67 (R)	5.0 kg	2
Potash solid fertilizer	209 kg	1.67 (R)	125.1 kg	1
Bortrac liquid foliar fertilizer (150 g boron / litre, 65 g nitrogen / litre)	2.49 kg	4.98 (C)	0.5 kg	1
Fungicide (Systhane)	2.0 litres	4.98 (C)	0.4 litres	2
Fungicide (Indar)	2.49 litres	4.98 (C)	0.5 litres	2
Fungicide (Signum)	1.7 litres	4.98 (C)	0.3 litres	1
Fungicide (Teldor)	1.0 litres	4.98 (C)	0.2 litres	1
Insecticide (Equity)	10.0 litres	4.98 (C)	2.0 litres	4
Herbicide (Trinity)	0.8 litres	1.67 (R)	0.5 litres	1

Notes: * Rates are totals for all applications in a year, not for each application. Solid inorganic fertilizers and herbicides were applied to the area of ground along the tree rows (R), liquid fertilizers and pesticides were sprayed onto the canopy area of the fruit trees (C). Total number of spraying events / year for tree canopies were 7 for Salt Box and 9 for Village Plum because some chemicals were mixed prior to application.

Management of Romulus Orchard

3.10 Romulus Orchard is an intensively managed cider apple orchard. It is managed in a similar way to Salt Box Orchard and Village Plum Orchard. The trees were planted in 1994. The trees are all pruned every year. Prunings and fallen dead wood used to be cleared and burnt, but recently a chipper and mulcher for this wood has been acquired. In 2007, fruit yield was 326 tonnes (49.4 tonnes / ha). The fruit is harvested mechanically using a tree shaker, blower and harvester. The grassland between the tree rows is mown twice a year and the ground beneath the tree rows is treated with herbicide. Inorganic fertilizers are applied to the tree rows and a fungicide and insecticide spray regime is followed to control pests and diseases.

Orchard economics

Scope of economic assessment

3.11 The three types of economic value of orchards considered by the project are the profit earned by the orchard owner, the cash flows generated in the local economy through the management of the orchards and the benefit to earnings from tourism that derive from the presence of orchards. The foundation for the first two types of value is considered below. Both values can be directly expressed in monetary terms by assessing income and expenditure for each orchard and the multiplier effect that expenditure by the orchard owner on orchard management may have on cash flows in the local economy. In contrast, the role of orchards in encouraging tourism, and thus spend by tourists in the local economy, is more complex. Value may in part be related to social factors, including the perceptions of visitors as to the attractiveness of orchards. This topic is examined in Chapter 6. The landscape setting of individual orchards might also have an impact, as it affects the visibility of each orchard, as described in Chapter 2. In Chapter 7 a monetary value for each orchard in terms of tourism earnings is assessed from economic data on tourism earnings in Herefordshire as a whole, informed by these social and environmental aspects of orchards.

Orchard profitability

3.12 The structured questionnaires used to gather management information from the orchard owners also included questions about income and expenditure over a previous 12 month period. In most cases the main calendar year covered was 2006 but was 2007 for Half Hyde and Village Plum orchards. All of the six main study orchards generated income and incurred expenditure, even though only 5 of the orchards were harvested for fruit. As with other aspects of assigning monetary values to orchard functions, such as resource protection (see Chapter 7), economic value was restricted to 'flow' of annual income and expenditure, not to capital valuations or depreciation. Since each orchard comprised only one part of the land holdings of individual owners, information was collected to allow costs to be apportioned to the orchard as far as was possible. Where necessary, estimates were made in discussion with the owner, or standardized estimates were used across all orchards. The assumptions used to make these estimates are set out below. In addition, it should be noted that the types of income and expenditure are simplified estimates because no account has been taken of overheads, taxation or the costs of centralised farm business functions. As a result, the final figures for overall profits are not 'actual' but are estimates. Nevertheless, these estimates are considered to indicate the scale of potential profit and loss attached to management of each orchard and the key income and expenditure items.

Income from the orchards

3.13 Several income streams were identified in the questionnaire results. The income from the sale of fruit was received for all orchards except Lady Close where no fruit was harvested.

Note that the income from fruit is treated as gross income, and costs of packing and delivery appear under the costs heading.

3.14 The livesock grazing in the traditional orchards, ie Henhope, Tidnor, Lady Close and Half Hyde, provided a service through management of the orchard floor, and was part of the owner's farm enterprise for two of the orchards. The value of this service was included as income for all the traditional orchards, even if no payment was received by the owner from the livestock grazing. Income was estimated based upon a notional income of 50p per head of livestock per week of grazing.

3.15 The traditional orchards were all eligible for Single Payment under the Common Agricultural Policy of the European Union. At the time of the study, three of these orchards received Single Payment. All the orchards met the specific criteria for orchards of environmental value that were eligible for the Single Payment, such as no evidence of herbicide-treated or mechanically created strips beneath the tree canopies, inclusion within the orchard options in Government agri-environment schemes such as the Countryside Stewardship Scheme or evidence of livestock grazing throughout the orchard (Defra 2005). These criteria excluded the intensive orchards from eligibility for Single Payment. It could be argued that as the orchard Single Payment recognized the environmental value of traditional orchards it should be included in a monetary value for biodiversity. However, the exclusion of intensive orchards was only temporary. Subsequent reform of the EU fruit and vegetable regime meant that all orchards were eligible to apply to be allocated new Single Payment from 2010 (Defra 2008). It was therefore decided to keep the Single Payment in the economic valuation of the orchards to avoid confusion if the figures from the project are compared to future studies of orchard profitability and biodiversity value.

3.16 To avoid double-counting in the Triple Bottom Line Accounts, the economic accounts exclude any income received by traditional orchards from orchard options in Government agri-environment schemes because these are used in the valuation of biodiversity. The traditional orchards are the only ones eligible for orchard options under the previous scheme (Countryside Stewardship) or the current scheme (Higher Level Environmental Stewardship). The payment under this latter scheme has been used as a proxy for monetary value of biodiversity in Chapter 7.

3.17 Only Tidnor Wood Orchards received income from other sources than fruit, livestock or Single Payment. An innovative approach has been taken to the development and management of the orchard through the setting up of the Tidnor Wood Orchards Community Interest Company (CIC), into which it is the owner's intention to transfer at least Museum Orchard. The objective of this Company is protect all the varieties of UK, Channel Islands and Eire cider apples that can still be found. The Company can trade and make a profit but assets must be disposed of to another CIC or to a charity. Income has been derived from sponsorship of trees for their lifetime and donations. Other income has come from sale of firewood from pruning and thinning activities and from sale of mistletoe, which is abundant in the orchard tree canopies.

Expenditure on orchard management

3.18 Direct employment costs included the number of hours of the owner's own time and of family members as well as that of employees. The owner and family time was not often routinely recorded for the business so estimates were made in discussion with the owner. A notional cost of £7 per hour was assumed for farmer or family member time spent in the orchard. Directly-employed labour included locally-based workers, and, in the case of Village Plum Orchard, migrant workers from continental Europe. Other work in the orchards was primarily carried out by local contractors. Contractor costs were broken down into different elements, corresponding to the cost categories assessed for each orchard. Contractor fuel costs and contract fruit delivery costs were separated from 'labour' (which incorporated any other contractor costs).

3.19 Delivery and packing costs were treated as a separate item. Where necessary, a standard cost of £5.50 per tonne was used to estimate delivery cost of the fruit to the point of sale, the cider mill in the case of cider fruit. The cost type was included in the assessment of overall profitability because it was a critical cost in determining the level of profit from the fruit crop. This profit would be over-estimated if the fruit sale price was used without recognising the cost of delivering the fruit to the point of sale. It was a cost item which extended 'beyond the orchard gate', meaning that the economic valuation of the orchards had somewhat different boundaries to those used in other types of orchard valuation in the project, in particular for carbon sequestration. However, the separation of delivery and packing as a discrete item allows comparisons with other values on an equivalent, strictly site-limited, basis if desired.

3.20 Several categories of purchases for orchard management and maintenance were identified. Agrochemicals comprised the inorganic fertilizers and pesticides used in Salt Box Orchard and Village Plum Orchard. Replacement fruit trees included cost of tree guards where protection from grazing animals was required. A category of miscellaneous items included fencing and other materials and hire of special equipment, such as the cost of a wood-chipper at Tidnor Wood Orchards. Cost of fuel was based on the owner's estimate of the time needed to carry out orchard management operations using large machinery. Use of machines like chain saws and strimmers was not included. Fuel use included the amounts expended by contractors and all other workers in the orchards. As explained in the management section of this chapter and in paragraph 5.65, a standard fuel consumption per hour was used. For economic valuation, a standard cost per litre of fuel was applied to the estimate of total fuel consumption. This cost was the average price of red diesel from April 2006 to March 2007 of 40 p / litre (Defra and others 2007). Costs of the management of boundary hedgerows around the orchards were not included in the estimates of costs of orchard management.

Income and expenditure accounts for each orchard

3.21 Based upon the assumptions and estimates described above, the estimated income and expenditure accounts for each orchard are given in Table 3.5 below. Income and expenditure categories are listed, together with their monetary value, and an overall net profit is given to represent the economic value attached to each orchard. These values are expressed on a per hectare basis in Table 3.6 to aid comparison between orchards.

Table 3.5 Estimated income and expenditure accounts for each orchard in pounds sterling (£)

	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Year of accounts	2006	2006	2006	2007	2006	2007
Orchard area (ha)	4.5	10.3	1.8	2.5	5.4	6.2
Income types *(%)*						
Fruit crop*	6,750 *(79.2)*	18,060 *(90.2)*	0	1,656 *(77.5)*	20,930 *(100)*	76,824 *(100)*
Grazing	510 *(6)*	240 *(1.2)*	200 *(88.9)*	109 *(5.1)*	0	0
Single Payment	1,260 *(14.8)*	0	25 *(11.1)*	371 *(17.4)*	0	0
Other	0	1,715 *(8.6)*	0	0	0	0
Total income	8,520 *(100)*	20,015 *(100)*	225 *(100)*	2,136 *(100)*	20,930 *(100)*	76,824 *(100)*
Cost types *(%)*						
Direct employment	350 *(12.3)*	12,447 *(45.8)*	140 *(73.3)*	56 *(7.3)*	1,887 *(32.9)*	40,018 *(56.8)*
Contractors**	1,722 *(60.4)*	10,576 *(38.9)*	0	473 *(62)*	0	0
Delivery and packing	413 *(14.5)*	1,183 *(4.4)*	0	99 *(13)*	1,955 *(34.1)*	28,867 *(41)*
Agrochemicals	0	0	0	0	1,388 *(24.2)*	1,076 *(1.5)*
Tree restocking /guards	132 *(4.6)*	2,376 *(8.7)*	45 *(23.6)*	0	60 *(1.1)*	300 *(0.4)*
Materials, machinery and fencing	0	250 *(0.9)*	0	100 *(13.1)*	0	0
Fuel	237 *(8.3)*	355 *(1.3)*	6 *(3.1)*	35 *(4.6)*	443 *(7.7)*	198 *(0.3)*
Total cost	2,854 *(100)*	27,187 *(100)*	191 *(100)*	763 *(100)*	5,733 *(100)*	70,459 *(100)*
Net profit (total income – total cost)	5,666	-7,172	34	1,372	15,197	6,365

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound. *Fruit crop is gross of delivery and packing. **Contractors excludes fuel and delivery charges which are in other items in the table.

Table 3.6 Estimated income, expenditure and net profit per hectare for each orchard, in pounds sterling (£)

	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Income types / ha						
Fruit crop*	1,500	1,753	0	662	3,876	12,391
Grazing	113	23	111	44	0	0
Single Payment	280	0	14	148	0	0
Other	0	167	0	0	0	0
Total income / ha	1,893	1,943	125	854	3,876	12,391
Cost types / ha						
Direct employment	78	1,208	78	22	349	6,454
Contractors**	383	1,027	0	189	0	0
Delivery and packing	92	115	0	40	362	4,656
Agrochemicals	0	0	0	0	257	174
Tree restocking /guards	29	231	25	0	11	48
Materials, machinery and fencing	0	24	0	40	0	0
Fuel	53	34	3	14	82	32
Total cost / ha	634	2,639	106	305	1,062	11,364
Net profit / ha (total income / ha – total cost / ha)	1,259	-696	19	549	2,814	1,027

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound. *Fruit crop is gross of delivery and packing. **Contractors excludes fuel and delivery charges which are in other items in the table.

Impact of orchard expenditure on the local economy

3.22 The work of the New Economics Foundation (NEF) has shown that spending by businesses with local suppliers has a positive impact upon the local economy which is worth more than the face value of the expenditure because cash put into the local economy can be spent again on further local goods and services (Sacks 2002). This re-spending is termed the local multiplier effect. NEF has developed a methodology for calculating the impact of this local spending by tracking how much of this spend is then re-spent locally, through three iterations – termed the Local Multiplier 3 (LM3). Whilst this measure has limitations, it is recognised as a simple tool for estimating the impact of local spending patterns (Mills and others 2010).

3.23 For the purposes of the orchard project, purchases by the orchard owner from local suppliers or employment of people who may spend their wages locally were recorded on the questionnaire. 'Local' was defined as the unitary authority area of Herefordshire. Sometimes part of the expenditure on a cost item was with local suppliers and the remainder was with suppliers elsewhere. For example, some of the new trees at Tidnor were sourced locally, while others were purchased from outside Herefordshire. In these cases only the local purchase proportion was included in local expenditure totals. However, the spend in the local economy by migrant workers employed at Village Plum Orchard required further consideration as different assumptions about local spending by employees might needed to be applied to the proportion of earnings spent locally, because some money could have been sent overseas due to the migrant status of the employees. Four representatives of the workers, who were mainly from Poland, were asked about their spending patterns and the extent to which take-home pay after tax was remitted overseas. The workers interviewed spent about 34% of earned take-home pay locally on accommodation, other living costs and entertainment. The balance of 66% was repatriated to their home country. Direct employment costs were estimated as notional take-home pay after deduction of 20% tax. This is because, unlike payments to other suppliers, which are inclusive of tax, employees only receive the net amount upon which to choose whether to spend locally.

3.24 It was decided not to include the notional costs of owner and family time spent managing the orchard in the direct employment cost that could be spent locally, in contrast to the main cost estimates for direct employment in Tables 3.5 and 3.6. Unlike the payments to employees, the costs of owner and family time spent on orchard management were not actual cash payments that could be re-circulated in the local economy. Delivery and packing costs were also not included in local expenditure because such expenditure was considered to apply more appropriately outside the orchard boundary, rather than being generated within the orchard itself. Note that this treatment of delivery costs differs from the income and expenditure accounts (Tables 3.5 and 3.6). Agrochemicals were purchased from national suppliers so were not included in local spend. The contribution to local spend from fuel costs may be an over-estimate, because fuel is produced by national and multi-national companies, with a small proportion of sale prices going to local retailers. Tax taken on various items, apart from labour costs, would also have reduced the actual amounts spent in the local economy but was too complicated and indirect in character to be taken into account.

3.25 It was beyond the scope of this study to track expenditure on the orchards through the subsequent payment cycles to complete a LM3 analysis. An estimated multiplier was therefore applied to the total of local purchases for labour, goods and services for each orchard, based upon the published research from other projects and organizations. Some examples of LM3 cited by Sacks (2002) are: 1.87 scored by Eden Community Outdoors; 1.23 scored by North Norfolk District Council for procurement contracts with a non-local contractor and 2.15 for contracts with a local contractor; 2.00 scored by Cusgarne Organics and 2.15 scored by Graig Farm Organics, in which staff and suppliers were mainly local. Mills and others (2010) record multipliers of between 1.29 and 2.49 for agri-environment activities, including induced benefits from expenditure of wages, salaries and profits by local employees, and calculated a multiplier of 2.78 for all environmental stewardship schemes. The lowest possible score for LM3 is 1.00 (where nothing is bought locally) and the theoretical maximum is 3.00 where the purchases in the three rounds are entirely made locally. The studies referenced in Sacks (2002) suggest that when buying from a local supplier, the multiplier could be expected to be around 2.00 and this is the indicator chosen to calculate the value of orchard expenditure to the local economy. The value added to the local economy of buying from local suppliers is the difference between this LM3 of 2.00 and the LM3 if entirely sourced from outside the locality of 1.00; that is, 1.00 times the value of local purchases. The value of orchard expenditure in the local economy using this LM3 multiplier is shown in Table 3.7.

Table 3.7 Estimated economic value of orchard expenditure to the local economy in pounds sterling (£)

Local expenditure	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Orchard area	4.5	10.3	1.8	2.5	5.4	6.2
Cost types						
Direct employment	0	0	112	0	1,442	9,387
Contractors	1,722	9,076	0	473	0	0
Tree restocking /guards	132	850	45	0	0	0
Materials, machinery and fencing	0	250	0	100	0	0
Fuel	237	355	6	35	443	198
Additional local economy value (Total local expenditure x LM3 of 1.0)	2,091	10,532	163	608	1,885	9,585
Additional local economy value / ha	465	1,022	91	243	349	1,546

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound.

Factors affecting orchard income, expenditure and cash flow in the local economy

3.26 All the orchards generated income, even Lady Close Orchard where no fruit was harvested, although income here was small. Nevertheless, the low management costs for Lady Close meant that a small positive net profit was recorded for the orchard (Table 3.5). The fruit crop dominated earnings in the other 5 orchards. However, as described in the management summaries for each orchard, the yield from the orchard can vary widely from year to year owing to the cropping behaviour of the trees or due to weather conditions. An exception was Salt Box Orchard, which was reported by the owner as having a relatively stable yield from year to year. The results also show the marked difference in value between cider apple crops and fresh plums. The value of the plum crop was about 3 times larger than the value of the highest-earning cider apple crop (Table 3.5).

3.27 Horticultural statistics produced by Defra (2010) show that fairly similar average crop values are achieved for the UK as for the fruit crops from the 6 orchards. UK values are expressed as farmgate prices so that they are as close as possible to the raw material price the farmer receives, excluding costs of delivery and packaging (Julie Dobson, Defra pers. comm.). The UK average farmgate price for plums is £11,100 / ha, rather less than the estimated income / ha from fruit for Village Plum Orchard of £12,391 (Table 3.6). This UK figure for plums is over 5 times larger than the average UK farmgate price for cider apples (£1,893 / ha). The estimated income / ha from the cider apple crops from the study orchards range higher and lower than the UK average (Table 3.6). The estimated income from Salt Box Orchard is considerably higher (£3,876 / ha) while that from Half Hyde Orchard is substantially lower (£662 / ha).

3.28 Table 3.1 shows that Salt Box had a much greater yield per hectare than the other cider orchards, even though the yield per tree was lower than the trees in the other orchards. The yield and income from fruit was higher per hectare from Salt Box because of the much higher numbers of productive trees / ha in this orchard (Table 3.1). These densely-planted ‘bush’ trees in Salt Box Orchard therefore produced a much higher total yield than the more widely-spaced standard and half-standard trees in the other cider orchards.

3.29 Comparison of income from fruit with costs of production alters the picture as regards relative net income from cider apples and plums. Plums are a delicate crop and must be hand-picked and then packed in protective trays. Labour and packing costs were therefore high and comprised the largest proportion of the expenditure on orchard management at Village Plum Orchard (Table 3.5). The more robust cider apples can be mechanically harvested and transported in bulk with minimal protection. These lower costs mean that overall costs of management for the cider orchards were considerably lower than at Village Plum Orchard.

3.30 Agrochemicals were the third largest cost after labour and delivery at Salt Box Orchard and Village Plum Orchard, though proportionately more important at Salt Box given the lower labour and delivery and packing costs here (Table 3.5). Perhaps surprisingly, fuel cost was a relatively small item in the management of the six orchards, despite quite extensive use of machinery in all of the orchards except Lady Close Orchard. Overall, the income from the intensive orchards was higher but costs were higher as well, compared to the traditional orchards, with the exception of Tidnor, which was a special case (see paragraph 3.31). There was no clear difference in profitability between traditional and intensive orchards. Salt Box, an intensive orchard, had the highest profit / ha, but a traditional orchard, Henhope, had the second highest profit / ha (Table 3.6). However, when comparing like with like, ie intensive and traditional cider apple orchards, the profit from the intensive orchard (Salt Box) was over £1500 / ha greater than the profit from the most profitable traditional orchard (Henhope).

3.31 Tidnor Wood Orchards was a special case as far as income and expenditure were concerned. It was the only orchard to have a negative net profit (Tables 3.5, 3.6). Labour costs were high because of significant work being undertaken by the owner to develop the orchard in several ways. These included the establishment of the site as a registered National Collection of cider apples, acquisition of sponsors for the trees, conversion of the orchard to certified organic status, development of the Tidnor Wood Orchards Community Interest Company and construction of educational facilities on site. High numbers of new trees, acquired for the cider apple collection, also added to costs. If the cost of the owner’s time is excluded from the overall cost, this drops to £14,740, giving a positive net overall profit of £5,276 and a net profit per hectare of £512.

3.32 The assessment of income and expenditure for the six orchards was limited to a single year. In terms of the overall costs of orchard management no account was taken of ‘irregular’ costs or long-term costs. Factors such as depreciation in the value of machinery have not been taken into account. Of particular importance in the long-term would be the costs replacing the orchard. Fruit trees have a finite productive life-span and have to be replaced once this draws to an end if production is to be maintained. Where the orchard trees are more or less even-aged replacement costs in a single year could be heavy. A rough estimate of orchard establishment costs would be about £7,500 per hectare (Chris Fairs, Bulmer Orcharding, pers. comm.).

3.33 All the orchards contributed to expenditure in the local economy (Table 3.7). In particular the contributions from wages or contract payments were relatively large. The estimate of amount of money sent home by migrant workers at Village Plum Orchard (66%) was significantly higher than an estimate of the average level of income sent home by migrant workers in London (Datta and others 2006). This study comprised interviews with 362 migrants from 56 countries and found that the average proportion of income sent home was 20% - 30% and the range was from 4% to 65%. It should be noted though that definitions of pay made in that study may differ from the one used for Village Plum Orchard. However, despite the large proportion of pay being sent home rather than spent locally, Village Plum made the largest contribution to local expenditure per hectare (Table 3.7) primarily because of the money paid to the migrant workers and their spending in the local economy. Relative spend in the local economy showed no clear difference between traditional and intensive orchards. Village Plum Orchard, an intensive orchard, made the greatest contribution because of the manual harvesting of plums, while Tidnor and Henhope, traditional orchards, made a greater contribution than Salt Box, an intensive orchard (Table 3.7).

Conclusions on the economics of orchard management

3.34 The profitability of the six orchards largely reflects the management objectives that were in place for each orchard. Four orchards, Henhope, Half Hyde, Salt Box and Village Plum, were managed primarily for the fruit crop. Lady Close was managed for public amenity and nature conservation, while Tidnor had community and conservation objectives, such as preservation of cider varieties, nature conservation and educational use, as well as the fruit crop objective. The crop type grown had a major impact on profitability, there being a marked contrast in cider apple production compared to growing of fresh plums. All the orchards contributed towards spending in the local economy, in particular Village Plum Orchard, where labour costs were high, and as a consequence, spending locally was also estimated to be high. There were no clear differences between traditional and intensive orchards in profitability or spend in the local economy. However, the intensive cider orchard, Salt Box, was more profitable / ha than the traditional cider orchards.

Topics for further work

3.35 The six orchards were very much case studies and larger samples of orchards of different types are needed to get a better picture of orchard economics under different management regimes, for example organic production compared to conventional management with pesticides and inorganic fertilisers. Orchard economics also need to be examined over several years to assess the impact of variable cropping on longer-term returns, and other costs such as depreciation need to be taken into account. The multiplier effect of orchard expenditure on local businesses requires a full assessment over several payment cycles to gain an understanding of the actual impact of orchard management expenditure on the local economy.

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4 Orchard biodiversity

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Introduction

4.1 There have been very few systematic surveys of the biodiversity of orchards in the UK. In recent years traditional orchards have received some attention (Smart and Winnall 2006, Lush and others 2009) but intensive orchards have rarely been examined for general wildlife, although pests and their natural enemies have been well-studied in the UK and beyond (Cross 2010, Pekár 1999, Bostanian and others 2004). The biodiversity of the Herefordshire study orchards was investigated through a variety of surveys. The habitat survey yielded information on the range of habitats available for wildlife in the orchards and provided the context for species surveys of selected groups and for a brief review of potential value of the orchard habitats for invertebrates and birds. The species surveys reported in this chapter are of taxonomically difficult groups where existing survey information is sparse. Bryophytes (comprising mosses and liverworts), lichens, fungi and myxomycetes were recorded by expert naturalists. Every orchard was visited although fungi recorders were not able to visit all sites with the same frequency. The conservation status of the habitats and species found were assessed and are reported below, in particular, the presence of habitats and species listed as priorities for conservation action in the UK Government's Biodiversity Action Plan (BAP).

Orchard habitats

Overview of the orchard habitat survey

4.2 Orchard habitats are defined by their structure of open-grown fruit trees rather than by a particular plant species assemblage (Robertson and Wedge, 2008). In practice, orchards are really habitat complexes or mosaics, not just a collection of trees. The wildlife of the orchard depends on this mosaic of habitats, which includes the fruit trees, scrub, hedgerows, hedgerow trees, 'non-fruit' trees within the orchard, the orchard floor habitats, fallen dead wood and, sometimes, associated features such as ponds and streams.

4.3 Three main components of the orchard habitat mosaic at each site were surveyed by Elizabeth Slingsby: the orchard fruit trees, the orchard floor and the orchard boundaries. Survey information was mostly collected in September 2008 (07/09/08 to 10/09/08), with some follow-up work in May 2009 (02/05/09, 03/05/09 and 12/05/09). John Bingham, who worked for Natural England at that time, surveyed some of the orchard grasslands, with Elizabeth Slingsby, on 12/05/09. Some general information derived from the habitat survey on the character of the orchards and surrounding land use is given in Chapter 2, to help to describe orchard character, including maps of each site (Maps 2.2 to 2.8). More detailed findings on habitats are reported in the following section of Chapter 4. After the survey methods are described below, the results for each orchard are presented and then summary tables are given in a section discussing management factors affecting the habitats across the 7 orchards. Nomenclature of vascular plants follows Stace (2010).

Orchard habitat survey methods

Fruit tree survey

4.4 The features surveyed in each orchard are described in Table 4.1. Orchard character features have been used in Chapter 2 in the general descriptions of the different orchards and the results are not reported on again here. The survey of fruit trees tried to assess features that would provide clues as to the various micro-habitats available in the orchards for wild flora and fauna. The girth size of the trees gives a broad indication of the age structure or 'stage' structure of the trees and likely value for organisms, such as wood decay beetles, which favour veteran trees (Read 2000). Similarly the abundance and type of veteran tree features present across the sample of trees in an orchard indicates the wood decay micro-habitats available (Lush and others 2009). The incidence of fallen dead wood below sample trees points to the relative abundance of this micro-habitat in the orchards. Mistletoe (*Viscum album*) has its own associated wildlife (Robertson and Wedge 2008, Briggs 2011) and can be an important micro-habitat in an orchard. Trees which are not grown for fruit production, but which are present in an orchard, can also add to the habitats available within an orchard. Ivy growing up fruit trees can provide habitats, for example for nesting birds, but along with scrub can shade trunks and branches, making conditions less suitable for warmth-loving invertebrates. The occurrence of ivy on fruit trees was looked for but no ivy was found on any of the fruit trees in the orchards.

4.5 Information was gathered from the orchard owners and others about the identity of fruit varieties within each fruit type (apple and plum) in each orchard.

Table 4.1 Features recorded in the fruit tree survey at each orchard, including orchard character features

Feature	Survey method and comments
Orchard character*	
Fruit tree type	Identified as apple / pear / plum, not fruit variety.
Tree form	Visual estimate for the orchard as a whole. The definitions of tree form, for the purposes of the current survey, relate to the height of the trunk up to the first branch. A 'bush' tree had less than 1m (metre) of trunk, a 'half-standard' tree had a trunk around 1-2m, and a 'standard' tree had a trunk of 2m or more.
Canopy cover	The amount of closure of the tree canopy was visually estimated. A closed canopy was defined as where the crowns of the trees were touching, an open canopy was defined as where there were gaps between the crowns.
Distance between trees	Where there was a clear pattern of tree rows and wider alleys between tree rows, distance (m) between trees in a row was measured with a tape for 6 randomly chosen trees in the row and the distance between trees across alleys measured in the same way. Where there was no clear pattern of rows and alleys, distance to the nearest neighbour was measured for 6 randomly chosen trees.
Tree features	
Girth of trunk	Girth size (tree circumference) was measured in centimetres for 20 randomly chosen trees using a tape measure. Girth was measured at 1.3m height (breast height) unless the tree branched below this height, in which case it was measured below the first branch. In the bush orchards the latter situation was normal.
Presence of veteran tree features	The same 20 randomly chosen trees for which girth was measured were visually surveyed for the following veteran tree features: hollow trunks or hollow major branches, rot sites or holes in the trunk or major branches, sap runs, split bark.
Other features	
Mistletoe	The presence of mistletoe growing in any of the 20 sample trees was recorded.
Amount of fallen dead wood	The presence or absence of fallen deadwood on the ground directly beneath the tree canopy was recorded for each of the 20 sample trees.
Presence of 'non-fruit' trees	The presence of any trees not grown for fruit within the orchard boundary was recorded and their locations marked on the site map.
Tree management	Notes were made on any obvious recent management activities, for example, pruning of existing trees, replacement planting of trees.

Notes: * see Chapter 2 for results.

Orchard floor survey

4.6 In September 2008 the species composition, defined as groups of taxa, and height of the grassland were recorded using five randomly placed 1m x 1m (1m2) quadrats in each orchard (Table 4.2). The cover of the plant groups was estimated in each quadrat. Further species information was collected for some sites in May 2009, including 2 of the intensive orchards, because little existing information on orchard floor habitats is available in the literature for such orchards. In addition, an attempt was made to assign National Vegetation Classification types (Rodwell 1992) to the orchard floor habitats, but these assessments of types were not based on detailed quadrat recording and should be regarded as tentative. The plant groups chosen for the quadrat recording were based on the indicators used in the grassland condition assessment method for Sites of Special Scientific Interest (Robertson and Jefferson 2000). A high cover of grasses compared to broad-leaved herbs can indicate a high degree of nutrient enrichment or lack of grazing or mowing and thus unsuitability for maintenance of high plant species richness, although in orchards the shading effects of the tree canopy can also reduce the species-richness of the sward. The group of 'broad-leaved herbs' excluded several broad-leaved herb indicators of eutrophication and disturbance such as nettles, *Urtica* species. The 'negative' eutrophication and disturbance indicators recorded were nettles, thistles (*Cirsium* spp.) and docks (*Rumex* spp.). Bramble (*Rubus* spp.) cover was recorded to indicate whether scrub invasion could be affecting grassland species-richness or be affecting fruit tree survival or condition by growing over the fruit trees (Lush and others 2009).

4.7 Estimates of sward height were made to give a snapshot of intensity of sward management, though sward height usually changes through the year in response to grazing and mowing. The presence or absence of anthills, a micro-habitat of grassland, was also noted. In fact, no anthills were seen in any of the orchards.

Table 4.2 Features recorded in the orchard floor survey at each orchard

Feature	**Survey method and comments**
Presence / absence of bare strips along tree rows	Visual inspection. Herbicide is used regularly in intensively managed orchards to reduce competition from herbaceous vegetation, in contrast to the fully grassed orchard floor of traditional orchards.
Grassland species composition	A 1m^2 quadrat was placed at 5 randomly chosen points within orchard grassland. A visual estimate was made of the percentage covers of grasses (Poaceae), nettles (*Urtica* spp.), brambles (*Rubus* spp.), thistles (*Cirsium arvense*, *C. vulgaris*), docks (*Rumex obtusifolius* / *R. crispus*), other broad-leaved herbs as a group, and bare ground. Herbicide strips were not sampled, although patches of herbaceous vegetation were sometimes present.
Height of grassland sward	One estimate of the average height of the sward was made in each quadrat, by measuring with a tape (cm) the height of one leaf blade judged to be of average height.
Orchard floor management	Notes made on any obvious recent management activities, for example, mowing.

Orchard boundary survey

4.8 In September 2008, the type of boundaries around each of the 7 orchards was surveyed from the side of the hedgerow facing the orchard. The woody species-richness and cover of native woody species in hedgerows were recorded (Table 4.3). Cover of native woody species was used to determine if the hedgerow was a national priority BAP hedgerow according to the revised definition of BAP hedgerows (Maddock 2010). Definitions of the particular hedgerow types found and the definition of species-rich hedgerows were taken from the hedgerow survey handbook (Defra 2007). A general picture of the composition of the hedgerow basal flora across each orchard was also made in September 2008 by quadrat sampling (Table 4.3).

Table 4.3 Boundary type and general hedgerow features recorded in the hedgerow survey at each orchard

Feature	**Survey method and comments**
Boundary type	The type of boundary was recorded: hedgerow, fence, mixed hedgerow and fence, other (tall herbs on river bank). A hedgerow is defined as any line of trees or shrubs over 20m long and less than 5m wide at the base of the trunks of woody species, and where any gaps between trees or shrubs along the line are less than 20m in width.
General hedgerow features	
Hedgerow type	The hedgerow types recorded were shrubby hedgerow, shrubby hedgerow with trees and line of trees. A shrubby hedgerow is a line of woody plants that have some or all of their leafy canopies less than 2m in height from the ground. A line of trees has the base of the tree canopies greater than 2m from the ground and the gap between the individual tree canopies is less than 20m. Where both types are present on the same section of boundary, the type is classed as a shrubby hedgerow with trees.
Woody species number	The number of woody structural species making up the hedgerow was counted on a 30m section of each hedgerow. Hedgerows with 5 or more woody species were defined as species-rich (excluding bramble and climbers, except rose *Rosa* spp.). Woody species had to be either native to the UK or archaeophytes (non-native but naturalised in the wild before 1500 AD). The 30m section of the hedgerow was measured from one end point of a hedgerow to a distance of 30m along the hedgerow.
Cover of native woody species	The combined percentage cover of native (UK) woody structural species making up the hedgerow was visually estimated in a 30m section of each hedgerow (same sample as for woody species number above), in comparison with percentage cover of non-native structural woody species. Native was defined as excluding archaeophytes and sycamore (*Acer pseudoplatanus*). Hedgerows with at least 80% cover of native woody species were defined as priority BAP hedgerows.
Hedgerow basal flora	Hedgerow flora was sampled at 5 randomly chosen points along the total hedgerow length in each orchard (not on each hedgerow). A $1m^2$ quadrat was placed in the herbaceous vegetation border immediately adjacent to the hedgerow, not directly underneath the hedgerow. A visual estimate of the percentage covers of grasses (Poaceae), nettles (*Urtica* spp.), brambles (*Rubus* spp.), thistles (*Cirsium arvense*, *C. vulgaris*), docks (*Rumex obtusifolius* / *R. crispus*), cleavers (*Galium aparine*), other broad-leaved herbs as a group, and bare ground was made.
Height of hedgerow basal flora	One estimate of the average height of the basal layer of the hedgerow was made in each quadrat, by measuring with a tape (cm) the height of one leaf blade judged to be of average height.

4.9 Hedgerow condition was assessed for each hedgerow, beginning in 2008 and being completed in 2009. The method adopted was that developed by Hedgerow Habitat Action Plan Group (Defra 2007). The method assesses whether or not a hedgerow is in ‘favourable condition’ for biodiversity, that is, if it is still capable of supporting abundant and diverse wild flora and fauna (Defra 2007). The method uses the features (attributes) described in Table 4.4 below. These features were recorded along the length of each hedgerow, on the inner, orchard-facing side. To be in a favourable condition a hedgerow must meet all the thresholds listed in Table 4.4 below.

Table 4.4 Features of hedgerows recorded to assess condition of each hedgerow

Feature	Survey method	Threshold for hedgerow to be in favourable condition
Hedgerow dimensions		
Height	Visual estimate, with the aid of a metre-length stick, of the average height of the top of the hedgerow from the ground, excluding any banks from the height measure.	At least 1m in height
Width	Visual estimate, with the aid of a metre-length stick, of the average width at widest point of the hedgerow canopy, shoot-tip to shoot-tip.	At least 1.5m in width
Cross-sectional area	Calculated by multiplying average height and width for the hedgerow.	Minimum of $3m^2$ in cross-sectional area
Hedgerow integrity		
Overall continuity of canopy along the hedgerow	A visual estimate was made of the total length of gaps present along the hedgerow as a percentage of total hedgerow length.	<10% of total length of hedgerow as gaps
Size of gaps along the hedgerow	A visual estimate was made to identify any gaps > 5m wide along the hedgerow, excluding access points.	No gaps >5m wide
Average height of base of hedgerow canopy, ie gap at base	A visual estimate was made, with the aid of a tape, of the average height from the ground below the hedgerow to the lowest leafy growth.	Base of canopy less than 0.5m above ground. This threshold is only applied to shrubby components of hedgerows, not to lines of trees.
Undisturbed ground and perennial herbaceous vegetation cover		
Average width of undisturbed ground	Visual estimate, with the aid of a metre-length stick, of the average width of undisturbed (uncultivated) ground from the centre-line of the hedgerow.	At least 2m of undisturbed ground. Automatically favourable if the hedgerows borders undisturbed grassland vegetation.
Average width of perennial herbaceous vegetation	Visual estimate, with the aid of a metre-length stick, of the average width of perennial herbaceous vegetation between the centre-line of the hedgerow and any adjacent disturbed ground.	At least 1m width of perennial herbaceous vegetation
Nutrient enrichment and disturbance		
Cover of herbaceous flora indicator species	Visual estimate of the overall percentage cover of nettles (*Urtica* spp.), docks (*Rumex obtusifolius* / *R. crispus*) and cleavers (*Galium aparine*), within a 2m wide band alongside the hedgerow.	No suitable thresholds have been developed, but rule of thumb used of less than 20% combined cover of nettles, cleavers and docks
Recently introduced, non-native species		
Cover of non-native woody species	Visual estimate of the cover of all recently introduced non-native woody species as percentage of area of the vertical face of hedgerow.	Maximum of 10% cover of non-native woody species.
Cover of non-native herbaceous species	Visual estimate of the cover of all recently introduced non-native herbaceous species as percentage of a band along the hedgerow of 2m width, extending from the centre-line of the hedgerow.	Maximum of 10% cover of non-native herbaceous species*.

Notes: * No instances were recorded of this threshold being exceeded by the orchard hedgerows.

Overview of habitat survey results for each orchard

4.10 The key features of the habitats surveyed in each orchard are briefly described in the next section, while the quantitative results are primarily given in Appendix 1 and Appendix 2, and in the summary tables, Table 4.5 to Table 4.11. Reference is also made to the maps of each site, which can be found in Chapter 2 (Maps 2.2 to Map 2.8) along with orchard character results (Table 2.5). The fruit varieties present in each orchard are described after the fruit tree survey results and the names of the varieties are listed in Appendix 3. For convenience, hedgerow management information from the orchard owners is reported in the orchard boundary sections for each site in Chapter 4, rather than in Chapter 3.

Henhope Orchard habitat survey results

Fruit trees in Henhope Orchard

4.11 The cider apple fruit trees in the orchard had quite a diverse age structure (Table 4.6, Map 2.2). This age variation was reflected in the girth sizes measured, which varied widely from 45cm to 144cm. The oldest age class (60 + years) predominated however (Table 4.6) and the average girth size of trees was 90cm. The age of many of the trees means that veteran tree features existed on the majority of sample trees in some form (Table 4.5, Appendix (A) 1, Table A1.1). Rot sites and holes were particularly prevalent, with 55% of trees having these features, some of the features being fairly large holes. Mistletoe (*Viscum album*) grew on 35% of trees, in large clumps, and was also observed on a hawthorn tree in the hedgerow.

4.12 Beneath 15% of trees there was fallen deadwood, often in the form of large branches or logs. Towards the top slopes of the orchard particularly, there were several dead trees that had not been replaced, some were still standing and were some lying on the ground.

4.13 Apple fruit varieties in the orchard were identified by Chris Fairs (Bulmer Orcharding) and the orchard owner (Appendix 3, Table A3.1). All the varieties were cider apples except for one dessert apple, Egremont Russet, and one cooking apple, Bramley's Seedling. There was also a pear tree in the orchard. Several of the cider varieties originated in France and most of the varieties dated from about 100 years ago. The cider apple trees were on a M25 (standard) root stock with a Bulmers Norman trunk and the chosen grafted fruiting variety.

Orchard floor in Henhope Orchard

4.14 The orchard floor was fully grassed, there were no bare strips below the tree rows. In September 2008, sward height was variable and had an average height of 18cm (Table 4.8, Table A1.2). As Table A1.2 shows, the grassland was dominated by grasses rather than broad-leaved herbs, and there were enriched patches containing nettles, thistles and docks. These occurred predominantly around the edges of the orchard, probably due to trampling and dung deposition by livestock, and in areas on the lower slopes of the orchard, possibly due to nutrient run-off down-slope.

4.15 The grassland in the northern end of the orchard appeared to have been re-seeded in the past and sweet vernal-grass (*Anthoxanthum odoratum*) and white clover (*Trifolium repens*) were abundant. National Vegetation Classification (NVC) type was closest to MG7 *Lolium perenne* grassland (Rodwell 1992). Further south (upslope) the sward was more like NVC type MG6 *Lolium perenne-Cynosurus cristatus* grassland (Rodwell 1992). It included finer grasses in quantity but cover of broad-leaved herbs was low, suggesting that inorganic fertilisers and herbicides might have been used in the past. Scattered patches of broad-leaved herbs were present in the sward including species such as bluebell (*Hyacinthoides non-scripta*), cowslip (*Primula veris*), buttercup (*Ranunculus sp*), pignut (*Conopodium majus*), self-heal (*Prunella vulgaris*), lesser celandine (*Ficaria verna*), creeping cinquefoil (*Potentilla reptans*), speedwell (*Veronica* sp.) and bugle (*Ajuga reptans*).

4.16 There was a small area of a few square metres in extent of species-rich grassland located on the steeper margin of the grassland on north west side of the orchard. Here the grassland may not have been fertilised. In this area the uncommon adder's tongue (*Ophioglossum vulgatum*) was found with a mix of broad-leaved herbs and fine-leaved grasses, indicating agriculturally unimproved grassland. NVC type resembled an acidic form of MG5 *Cynosurus cristatus-Centaurea nigra* grassland (Rodwell 1992), and would qualify as lowland meadow habitat in the BAP priority list of grassland types.

Orchard boundaries around Henhope Orchard

4.17 There was only one hedgerow bordering Henhope orchard, boundary 2 (Map 2.2). The hedgerow was made up of hawthorn (*Crataegus monogyna*), blackthorn (*Prunus spinosa*), hazel (*Corylus avellana*), sweet chestnut (*Castanea sativa*), oak (*Quercus* sp.) and ash (*Fraxinus excelsior*). The hedgerow consisted predominantly of native woody species and qualified as a priority BAP hedgerow. It contained five native woody species in a 30m stretch, making it a species-rich hedgerow (Table 4.3). The gaps along the hedgerow and at the base of the hedgerow suggested that it had not been laid for a long time. Beneath the hedgerow there were areas of shaded bare ground and large patches of nettles and some docks. The quadrat data also show that nettles had a high cover (Table A1.3). Vegetation height was greater than the grassland sward (Tables 4.8 and 4.11), probably largely because of the 'tall herb' component supplied by the abundant nettles. The gaps in the hedgerow structure and the disturbed, nutrient enriched ground (Table A1.4) meant that the hedgerow could not be described as in favourable condition according to the criteria in Table 4.4. According to the orchard owner, the hedgerow is unmanaged.

4.18 The other boundaries of Henhope Orchard were all fences. Along boundaries 3 and 4 (Map 2.2) the wire fences were very overgrown by bramble, rose and trees of the adjacent woodland, including hawthorn, blackthorn, elder (*Sambucus nigra*), hazel, cherry (*Prunus* sp.), sweet chestnut, oak and ash. In some places, the NVC type in these boundary zones resembled W24 *Rubus fruticosus-Holcus lanatus* underscrub community (Rodwell 1991). Beneath the fences the plant community was dominated by nettles but also included grasses and some broad-leaved herbs. Patches of gorse and bracken in boundary 4 suggested that the soil may have been acidic here.

Tidnor Wood Orchards habitat survey results

Fruit trees in Tidnor Wood Orchards

4.19 Tidnor Wood Orchards was comprised of several stands of trees of differing ages (Map 2.3). The young trees of the orchard, in an area known as Museum Orchard, were sampled separately to the trees in the remainder of the orchard, 20 trees being randomly selected in each of the two areas. The trees in Museum Orchard had small girths, averaging 14 cm. The trees had few veteran trees features although there was some split bark on several tree trunks, apparently due to damage from the wire tree guards (Table 4.5, Table A1.5). Mature cider apple trees occupied the rest of the remaining site area except for a small stand of old trees (Map 2.3). These mature and old stands (known as French Orchard, Bottom Orchard and Old Orchard) were sampled together, and the trees had an average girth size of 85 cm. Many of the trees had veteran tree features, for instance 65% of trees had rot sites and holes (Table 4.5, Table A1.6). Mistletoe was frequent in the tree canopy and present in large bunches (Table 4.5).

4.20 There was little dead wood under the trees in Tidnor Wood Orchards and none under the sample trees (Table 4.5). No standing dead wood was seen. However, the owner noted that as part of the management of the orchard, piles of dead wood were stacked at the edge of the site, so some fallen dead wood habitat was available.

4.21 In recent years Museum Orchard had been planted with a huge number of cider apple varieties. This collection has been recognised as a National Collection® (*Malus*-Cider making) by the National Council for the Conservation of Plants and Gardens (NCCPG). At the time that the collection was recognised by the NCCPG, 400 varieties were present, although subsequent planting has increased this number. The names of the varieties are not listed in Appendix 3 in this report, but names are listed on the web site of the Tidnor Wood Orchards CIC (undated), which is given in the references at the end of Chapter 4. Note that some of the names on this list are synonyms.

Orchard floor in Tidnor Wood Orchards

4.22 All the orchard stands were fully grassed at the time of the survey and no bare strips were evident, although as described in Chapter 2, most of the site was managed intensively less than 10 years before and an aerial photograph dated 1999 shows that bare strips were once present along tree rows, except under the stand of old trees (Map 2.3).

4.23 The area of young trees (Museum Orchard) had a distinctive orchard floor vegetation compared to the grassland in the remainder of the orchard and a separate sample of 5 quadrats was taken in this orchard area. Overall broad-leaved herb cover in the quadrats was high (Table A1.7), averaging similar cover to grasses (Table 4.8). Some bramble cover was also noted (Table A1.7). In May 2009 a species list was compiled. The grassland in Museum Orchard had quite a species-rich sward, with 32 broad-leaved herb and 10 grass species recorded in total. The species list made for the area is given in Appendix 2, Table A2.1. Assigning an NVC type to the grassland was difficult as it appeared to be in transition from a recent disturbance, probably when the previous fruit trees were removed to make way for the young trees (see Chapter 2). Species characteristic of disturbance were recorded, for example prickly sowthistle (*Sonchus asper*) and creeping thistle (*Cirsium arvense*). However, grassland and woodland species were predominant, and the NVC type had some resemblance to a diverse MG6 *Lolium perenne-Cynosurus cristatus* grassland and to W24 *Rubus fruticosus-Holcus lanatus* underscrub.

4.24 The grassland of Museum Orchard was adjacent to plantation woodland on an ancient woodland site (Map 2.3) and this woodland once occupied the area in which Museum Orchard was later created (see Chapter 2). The presence of ancient woodland indicator species in Museum Orchard is therefore interesting. Several woodland species present are included in an unpublished list of Ancient Woodland Indicators (AWIs) produced by Dr Keith Kirby, Principal Woodland Specialist for Natural England. There are regional differences in species regarded as AWIs, those for South West England occurring at Tidnor Wood Orchards were: wood-sedge *Carex sylvatica*, bluebell *Hyacinthoides non-scripta*, primrose *Primula vulgaris*, and bush vetch *Vicia sepium*. Peterken (2009) notes that several constituent species of meadows are found widely in ancient woodland. Such species include common bent *Agrostis capillaris*, sweet-vernal grass *Anthoxanthum odoratum*, cuckooflower *Cardamine pratensis*, large bird's-foot trefoil *Lotus pedunculatus*, and creeping buttercup *Ranunculus repens*, all of which were found in Museum Orchard. The origin of woodland herb species in Museum Orchard is unknown, they may have colonized from the woodland or survived as seed in the soil when the woodland was cleared.

4.25 The orchard floor in the areas occupied by mature trees had limited cover of broadleaved herbs, and grass cover was much higher (Table A1.8). The community resembled a species-poor MG6, perhaps because of shading by the closed canopy of fruit trees and the history of intensive management. However, indicators of eutrophication and disturbance had low cover (Table 4.8, Table A1.8) and species diversity may increase over time under the regime of organic management and thinning of the fruit trees (see Chapter 3). The grassland sward under the stand of old trees appeared to be somewhat richer, bluebell was noted here.

Orchard boundaries around Tidnor Wood Orchards

4.26 Three of the five boundaries in this orchard were hedgerows (Map 2.3). All three hedgerows had at least 80% cover of native woody species so they qualified as priority BAP hedgerows. Boundary 1 was a tall hawthorn hedge, covered with much ivy. The hedgerow was somewhat gappy at the base. Nettles were dominant in the herbaceous flora at the base of the hedgerow. There was disturbance from vehicle access within a metre of the hedgerow. These features mean that the hedgerow was in unfavourable condition (Table A1.10). Boundary 2 was a hawthorn, hazel and elder hedgerow, with larger hawthorn trees standing above the main shrubby hedgerow. Although there was little disturbance or eutrophication evident at the base of the hedgerow, the woody canopy was narrow and gappy, and as a result the hedgerow was judged to be in unfavourable condition (Table A1.10). Boundary 5 was a young hedgerow composed of hazel and hawthorn shrubs (about 1.5m tall in May 2009). Fruit trees, including pears, had also been planted along the new hedgerow. The hedgerow condition was not assessed because the hedgerow had been recently planted. Across the hedgerows in the orchard site, the abundance of nettles in the basal flora was apparent (Table A1.9, Table 4.11) and patches of bramble also occurred.

4.27 Boundaries 3 and 4 (Map 2.3) were wire fences overgrown with bramble and some rose. Trees from the adjacent woodland overhung the fences, and included oak, ash, hawthorn, spruce (*Picea* sp.), pine (*Pinus* sp.), hazel, sycamore and elder.

4.28 Hedgerow management described by the orchard owner included annual trimming in February of the roadside hedgerow (boundary 1) and trimming of the other hedgerows every two to three years. Some gapping up of boundary 1 has been done and the new section of hedgerow (boundary 5) was planted in 2006.

Lady Close Orchard habitat survey results

Fruit trees in Lady Close Orchard

4.29 There were two distinct age classes of fruit trees in the orchard (Table 4.6) and they were sampled separately, with 10 trees randomly selected from each age class. There were 30 old trees of about 80 to 100 years old and 70 young trees about 8 years old at the time of survey. The young trees had an average girth size of 22 cm. Although veteran tree features would not be expected in such young trees, 40% did have split bark on their trunks, apparently due to damage caused by tight wire tree guards (Table A1.11, Table 4.5). The older standard trees had an average girth of 125cm and the largest girth was 184cm. This latter girth size was the largest of among the trees sampled across the 7 orchards. Veteran trees features were common, for instance, 20% of trees had hollow branches or trunks, 80% had rot sites or holes, and sap runs existed on 30% of trees (Table A1.11, Table 4.5). Mistletoe was very frequent in the tree canopies of the old trees, being present in 80% of trees, though none was seen in the canopies of the young trees (Table A1.11).

4.30 Fallen dead wood was fairly frequent under the sampled trees, 10% of young trees had some deadwood beneath their canopies, while 50% of the old trees had fallen deadwood beneath their canopies (Table 4.5).

4.31 Information on the fruit varieties was provided by Herefordshire Council who own the orchard. The orchard contained 37 varieties of standard culinary and dessert apple, including a mixture of mid-season and late fruiters from around the UK and abroad (Table A3.2, Table A3.3). There were also pear trees and two veteran plum trees but the varieties were unknown. None of the old apple trees left in the orchard were local varieties but 14 of the recently planted varieties were local Herefordshire ones. Only one variety, Herefordshire Russet, was a modern variety, the others were old varieties introduced into cultivation at different dates, spanning a period of about 300 years since the early 1600s (Table A3.2, A3.3).

Orchard floor in Lady Close Orchard

4.32 The orchard floor was fully grassed, no bare strips below the trees were present. The grassland, which averaged 16 cm in height at the time of survey in September 2008, resembled NVC type MG7 *Lolium perenne* grassland, and contained some large areas overgrown by nettles, thistles, and docks, particularly around the old trees. The quadrat samples also indicated quite high cover of these eutrophication and disturbance indicators (Table A1.12, Table 4.8). Grasses predominated in the sward, and cover of broad-leaved herbs was low (Table A1.12). Broad-leaved herbs present included buttercups (*Ranunculus sp*.), common mouse-ear (*Cerastium fontanum*), clover (*Trifolium sp*.), ground-ivy (*Glechoma hederacea*), speedwells (*Veronica arvensis, V. chamaedrys and V. filiformis*), white dead-nettle (*Lamium album*), crane's-bills (*Geranium dissectum and G. molle*) and cuckooflower. An ecological survey carried out in 1995 (Herefordshire Nature Trust, unpublished report) described the orchard grassland as species-poor and overgrazed. Intensive grazing pressure may have been a causal factor in explaining the low species-richness of the grassland, as heavy grazing can reduce species richness (Gibson 1997).

Orchard boundaries around Lady Close Orchard

4.33 The orchard boundaries were comprised of hedgerows, except for boundary 4 which was a fence (Map 2.4). The orchard was bounded on two sides (boundaries 2 and 3, Map 2.4) by shrubby hedgerows composed of hawthorn, blackthorn, buckthorn (*Rhamnus cathartica*), elder, field maple (*Acer campestre*), rose and guelder-rose (*Viburnum opulus*), with occasional willow (*Salix* spp.) and holly (*Ilex aquifolium*) trees in the hedgerow. Both hedgerows had greater than 80% cover of native woody species and were thus priority BAP hedgerows and both were species-rich. Both hedgerows were gappy at the base, despite boundary 2 being relatively young, at about 8 years old according to the orchard owner. Nettles were a very dominant component of the ground flora of both the hedgerows, although broad-leaved herbs such as ground ivy, bluebell, lords-and-ladies (*Arum maculatum*), white deadnettle, speedwell and forget-me-not (*Myosotis* spp.) were also found. Boundary 3 had five non-native buddleja (*Buddleja* sp.) shrubs within the hedgerow, however, they composed less than 10% of the cover of woody structural species.

4.34 Boundary 1 was a hedgerow in the form of a line of trees with shrubs, with 8-20m tall poplar (*Populus* sp.), fir, hawthorn, blackthorn, elder, willow and ash trees. Ivy was quite dominant on many of the trees, and several ash and poplar trees had mistletoe in the canopy. Beneath the trees there was a wire fence. As poplars and firs are non-native species and they composed more than 20% of the boundary length, this hedgerow was not a priority BAP hedgerow. The shrubby component of the hedgerow was gappy at the base and cover of eutrophication and disturbance indicators was high (Table A1.14).

4.35 Boundary 5 was strip of tall hawthorn and holly trees within the orchard itself (Map 2.4), extending into the orchard from boundary 3. The 1890 / 1891 First Edition 1:10560 Ordnance Survey map shows that this hedgerow used to divide the orchard into two halves and connected boundary 1 and boundary 3 (Map 2.4). It qualified as a priority BAP hedgerow as it had more than 80% cover of native woody species. The structure of the hedgerow indicated that the hedgerow had been laid in the past, however, it had not been managed for a long time and was gappy at the base of the canopy. The ground beneath the hedgerow was shaded and bare apart from large clumps of nettles.

4.36 The quadrat samples from the hedgerows as a whole show eutrophication indicators had the greatest average cover (Table 4.11) reflecting the estimates of abundance of these species estimates made for each hedgerow. None of the hedgerows were in favourable condition, all had high cover of eutrophication and disturbance indicators and were too gappy at the base (Table A1.14). The quadrats also showed that in some areas there were patches of bare ground, averaging 24% across the quadrats (Table A1.13). This bare ground was treated as being due to shading, although it is possible that in some places bare ground may have been caused by trampling by livestock. Boundary 1 was assessed for condition in the same way as the BAP hedgerows but it should be noted that such non-BAP hedgerows automatically fail the threshold of 10% cover for recent woody species introductions on this basis, as they are defined as hedgerows having more than 20% cover of recent non-native woody species.

4.37 The orchard owner noted that the hedgerow of boundary 3 was trimmed annually on the side adjacent to the road, while the orchard side was trimmed every 2 to 3 years. The other hedgerows were not trimmed, either because they were recently planted (boundary 2) or mostly mature trees (boundary 1). Some gapping up had been done on boundary 3.

Half Hyde Orchard habitat survey results

Fruit trees in Half Hyde Orchard

4.38 Most of the trees were mature trees of about 50 years of age but a few younger trees were also present. The age classes were not sampled separately. Average girth size was 109 cm and ranged from 41 cm to 155 cm (Table A1.15). Many of the trees had been damaged by livestock a few years ago and had died, however they had been left in place as standing or fallen dead wood. The 125 live trees exhibited abundant veteran tree features, 10% had hollow trunks or branches and 70% had rot sites or holes in the trunk or branches. Sap runs were present on 10% of the trees. Mistletoe was abundant in the orchard, being present in large bunches on 90% of the trees (Table A1.15, Table 4.5). Fallen dead wood was noted beneath 20% of the sample trees, adding to the considerable amount of dead wood habitat in the orchard.

4.39 The 7 named fruit varieties in Half Hyde Orchard were cider apples, one of which, Brown Snout, was a Herefordshire apple, while 2 others originated from France (Table A3.4).

Orchard floor in Half Hyde Orchard

4.40 The vegetation cover beneath the trees was dominated by coarse grasses and eutrophication and disturbance indicators, especially nettles and docks (Table A1.16, Table 4.8). The NVC type resembled MG7 *Lolium perenne* grassland, perhaps with transitions to OV24 *Urtica dioica-Galium aparine* community or OV25 *Urtica dioica-Cirsium arvense* community (Rodwell 2000). Nettles, thistles and brambles had also grown in large patches around the standing and lying dead trees in the orchard. There was localized bare ground in the sward produced by trampling by livestock, particularly at the bottom of the slope on the western side of the orchard, where the ground was wetter and therefore more vulnerable to the effects of trampling.

Orchard boundaries around Half Hyde Orchard

4.41 Two of the boundaries (1 and 2, Map 2.5) of the orchard were hedgerows in the form of lines of trees plus shrubs about 7-15m tall. They were composed of holly, hawthorn, hazel, field maple, elder, ash, oak and rose. Both hedgerows qualified as priority BAP hedgerows and were species-rich (Table A1.18). The ground flora of the hedgerows was dominated by nettles and there were patches of bramble (Table A1.17). Bare ground also featured along the hedgerows and was treated as being primarily due to shade from the tall hedgerows but livestock trampling could also have played a role. Both hedgerows were gappy at the base and this feature, along with the abundance of eutrophication and disturbance indicators, meant that neither hedgerow was in favourable condition (Table A1.18). The owner recorded that neither hedgerow is currently managed on the Half Hyde side of the boundary (see Romulus Orchard below for further detail).

4.42 The other two boundaries, 3 and 4, around the orchard were wire fences (Map 2.5). Boundary 4 was very overgrown by bramble and there were several hawthorn and ash trees standing along the fence line.

Romulus Orchard habitat survey results

Fruit trees in Romulus Orchard

4.43 Almost all the trees were of the same age, about 14 years old, with very few younger trees. Average girth size was 40cm. Veteran tree features were limited to small rot holes in 5% of trees although split bark was seen on 20% of trees, possibly due to damage in earlier years from tree guards. No mistletoe was seen. There was fallen dead wood beneath 25% of trees, apparently being the remains of pruned material (Table A1.19, Table 4.5).

4.44 The cider apple varieties recorded by the owner were Dabinett and Michelin, which are relatively old varieties, first brought into cultivation about 100 years ago (Table A3.5).

Orchard floor in Romulus Orchard

4.45 The orchard floor was composed of bare strips beneath the trees in each tree row and grassed alleyways between the tree rows. The bare strips were not completely devoid of vegetation at the time of the survey in September 2008, the strips had been colonized by some patches of herbaceous plants. The grassland in the alleyways resembled NVC type MG7 *Lolium perenne* grassland. In September 2008 this sward was fairly uniform in height, averaging 19 cm. The grassland was dominated by grasses but with some broad-leaved herbs, which were sometimes locally abundant (Table A1.20). Dandelion *(Taraxacum sp.)* and buttercup *(Ranunculus sp.)* were quite common and there were several other species within the sward, including cut-leaved crane's-bill (*Geranium dissectum*), field forget-me-not (*Mysotis arvensis*), germander speedwell (*Veronica chamaedrys*) and lesser burdock (*Arctium minus*). There was limited cover of eutrophication and disturbance indicators such as nettles (Table A1.20).

Orchard boundaries around Romulus Orchard

4.46 Four of the five boundaries around Romulus Orchard were hedgerows, the fifth was a fence, which was over-grown by bramble and rose, and overhung by the trees of the adjacent woodland (Map 2.6). The four hedgerows all had more than 80% cover of native woody species, so were all priority BAP habitats. Boundaries 1 and 4 contained hazel, hawthorn, elder and rose but were not species-rich according to the criterion of five or more woody structural species per 30m. Boundary 2 was composed of a 1.5m tall hawthorn hedge for half its length, and a line of mixed trees and shrubs for the remainder of its length. This latter section was species-rich and was shared with Half Hyde Orchard, which is adjacent to Romulus Orchard (boundary 1, Map 2.5). Boundary 3 was hawthorn hedge, and also had three large oak trees located close to the junction of the hedgerow with boundary 2. Eutrophication and disturbance indicators formed the largest proportion of the sward (Table A1.21, Table 4.11), although some broad-leaved herbs were present such as buttercup, white deadnettle and lords-and-ladies. Localized bare ground along the hedgerows was probably caused by shading and by disturbance from vehicle movements.

4.47 None of the hedgerows were in favourable condition because of the amount of eutrophication and disturbance indicators, and, in the case of boundaries 1 and 4 because of gaps at the base of the canopy (Table A1.22). The part of boundary 2 shared with Half Hyde Orchard was also in unfavourable condition for the same reasons that this was in unfavourable condition, ie the amount of eutrophication and disturbance indicators and gaps at the base of the hedgerow canopy (Table A1.18, Table A1.22).

4.48 The orchard owner provided details of hedgerow management which consisted of more or less annual trimming in winter of all the hedgerows, including the Romulus side of the shared boundary with Half Hyde Orchard. The section of boundary 2 that was not shared with Half Hyde Orchard was last laid about 2003.

Salt Box Orchard habitat survey results

Fruit trees in Salt Box Orchard

4.49 This orchard was planted relatively recently and average girth size in September 2008 was 40cm. As expected, few true veteran tree features were found in these young trees, only 5% had rot sites or holes in their trunks. However, 40% of trees did have some split bark on their trunks, but the amount on each tree was small and mostly seemed to have been caused by rubbing of the protective wire of tree guards against the bark (Table A1.23). There was no mistletoe on the trees. Fallen dead wood was seen beneath 10% of trees. Some of this wood probably derived from pruning operations.

4.50 An important additional tree habitat in the orchard was provided by a large veteran pedunculate oak (*Quercus robur*) located as shown on Map 2.7. The tree was one of many similar 'parkland' trees scattered across the local landscape around Salt Box Orchard. The oak in Salt Box Orchard had a girth of 6.03m at 1.3m height, equivalent to a Diameter at Breast Height, (DBH) of 192cm. Using a rule of thumb described in the hedgerow survey handbook (Defra 2007) this trunk size puts it into the category of 'valuable' and very close to the category of 'truly ancient' (which requires a DBH of 1.99m for pedunculate oaks). The oak had large sections of hollow trunk as well as dead branches, and many large rot sites and holes. The form of the trunk and branches suggested that the tree had been pollarded in the past.

4.51 The cider apple varieties recorded by the owner were Dabinett and Michelin, the same as the varieties in Romulus Orchard (Table A3.5).

Orchard floor in Salt Box Orchard

4.52 Beneath the fruit trees were bare strips of ground, while the alleys between tree rows were grassland. This grassland appeared to have derived from re-seeding and was somewhat similar to NVC type MG7 *Lolium perenne* grassland, but with a greater diversity of grass species (Table A2.2), or similar perhaps to OV23 *Lolium perenne-Dactylis glomerata* community (Rodwell 2000). The quadrat records (Table A1.24) showed that grasses dominated and that there was patchy cover of broadleaved herbs. Dandelion was particularly abundant among the common herbs seen (Table A2.2). Cover of eutrophication and disturbance indicators such as nettle was zero in the quadrats (Table A1.24, Table 4.8) but several of these species were occasional or frequent in abundance in the general species list for the grassland (A2.2). No recording was done of any plants in the herbicided strips of ground beneath the tree rows.

Orchard boundaries around Salt Box Orchard

4.53 Boundaries 1 and 4 were hedgerows composed of hawthorn, blackthorn, elder and rose (Map 2.7). Both had more than 80% cover of native woody species and qualified as priority BAP hedgerows, though neither was species-rich. Several large oak trees, similar to the oak described in paragraph 4.50, were located along boundary 4. At the base of boundary 1 was a bank, which had a number of broad-leaved herbs such as wild strawberry (*Fragaria vesca*), white deadnettle, common field-speedwell (*Veronica persica*), field forget-me-not (*Mysotis arvensis*), cut-leaved crane's-bill, ragged robin (*Silene flos-cuculi*), lesser burdock (*Arctium minus*), redshank (*Polygonum maculosa*), nipplewort (*Lapsana communis*), creeping cinquefoil (*Potentilla reptans*), common bird's-foot-trefoil (*Lotus corniculatus*) and dog's mercury (*Mercurialis perennis*). The quadrat samples of the hedgerow basal flora across the orchard showed that cover of broad-leaved herbs was quite high (Table A1.25). Eutrophication and disturbance indicators had a moderate cover (Table A1.25, Table 4.11) but the visual assessments of amounts of these species along each hedgerow did not exceed 20% cover. Both hedgerows were in favourable condition, thresholds for condition attributes being passed in all cases, including for the eutrophication and disturbance indicators.

4.54 Hedgerow management described by the owner comprised trimming hedgerows more or less every other year in the period September to November.

4.55 Boundary 2 was a wire fence overgrown with bramble, bordering a mixed deciduous woodland (Map 2.7). The vegetation along the fence resembled NVC type W24 *Rubus fruticosus-Holcus lanatus* underscrub community, similar to the ground flora of the adjacent woodland, and broad-leaved herbs such as red campion (*Silene dioica*) were common. A number of young oak trees were growing along the fence boundary.

4.56 Boundary 3 was the steep river bank between the orchard and the River Wye (Map 2.7) and formed the border of this riverine Site of Special Scientific Interest. The river bank vegetation was primarily a tall herb plant community around 9m in width. The NVC type resembled OV26d *Epilobium hirsutum* community, *Arrhenatherum elatius-Heracleum sphondylium* sub-community (Rodwell 1995). Russian comfrey (*Symphytum x uplandicum*) and cow parsely (*Anthriscus sylvestris*) were both frequent to abundant. Frequent species were common nettle (Urtica dioica), hogweed (*Heracleum sphondylium*) and broad-leaved dock (*Rumex obtusifolius*), while giant hogweed (*Heracleum mantegazzianum*) was frequent to occasional. Occasional species included curled dock (*R. cripsus*), common sorrel (*Rumex acetosa*), red campion (*Silene dioica*), cleavers (*Galium aparine*), garlic mustard (*Alliara petiolata*) and great yellow-cress (*Rorippa amphibia*). Mugwort (*Artemisia vulgaris*) was rare as was Indian balsam (*Impatiens glandulifera*), although this species was more common towards the bottom of the river bank. There was also a mix of grass species. Meadow foxtail (*Alopecurus pratensis*) was frequent as was smooth meadow-grass (*Poa pratensis*). False oat-grass (*Arrhenatherum elatius*) was frequent to occasional and cock’s-foot (*Dactylis glomerata*) was occasional. At the bottom on the bank, at the water margin, there are some small zones of marginal swamp plant communities, similar to NVC types S5 *Glyceria maxima* swamp and S22 *Glyceria fluitans* water-margin vegetation (Rodwell 1995).

Village Plum Orchard habitat survey results

Fruit trees in Village Plum Orchard

4.57 The trees were planted over two time periods (Map 2.8) and the majority were about 20 years old (Table 4.6). The trees were sampled as one group, and average girth size was 40cm. The trees did not exhibit abundant veteran tree features (Table A1.27, Table 4.5), although many trees (65%) had some split bark on their trunks. The amount on each tree was small and may have derived from the same cause as split bark on trees in the other orchards, where damage was thought to be caused by wire tree guards. No mistletoe was seen growing in the fruit trees.

4.58 At the time of survey pruning had been done fairly recently and there were many dead branches lying on the ground beneath the trees, which resulted in the high percentage (60%) of trees which had fallen deadwood beneath their canopy (Table 4.5). According to the owner’s management information most of this would be collected during the year for disposal. However, there was some standing dead wood in the orchard, where dead trees had not yet been replaced and some quite large pieces of fallen dead wood had been left in place in locations where trees had been removed.

4.59 According to the owner, all the plums were of the variety Victoria, a variety introduced into cultivation in the UK about 150 years ago (Table A3.5).

Orchard floor in Village Plum Orchard

4.60 The orchard floor consisted of grassland in the alleyways between tree rows and bare strips under the trees. The grassland was fairly uniform in height in September 2008, averaging 23cm. The NVC type that the grassland most resembled in the northern and eastern parts of the site was MG7 *Lolium perenne* grassland, and appeared to be like a fairly typical reseeded sward with abundant white clover (*Trifolium repens*). In the western section of the orchard, which had been more recently planted with fruit trees (Map 2.8), the grass sward was more like NVC type OV 23 *Lolium perenne-Dactylis glomerata* community. A plant species list for the grassland in the orchard is given in Table A2.3. The quadrat data showed that broad-leaved herbs had significant cover (Table A1.28), and the species list indicates the common species which made up this herb cover. Cover of eutrophication and disturbance indicators was very low (Table A1.28, Table 4.8).

4.61 The ground under the trees was bare earth apart from a scattering of herbaceous vascular plant species and abundant bryophytes. The strips appeared to have been recently sprayed with herbicide before the field visit in May 2009 and it was very difficult to assign an NVC type to the vegetation. A tentative classification of OV10 *Poa annua-Senecio vulgaris* community (Rodwell 2000) was made. Groundsel (*Senecio vulgaris*) and grey field-speedwell (*Veronica polita*) were frequent, common chickweed (*Stellaria media*), annual meadow-grass and broad-leaved willowherb (*Epilobium montanum*) were occasional, white bryony (*Bryonia dioica*) was occasional to rare, creeping thistle and field bindweed (*Convolvulus arvensis*) were rare.

Orchard boundaries around Village Plum Orchard

4.62 The orchard was bordered by hedgerows, in places mixed with fences (Map 2.8). The hedgerows mostly qualified as BAP hedgerows, though there were sections where introduced woody species predominated. Only boundary 1 was species-rich in terms of woody species (Table A1.30). Boundary 1 was a shrubby hedgerow of hawthorn, blackthorn, hazel and rose, with a hedgerow tree about every 10m along the length of the hedgerow. These trees included holly, plum, crab apple and ornamental crab apple (*Malus* spp.). The hedgerow ground layer resembled NVC type W24 *Rubus fruticosus-Holcus lanatus* underscrub community and included woodland herbs such as bluebell and herb-robert (*Geranium robertianum*).

4.63 Boundary 2 was a hawthorn hedge with crab apple, damson (*Prunus domestica* ssp *institia*) and ornamental cherry (*Prunus* spp.) trees growing in the hedgerow about every 5m. Many of the trees have ivy growing up them. Boundary 2 contained some non-native species and was treated as a mixture of BAP hedgerow sections and non-BAP hedgerow sections. There were two sections of fence along this hedgerow, one around the garden of a house bordering the orchard. The hedgerow ground layer resembled NVC type W24 *Rubus fruticosus-Holcus lanatus* underscrub community and had a scattering of woodland herbs.

4.64 Boundary 3 was a line of tall silver birch (*Betula pendula*) trees, beneath which was a plant community including tall grasses and herbs such as vetches (*Vicia* spp.) and cow parsley. Boundary 4 was composed mostly of hedgerows bordering adjacent gardens and had stretches with abundant non-native conifers such as Leyland cypress (x *Cuprocyparis leylandii*). As non-native species composed more than 20% of the hedgerow length, this hedgerow was not a priority BAP hedgerow.

4.65 Boundaries 5 and 6 were hedgerows with mixtures of hawthorn and blackthorn and had occasional hedgerow trees (holly, crab apple and ornamental plum *Prunus* sp.). The herbaceous hedgerow flora was dominated by nettles, cleavers and docks. The NVC type on the western part of the orchard boundaries appeared to be OV24 *Urtica dioica-Galium aparine* community (Rodwell 2000) while along the northern side it appeared to be more like MG6 *Lolium perenne-Cynosurus cristatus* grassland. Herbs and grasses found in the OV24 type included hogweed (frequent), common nettle (frequent) sweet-vernal grass (frequent), and white dead nettle, cock's-foot, Russian comfrey and hedge woundwort (*Stachys sylvatica*), which were all occasional. Rarely occurring species were germander speedwell (*Veronica chamaedrys*), fumitory (*Fumaria* sp.,) goosefoot (*Chenopodium* sp.), and spurge (*Euphorbia* sp.). Other herbs noted in places along the hedgerows were bluebell, cow parsley and buttercup (*Ranunculus* sp.).

4.66 The herbaceous hedgerow flora as a whole had quite high cover of broad-leaved herbs and bramble in places (Table A1.29). Eutrophication and disturbance indicators had moderately low cover (Table A1.29, Table 4.11). However when each hedgerow was assessed for condition all except boundaries 1 and 3 were judged to have more than 20% cover of these indicators which meant that the hedgerows were unfavourable (Table A1.30). Boundary 2 also had gaps along its length, while boundary 1 was too narrow to be in favourable condition. However, boundary 3 was in favourable condition. Boundary 2 was treated as a BAP hedgerow for the purposes of condition assessment. Boundary 4 was treated in the same way although it should be noted that such non-BAP hedgerows automatically fail the threshold of 10% cover for recent woody species introductions on this basis, as they are defined as hedgerows having more than 20% cover of recent non-native woody species.

4.67 Hedgerow management involved trimming annually in the period January to March, according to information supplied by the owner. About 10 years ago the hedgerow of boundary 1 was coppiced and then re-laid.

Management factors affecting orchard habitats

4.68 Orchard management has a major role in determining the type of orchard habitats available in an orchard. The study orchards illustrate some of the effects of management on habitats, in particular the contrast in some features between traditional and intensive orchards. Summary tables of habitats in each orchard are given below to aid an assessment of these differences.

Fruit tree habitats

4.69 Planting dates and replacement times are critical in influencing the fruit tree habitats. The trees in the traditional orchards included older individuals (Table 4.6) and had larger girth sizes (Table 4.5) compared to the intensive orchards. Table 4.6 shows the age class distribution of the fruit trees in each orchard, based on the data in Table 2.5 which were provided by the owners. Class boundaries had to be set somewhat arbitrarily to cater for the varied periods of planting in each orchard. The planting time of younger trees at Half Hyde did not fit with the chosen class boundaries (Table 2.5) so the trees were placed in the youngest age class (Table 4.6) as more of the actual planting period was in this time period than in the previous period.

4.70 While the survey was only a snapshot of tree population structure, information from the orchard owners indicated that trees in the intensive orchards would be unlikely to reach the current sizes and ages of the old trees in the traditional orchards at a future time because the trees would be replaced before then to maintain high fruit productivity by the orchard.

4.71 The age and size reached by the trees had implications for the amount of veteran tree features present. The oldest trees among all those in the survey orchards were in Lady Close Orchard (Table 4.6) and all had veteran tree features (Table 4.5). The most recently planted trees in the study sites were in Tidnor Museum Orchard, which were planted from 2003-2007, and they had the lowest incidence of veteran tree features (Table 4.5).

4.72 With regard to particular veteran tree features only two orchards (Lady Close Orchard and Half Hyde Orchard) had sample trees that developed visible hollow trunks or branches and sap runs, and trees in these two orchards also had the greatest incidence of rot sites or holes (Table 4.5). The old trees in Lady Close Orchard were around 80-100 years old and at Half Hyde Orchard about 50 years old (Table 4.6), suggesting that considerable time may be required for such features to develop. Mistletoe occurrence also seemed to be associated with age of trees, being most frequent in the old trees in Lady Close and in Half Hyde orchards. Amount of pruning each year might also be a factor, both Lady Close and Half Hyde were not being pruned at the time of the project work (see Chapter 3).

4.73 The occurrence of split bark is probably misleading as an indication of true veteran feature development as in the younger orchards the feature seemed to be the result of damage from wire tree guards. In Tidnor's Museum Orchard, even the young trees, which were all less than 25 cm in girth, had some split bark. Re-calculation of the number of veteran trees without counting trees with split bark shows a greater contrast between the young trees in Tidnor, Lady Close and Salt Box orchards, together with the fairly young trees in Romulus and Village Plum orchards as compared to the older trees in the traditional orchards (Table 4.5). Note that the fruit type is different at Village Plum which could complicate the picture, plum trees seeming to be shorter-lived than apple and to develop veteran features after shorter periods since planting (Heather Robertson pers. obs.). However, not counting split bark, all the intensive orchards had similar amounts of veteran tree features, and most of the trees were in the same age class (Table 4.6).

4.74 The relative overall abundance of veteran tree features in each orchard was calculated by expressing the total number of observed features as a proportion of the total possible number of features for the sample trees. Again, the orchards with older trees had a greater abundance of veteran features, the contrast being even more marked if split bark was excluded (Table 4.5).

4.75 The abundance of fallen dead wood probably largely reflects the stage in the management cycle when the trees were surveyed and the overall management policy for dead wood. For example, Village Plum, where fallen dead wood was common (Table 4.5), was surveyed prior to the regular collection of prunings that is carried out in this orchard (see Chapter 3). Lady Close illustrates the other extreme of management policy, here the management policy was to leave most fallen dead wood. Half the sample of old trees had fallen dead wood beneath their canopies (Table 4.5). The measure for fallen dead wood used in the survey is likely to be too variable to be a useful attribute to record in other orchards because it can be affected so much by the timing of management.

Table 4.5 Fruit tree attributes, incidence of mistletoe and fallen dead wood in the seven study orchards

Tree attribute	Henhope (T)	Tidnor (T) A*	Tidnor (T) B*	Lady Close (T) C*	Lady Close (T) D*	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Tree girth average, cm	90	14	85	22	125	109	40	40	40
Tree girth range, cm	45-144	6-22	53-115	11–33	65-184	41-155	18-58	34-45	12-60
Trees with veteran tree features, %	75	10	75	40	100	90	25	40	65
Trees with veteran tree features minus split bark, %	55	5	65	0	100	70	5	5	5
Trees with hollow trunks/major branches, %	0	0	0	0	20	10	0	0	0
Trees with rot sites or holes, %	55	5	65	0	80	70	5	5	5
Trees with sap runs, %	0	0	0	0	30	10	0	0	0
Trees with split bark, %	55	10	40	40	80	75	20	40	65
Relative abundance of veteran tree features, %	27.5	3.8	26.3	10	52.5	41.3	6.3	11.3	17.5
Relative abundance of veteran tree features, minus split bark, %	18.3	1.7	21.7	0	43.3	30	1.7	1.7	1.7
Other data									
Mistletoe on trees, %	35	0	45	0	80	90	0	0	0
Fallen deadwood below trees, %	15	0	0	10	50	20	25	10	60

Notes: * sample identification as follows: A = young trees in Museum Orchard, B = trees in French Orchard, Bottom Orchard and Old Orchard, Tidnor Wood Orchards. C= young trees, D = old trees, in Lady Close Orchard. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Table 4.6 Age class distribution of orchard trees in each orchard

Tree age class	Period of years in class	Henhope % (T)	Tidnor %* (T)	Lady Close %* (T)	Half Hyde % (T)	Romulus % (I)	Salt Box % (I)	Village Plum % (I)
1900-1929	30	0	0	30	0	0	0	0
1930-1959	30	64.8	2.4	0	92	0	0	0
1960-1984	25	0	76.6	0	0	0	0	0
1985-2000	16	31.5	0	70	0	100	100	75.2
2001-2007	7	3.7	21	0	8	0	0	24.8

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details. * sample type: Tidnor and Lady Close had 2 age classes sampled separately to give the data in Table 4.5.

4.76 The number of fruit varieties grown in each of the orchards in the study is shown in Table 4.7. While the intensive orchards have just one or two varieties, the traditional orchards have a much greater diversity of varieties. Tidnor Wood Orchards is a special case as it has the status of a National Collection® (*Malus*-Cider making) of cider apple varieties.

Table 4.7 Number of named fruit varieties in each orchard

	Henhope (T)	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Romulus (I)**	**Salt Box (I)**	**Village Plum (I)**
Fruit type	Cider apple	Cider apple	Dessert & culinary apple	Cider apple	Cider apple	Cider apple	Plum
Number of named varieties	14	400*	37	7	2	2	1

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details. *Number of varieties notified to NCCPG (National Council for the Conservation of Plants and Gardens 2011). More varieties have since been planted.

Orchard floor habitats

4.77 The main difference in orchard floor habitats between the traditional and intensive orchards was the presence of bare ground beneath tree rows in the intensive orchards, compared to the fully grassed floors of the traditional orchards. The strips below the trees in the intensive orchards were kept clear of vegetation by use of herbicide (Chapter 3) but some ruderal plants, such as groundsel, were sometimes able to colonise in-between treatment, as shown at Village Plum Orchard. A high cover of bryophytes had been able to develop in the strips in Village Plum Orchard and bryophytes occurred in the same habitats in the other intensive orchards (see the species section on bryophytes in Chapter 4 for more detail).

4.78 Most of the grassland in the orchards was characteristic of agriculturally improved swards, typically NVC types MG6 and MG7 (Table 4.8) and was species-poor. Several of the sites had a recent history of arable cultivation or had been partially re-seeded (see Chapter 2) so the lack of a rich grassland flora was not unexpected. Museum Orchard in Tidnor Wood Orchards had the most diverse flora, probably due to the woodland history of the site and the low intensity management, which had allowed scrub elements to survive, as indicated by the transitional NVC type MG6/W24. Henhope had a very small area of unimproved species-rich grassland but the current management, which excludes inorganic fertilisers, combined with the low soil phosphorus level (Chapter 2, Table 2.3) may allow the sward to increase in richness more generally. Soils with low phosphorus levels have been identified as the most promising for development of species-rich grassland (Natural England 2009). Traditional orchards elsewhere have a similar range in species-richness, from species-rich grassland to species-poor grassland (Lush and others 2009).

4.79 The dominance of grasses in most of the orchard floor grasslands is clear in Table 4.8 but interestingly the cover of broad-leaved herbs was generally rather higher in the intensive orchards compared to the traditional orchards, particularly in Village Plum Orchard. The typical herbs found here are listed in Table A2.3. The majority are characteristic of fertile conditions as defined by the Ellenberg nitrogen attribute for each species given by Hill and others (2004). These values are also shown in Table A2.3. For example, creeping buttercup and ground ivy each have a value of 7, as they are found in richly fertile places. The grassland at Village Plum Orchard was only mown once a year, which may have allowed the broad-leaved herbs to maintain a relatively high cover, along with their ability to compete sufficiently with the grasses. Heavy grazing in the past in the traditional orchards, as recorded at Lady Close Orchard, may have restricted the broad-leaved species in some sites, as this effect has been identified in research elsewhere (Gibson 1997, Stewart and Pullin 2006). Eutrophication and disturbance indicators were a particular feature of three of the traditional orchards, Henhope, Lady Close and Half Hyde, and may have been related to the effects of livestock trampling and sward enrichment through dung deposition (Table 4.8).

Table 4.8 Orchard floor grassland attributes in each orchard

Grassland attribute	**Henhope (T)**	**Tidnor (T) A***	**Tidnor (T) B***	**Lady Close (T)**	**Half Hyde (T)**	**Romulus (I)**	**Salt Box (I)**	**Village Plum (I)**
NVC type	MG5, MG6, MG7	MG6/ W24	MG6	MG7	MG7, OV24/ OV25	MG7	MG7/ OV23	MG7, OV23, OV10
Grassland height cm (*range*)	17.6 (*14-25*)	16.6 (*10-24*)	12 (*7-20*)	16.6 (*13-25*)	60.2 (*12-121*)	19.2 (*15-23*)	30 (*20-40*)	22.6 (*15-35*)
Grasses % cover: average (*range*)	70 (*20-95*)	43 (*10-65*)	87 (*75-100*)	72 (*60-80*)	48 (*20-100*)	74 (*55-90*)	84 (*50-100*)	70 (*40-85*)
Broad-leaved herbs % cover: average (*range*)	6.4 (*0-15*)	47 (*20-80*)	10 (*0-25*)	7 (*0-10*)	0	17 (*0-40*)	16 (*0-50*)	29 (*15-55*)
Eutrophication / disturbance indicators % cover: average (*range*)	23.6 (*0-80*)	8 (*0-20*)	0.4 (*0-2*)	21 (*15-30*)	50 (*0-80*)	9 (*0-20*)	0	1 (*0-5*)
Bramble % cover: average (*range*)	0	2 (*0-10*)	0	0	0	0	0	0
Bare ground % cover: average (*range*)	0	0	2.6 (*0-10*)	0	2 (*0-10*)	0	0	0

Notes: A = grassland in area of young trees in Museum Orchard, B = grassland beneath mature trees in French and Bottom Orchards, Tidnor Wood Orchards. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Orchard hedgerows

4.80 Hedgerows formed a substantial part of the boundaries of all the orchards (Table 4.9) and where a fence was the boundary, usually this marked the border of the orchard with adjoining woodland, in some cases ancient woodland (see Chapter 2 and Maps 2.2 to 2.8). All the orchards had priority BAP hedgerows, where native woody species predominate, along some part of their boundaries (Table 4.9).

4.81 Three traditional orchards, Henhope, Lady Close and Half Hyde, had high proportions of total hedgerow length that were rich in native woody species or archaeophytes, which might indicate that these boundaries are relatively old (Pollard and others 1974). Tidnor, where much of the orchard was created more recently than the other 3 traditional orchards (Chapter 2, Table 4.6), and the 3 intensive orchards, all had lower proportions of species-rich hedgerow, perhaps indicating that these orchards were set in a more recent hedgerow landscape. However, it should be noted that Half Hyde and Romulus were adjacent to one another so landscape age must vary over a small distance if the species-richness of the hedgerows is a reliable guide.

Table 4.9 Boundary types, lengths and hedgerow condition for each orchard

Boundary type	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Hedgerow boundaries							
BAP hedgerow length, metres	456	512	415	366	973	676	724
Other hedgerow length, metres	0	0	194	0	0	0	0
Sections of hedgerow, including BAP hedgerow, or fence, length, metres*	0	252**	0	0	0	0	565
Total length of hedgerow, including sections of fence and hedgerow	456	764	609	366	978	676	1289
Proportion of total length of hedgerow species-rich, %	100	0	61	100	14	0	15
Proportion of hedgerow length in unfavourable condition %	100	100	100	100	100	0	93***
Other boundaries							
Tall herb vegetation along river-side length, metres	0	0	0	0	0	188	0
Fence length, metres	695	595	41	279	75	206	0

Notes: *Boundary consists of sections of hedgerow and fence, individual sections were not mapped. ** Condition not assessed as recently planted. ***Proportion of length of BAP hedgerow alone unfavourable is 92%. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

4.82 Hedgerow condition across the orchards was mostly unfavourable, in both traditional and intensive orchards. Some of the hedgerows around the intensive orchards of Salt Box Orchard and Village Plum Orchard were the exceptions (Table 4.9). Analysis of the reasons for unfavourable condition shows that the main structural reason was the gappy base of the hedgerows, where the base of the woody plant canopy was more than 50 cm from the ground (Table 4.10). This attribute may have resulted from lack of recent laying or coppicing management or could have resulted from heavy grazing pressure in the past (Defra 2007). The other major reason for unfavourable condition was the amount of eutrophication and disturbance indicators, such as common nettle, in the herbaceous flora at the base of the hedgerow (Table 4.10). In some cases, eutrophication and disturbance indicators were the only reason for unfavourable condition, most notably at Village Plum Orchard (Table A1.14). Here, the proportion of unfavourable hedgerows drops to 59% if the eutrophication and disturbance indicator attribute is excluded.

Table 4.10 Reasons for unfavourable condition of hedgerows

Orchard	Reasons for unfavourable condition
Henhope (T)	Gaps along hedgerow, gappy base of hedgerow, eutrophication and disturbance plant indicators abundant
Tidnor (T)	Hedgerow too narrow, gappy base of hedgerows, disturbed ground close to hedgerow and lack of perennial herbaceous strip along hedgerow, eutrophication and disturbance plant indicators abundant
Lady Close (T)	Gappy base of hedgerows, eutrophication and disturbance plant indicators abundant. Introduced shrubs / trees abundant for one hedgerow, judged by BAP condition criterion, but hedgerow does not meet overall definition of 80% native woody plant cover.
Half Hyde (T)	Gappy base of hedgerows, eutrophication and disturbance plant indicators abundant
Romulus (I)	Gappy base of hedgerows, eutrophication and disturbance plant indicators abundant
Salt Box (I)	None
Village Plum (I)	Hedgerow too narrow, gaps along hedgerow, eutrophication and disturbance plant indicators abundant. Introduced shrubs / trees abundant for one hedgerow, judged by BAP condition criterion, but hedgerow does not meet overall definition of 80% native woody plant cover.

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

4.83 The quadrat samples taken from the base of the hedgerows across each site provide another description of the amount of eutrophication and disturbance indicators (Table 4.11). Quadrat recording included thistles, but note that these were not recorded in the cover of eutrophication and disturbance indicators for each hedgerow (Table 4.4). On average, eutrophication and disturbance indicators supplied the majority of the herbaceous cover in all orchard hedgerows except at Salt Box and Village Plum orchards, whether or not thistles are included or excluded (Table 4.11). Grasses predominated in the latter two sites. Vegetation height (Table 4.11) was greater than that of the grasslands of the orchard floor (Table 4.8) and might be characterized as 'tall herb' habitat, although broad-leaved herbs were generally not abundant, apart from the eutrophication and disturbance indicators (Table 4.11).

Table 4.11 Composition and cover of hedgerow ground vegetation in each orchard

Hedgerow ground vegetation attribute	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Romulus (I)**	**Salt Box (I)**	**Village Plum (I)**
Vegetation height cm (*range*)	101.4 (*57-190*)	53.2 (*23-90*)	37 (*20-57*)	79 (*43-112*)	29.8 (*14-60*)	59.2 (*20-90*)	80.8 (*20-130*)
Grasses % cover: average (*range*)	27 (*0-100*)	11 (*5-20*)	22 (*5-40*)	12 (*0-45*)	25 (*0-75*)	37 (*5-65*)	54 (*30-70*)
Broad-leaved herbs % cover: average (*range*)	5 (*0-25*)	14 (*5-40*)	16 (*5-35*)	6 (*0-25*)	22 (*5-55*)	25 (*15-35*)	18 (*5-30*)
Eutrophication / disturbance indicators % cover: average (*range*)	64 (*0-100*)	53 (*5-90*)	33 (*15-45*)	61 (*0-90*)	41 (*0-90*)	28 (*5-60*)	15 (*0-25*)
Eutrophication / disturbance indicators excluding thistles % cover: average (*range*)*	61 *(0-90)*	50 *(5-85)*	25 *(10-40)*	60 *(0-90)*	41 *(0-90)*	28 *(5-60)*	13 *(0-20)*
Bramble % cover: average (*range*)	0	17 (*0-80*)	5 (*0-15*)	10 (*0-50*)	1 (*0-5*)	10 (*0-20*)	11 (*0-20*)
Bare ground % cover: average (*range*)	4 (*0-20*)	5 (*0-20*)	24 (*0-45*)	11 (*0-20*)	11 (*0-40*)	0	2 (*0-5*)

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details. *Equivalent to hedgerow condition attribute of nutrient enrichment, see Table 4.4.

4.84 Between 2006 and 2008, several local hedgerow surveys were carried out in different parts of England using the condition assessment methodology (Wolton 2010). These surveys provide comparative information for the orchard study sites. These comparisons are based on numbers of hedgerows rather than lengths, as these data are not available in Wolton (2010). The orchard hedgerow sample is small and so comparisons can only be tentative. On average 96% of the local survey hedgerows were BAP hedgerows, while 91% of the study site hedgerows were BAP hedgerows.

4.85 Comparison of condition between the orchard hedgerows and the local surveys show a similar pattern in the results (Table 4.12). Hedgerows in both sets of surveys were most often in unfavourable condition because of nutrient enrichment and disturbance. The proportion of the study sites favourable for this attribute matched the lowest proportion in the range for the local surveys (Table 4.12). Basal canopy height was the hedgerow attribute with the second lowest proportion in favourable condition in both local surveys and the orchard sites, the orchard figure being somewhat lower than the average for the local surveys (Table 4.12). When all attributes except nutrient enrichment and disturbance were considered together, a rather smaller proportion of the study site hedgerows was favourable compared to the average of the local surveys but the figure was greater than the proportion favourable in some individual surveys (see the range in Table 4.12).

Table 4.12 Comparison of proportions of total numbers of hedgerows in favourable condition in the study sites and in local hedgerow surveys

Attribute	Herefordshire orchards: Proportion favourable (n=22)	Local hedgerow surveys: Average proportion favourable *(range)*	Number of local hedgerow surveys for average proportion assessment (range of n per survey = 92-773)
Hedgerow dimensions	91	81 *(64-91)*	16
Hedgerow integrity: gaps along hedgerow	91	78 *(38-90)*	16
Hedgerow integrity: gaps at base of hedgerow	50	70 *(35-91)*	16
Undisturbed ground	96	86 *(55-99)*	15
Perennial herbaceous vegetation cover	96	92 *(70-100)*	15
Recently introduced, non-native species	91	98 *(92-100)*	16
All above attributes	32	42 *(17-58)*	15
Nutrient enrichment and disturbance	32	63 *(32-84)*	15

Management and habitat links to orchard species

4.86 The habitats available in orchards and management operations both have major effects on the species that inhabit orchards. These influences are considered later in this chapter for the species groups surveyed in detail during the project, namely bryophtyes, epiphytic lichens and fungi. During the project, only a few observations were made of two other important groups, invertebrates and birds. However, existing literature, combined with the habitat and management information collected for the orchards, allows a brief assessment of likely potential of the orchards for these groups.

4.87 At the general level of traditional compared to intensive orchard management, differences in invertebrate and bird species assemblages have been found. Kornprobst (1994) reviewed the wildlife of traditional orchards in Bavaria. Part of the review was available in a translation funded by Natural England. Kornprobst quoted 2 other studies, not available in translation and not referenced in detail here, reporting greater numbers of invertebrate species and individuals in traditional orchards compared to intensive orchards (Kneitz 1987, Mader 1982). For example, the quantity of Hymenoptera in traditional orchards was 5 times that of intensive orchards and the total number of flying insects captured by window trap was 6 times greater in traditional orchards. The number of spider species was 85% greater and quantity of spiders 3 times greater in traditional orchards compared to intensive orchards (Mader 1982 in Kornprobst 1994). Crocker and others (1998) found more birds and bird species in traditional cider orchards in Herefordshire compared to intensive orchards. Stevens (1992) found more bird species and greater territory density in standard fruit orchards compared to bush fruit orchards in Belgium, though management details were not recorded. As Crocker and others (1998) point out, traditional and intensive orchards differ in several ways, which makes identifying the impact of particular management factors difficult. However, an attempt is made below to highlight such factors, based on existing literature.

4.88 The age and size of the fruit trees in the orchards are likely to have an impact on the range of invertebrates that they support, particularly those invertebrates associated with wood decay habitats, the saproxylic invertebrates. Orchard trees can support species characteristic of a wide range of micro-habitats, including species which rely on rotten heartwood, species living on fungi of dead wood, and invertebrate predators and parasites of wood decay species (Lush and others 2009). The saproxylic invertebrate fauna recorded to date across traditional orchards in Britain includes 403 species, 102 of which are Red data Book or Nationally Scarce species (Robertson and Wedge 2008). Ranius and Jansson (2002) found that numbers of beetle species were positively related to increasing trunk girth in oaks, while Grove (2002) found that the basal diameter of large trees was a robust indicator of abundance and richness of saproxylic invertebrates in lowland tropical forest in Australia. In orchards, the relative abundance of veteran tree features seems to affect the diversity of saproxylic invertebrates. Orchards with a greater amount of veteran tree features have a greater variety of saproxylic invertebrates than orchards with smaller amounts of veteran tree features (Lush and others 2009, Smart and Winnall 2006). The traditional orchards in the current study, with their older, larger, trees and greater amounts of veteran tree features, compared to the intensive orchards, are likely to have had a richer saproxylic fauna than the intensive orchards.

4.89 The traditional orchards were the only sites which had mistletoe (Table 4.5), perhaps because of the greater age of some of the trees and less rigorous pruning compared to the pruning regime in intensive orchards (Chapter 3). Mistletoe growing in the canopy of fruit trees supports a number of specialist invertebrates (Briggs 2011), including *Anthocoris visci*, a Nationally Scarce predatory bug, and mistletoe tortrix moth, *Celypha woodiana*, a priority BAP species (Robertson and Wedge 2008). Mistletoe also supplies winter food for birds, especially mistle thrush *Turdus viscivorus*, which actively defends the plants from other birds seeking to feed on the berries (Snow and Snow 1988).

4.90 Tree age can be important in influencing the birds inhabiting orchards. Wiaçek and Polak (2008) found more birds in older Polish apple orchards than younger ones. Cavities for nesting birds can occur in traditional orchards, where trees can reach an age where such features can develop or be made by birds. In contrast, trees in intensive orchards are replaced at relatively young ages and are not likely to be suitable for cavity-nesting birds. Orchards can be more productive for particular bird species than other habitats. Harthan (1947) reported that old orchards in Worcestershire were the main habitat of hole-nesters such as woodpeckers, starlings (*Sturnus vulgaris*) and tree sparrows (*Passer montanus*). Tree sparrows and lesser spotted woodpecker (*Dendrocopus minor*) were almost entirely confined to old orchards in Worcestershire during the nesting season (Harthan 1947). A study of the lesser spotted woodpecker in Germany (Höntsch 2005) found that most nesting and roosting cavities were located in orchards and that orchards had the highest habitat quality, measured by breeding success, compared to deciduous forest and spruce forest. Crocker and others (1998) found that tree sparrows were among the 10 most numerous species recorded in traditional Herefordshire cider orchards but were virtually absent from intensive orchards. Lesser spotted woodpecker, a priority BAP species, has been recorded breeding in Tidnor Wood Orchards in another project (Barker 2009).

4.91 Tree form might also be a factor, Crocker and others (1998) found more birds in Herefordshire cider orchards where fruit trees were not bush trees. However, within bush orchards, age of trees can still be important. Stevens (1992) found greater bird species richness with increasing tree age in bush orchards in Belgium. Age was measured by the average girth of the trees. Also Stevens found that in individual plots within the bush orchards, birds selected the trees with the largest girth as nest sites. The 3 intensive orchards in the current study had similar tree girth sizes (Table 4.5) and might therefore have had similar potential for breeding birds.

4.92 Another orchard feature which might favour birds, and be related to tree age, may be the abundance of invertebrates associated with older trees. Laiolo (2002) found a positive correlation between the abundance of hole-nesting and trunk-feeding and branch-feeding birds and forest age in north-west Italy. Laiolo suggested that one reason may be that invertebrate food in decaying trunks or branches in older forests was greater than in young growth forest. Overall, in relation to tree age, the traditional orchards in the study are judged likely to have had more potential for supporting birds than the intensive orchards. This difference would not disappear with time because, as mentioned above, the intensive orchards would be unlikely to reach the current sizes and ages of the old trees in the traditional orchards.

4.93 Management of the intensive orchards with pesticides is likely to be another significant factor affecting invertebrates and birds. Reductions in invertebrate species numbers and numbers of individuals have been reported in comparisons of management with and without pesticides. Examination of pest species and their natural enemies, such as spiders, have been a particular focus of research. Szentkirályi and Kozár (1991) found more insect species in Hungarian apple orchards that were not managed with insecticides and acaricides in comparison with orchards that were treated with these chemicals. In directly comparable plots, sampled with comparable methods, 419 species were recorded where these pesticides were not used compared to 210 species where they were used.

4.94 Brown and Welker (1992) studied young apple orchards in West Virginia, USA, and found that species richness of phytophagous arthropods was lowest in plots sprayed with insecticides compared to unsprayed plots. There were more unequal species abundances among the species recorded in the sprayed plots, some species, such as the pest species European red mite (*Panonychus ulmi*), being relatively very abundant in sprayed plots. Altieri and Schmidt (1986) found another pest species, rosy apple aphid (*Dysaphis plantaginea* Passerini), present in greater amounts in the centres of Californian apple orchards sprayed with synthetic pesticides, compared to unsprayed, unmanaged, plots and plots sprayed by non-synthetic pesticides (termed 'organic'). In contrast, insect predators and parasitic Hymenoptera were more abundant in the latter two plot types. There was more predation pressure, measured by consumption of introduced invertebrate prey, in the unsprayed and organic plot centres than in the sprayed plots. Masden and Masden (1982) recorded more species of natural enemies, especially spiders, in a Canadian apple orchard sprayed only with dormant oil and *Bacillus thuringiensis* compared to a 'conventional' orchard, ie sprayed with synthetic pesticides. Bostanian and others (1984) studied spiders in apple orchards in Quebec, Canada. In the orchard not sprayed with insecticides and acaricides, spider numbers were greater than in orchards treated with these chemicals, which included organophosphates. Miliczky and others (2000) also looked at spiders, comparing apple orchards managed in different ways in Washington State, USA. 'Organic' orchards, not treated with synthetic pesticides, had greater arboreal and understory (orchard floor) spider density than orchards treated with synthetic pesticides, including those where only a small number of spray applications were made. Pheromone mating disruption was used in the latter type of orchard as a pest control method. Chlorpyrifos, the broad spectrum insecticide used in Salt Box and Village Plum orchards, appeared responsible for a substantial decrease in spiders, which occurred after a spraying event, in one of these sites.

4.95 Invertebrates of the orchard floor may not always show similar responses to management. Miliczky and others (2000) found that there was overlap in species composition between the orchard floor and canopy spiders and in both habitats they were affected by pesticides as outlined above. However, Pearsall and Walde (1995) found no differences in species richness of predaceous ground beetles in apple orchards in Nova Scotia, Canada, among orchards that had not been sprayed with insecticides and those that had been sprayed. Abundances of beetles were greater in the sprayed orchards. The authors suggested that rapid recovery after spraying through immigration from surrounding habitats of these very mobile species was an explanation for this result. In contrast, Epstein and others (2000) found more carabid ground beetles in orchard blocks sprayed with selective insecticides compared to those sprayed with broad spectrum insecticides in apple orchards in Washington and Oregon, USA. Overall, pesticides appear to be significant in affecting invertebrates in orchards and the 4 traditional orchards in the current study seem likely to have supported greater quantities of invertebrates and more species of invertebrates on a per unit area basis than the intensive orchards.

4.96 Pesticides applications in spring and summer coincide with the bird nesting season in orchards and may act in several ways: through direct toxicity, indirectly by altering adult bird behavior, and indirectly through decreased food availability (Fleutsch and Sparling 1994). Pesticides regarded as of high toxicity to birds are sprayed on orchards, including organophospates such as chlorpyrifos (Bouvier and others 2005). This was the most frequently used pesticide in a study of birds in Herefordshire cider orchards (Crocker and others 1998) and chlorpyrifos was used at Salt Box and Village Plum orchards in the current project. Research has shown that organophosphate residues can be found on skin, feathers and feet of birds introduced to an orchard after a spray event (Vyas and others 2007) and physiological effects relating to lowered enzyme activity detected in birds from sprayed orchards (Hooper and others 1989, Graham and DesGranges 1993). Other work in orchards has shown that spray residues can be found in or near nests (Fleutsch and Sparling 1994) and on tree leaves and soil (Vyas and others 2007) after spraying events.

4.97 Use of pesticides in intensively managed orchards could affect bird species and abundances but researching impacts is difficult. Crocker and others (1998) set out to investigate whether bird species and numbers were different in sprayed and unsprayed orchards in Herefordshire but found that while pesticide use was a possible reason, the orchards varied in other ways as well, such as the presence of older, larger trees in the unsprayed orchards and smaller, younger trees in sprayed orchards, which meant identification of pesticides as a single cause was impossible. However there have been a number of studies where other factors have been taken into account as far as possible, for example, by ensuring that the habitats in surrounding sprayed and unsprayed orchards were similar (Bouvier and others 2011).

4.98 Comparisons in breeding bird communities between orchards unsprayed with synthetic pesticides (‘organic’) and ‘conventional’ orchards sprayed with these chemicals have been made in Pennsylvania, USA (Fleutsh and Sparling 1994), south-east France (Bouvier and others 2011) and northern Italy (Genghini and others 2006). From here onward in this paragraph, author names are not repeated but the studies distinguished by location. Number of species, expressed as species richness or diversity (Shannon-Weiner index), was greater in organic than conventional orchards in the three studies. In France birds were more abundant in organic orchards than conventional orchards but not in the Italian study. Overall abundance was not reported in the American project. The Italian and French studies included comparisons with ‘integrated pest management’ (IPM) orchards, which in both cases received some broad spectrum synthetic pesticides. There were mixed results for these orchards, in France birds were always more abundant in the organic orchards than the IPM ones and with greater species richness in 2 years out of 3, while diversity was similar in the two types in the Italian study. In each of the 3 studies various measures of relative incidence or abundance of insectivorous birds showed that these species were associated with the organic orchards rather than the conventional orchards. Sometimes these types of birds were more associated with organic orchards rather than IPM orchards. The diet of insectivorous birds might be expected to be particularly affected by insecticide sprays. Granivorous (seed-eating) birds seemed to be less affected by management regime. In the Italian orchards there was no difference in frequency of granivorous birds between orchard types, and granivores did not differ in abundance in the French orchard types.

4.99 While information about numbers of birds and bird species in orchards managed in different ways is useful, bird survival and reproduction must be studied directly to assess population effects. Fleutsch and Sparling (1994) found that reproductive success and survival of mourning doves (*Zenaida macroura*) and American robin (*Turdus migratorius*) was reduced in the orchards managed with synthetic pesticides compared to organic orchards, although there was no statistically significant difference in one year out of two. Fewer high toxicity pesticide applications were made to the conventional orchards in that year. Bishop and others (2000) found associations between toxicity scores of pesticides, including organophosphates, used in sprayed apple orchards in southern Ontario, Canada and at least one reproductive parameter in every year of the study (1998-1994) of tree swallows (*Tachycineta bicolor*) and eastern bluebirds (*Sialia sialis*). Bouvier and others (2005) found that mean number of young great tits (*Parus major*) produced per hectare in apple orchards in south-east France was higher in organic orchards than conventional or IPM orchards. The mechanisms by which pesticide use causes such effects remain to be investigated. Based on these various strands of evidence from the literature, the unsprayed, traditional, orchards in the current project are likely to have maintained greater species richness and abundances of birds than the intensive orchards. Among bird species, the potential for large and rich insectivorous bird populations seems higher in traditional orchards but such differences may not have existed between traditional and intensive orchards with regard to granivorous birds.

4.100 Plant species composition of the orchard floor may play a role in determining orchard floor invertebrate faunas and bird species present. Traditional orchards from several locations across England were studied by Lush and others (2009). The more diverse invertebrate species assemblages in the field layer were recorded in the sites with orchard floor grasslands containing the most plant species. In traditional orchards, flowers of herbaceous plants on the orchard floor and along hedgerows can be important as nectar and pollen sources for saproxylic invertebrates (Robertson and Wedge 2008). On this basis, Tidnor Museum Orchard, which had a relatively rich flora, may have had the richest invertebrate fauna among the study sites. The other sites had orchard floor vegetation that was relatively species-poor and probably of relatively limited value for invertebrates. Hedgerow herbaceous vegetation can support invertebrates but was mostly dominated by a few species characteristic of enriched or disturbed conditions. However, the tall herb vegetation of boundary 3 in Salt Box Orchard could have had value for a variety of invertebrates such as insect pollinators, as could places along hedgerows where a greater plant species richness was evident, such as the bank below boundary 1 at Salt Box Orchard.

4.101 Particular plant species can be important for invertebrates, including common plant species. For example, dandelion, found in some quantity in grassland at Salt Box and occasionally at Village Plum (Table A2.2, Table A2.3), has a high number of polyphagous insects associated with it (Mortimer and others 2006). Intensity of mowing could have an effect on invertebrates utilizing flower and seed heads of such plants, for instance insect pollinaters. Village Plum's mowing regime of once a year was more likely to have been conducive to such invertebrates than that at Salt Box, which was mown 5 times a year (Table 3.2). Interactions with pesticide use may have been possible, given the evidence produced by Miliczky and others (2000) of pesticide effects on spiders of the orchard floor.

4.102 In the Herefordshire orchards studied by Crocker and others (1998) some bird species such as goldfinch (*Carduelis carduelis)* and linnet (*Carduelis cannabina*) were actually more abundant in the intensive orchards than traditional orchards. These bird species are granivorous and like the granivorous species in the orchards studied by Genghini and others (2006) and Bouvier and others (2011) may be less affected by insecticide sprays than insectivorous birds. Crocker and others (1998) suggest that the greater proportion of finches in the sprayed orchards that they surveyed, compared to unsprayed orchards, is possibly due to good foraging habitat provided by the strips of bare ground beneath tree rows. Bare ground may also have allowed ruderal plants to colonize. Seeds set by these plants could have been a food source for granivorous birds. In addition, Crocker and others (1998) found that, within sprayed orchards, birds were more abundant where there were more broad-leaved plant species and greater cover of these species, compared to grasses, in the grassland between tree rows. All the intensive orchards in the current project had bare ground beneath tree rows and might have attracted granivorous birds, but in relation to cover of broad-leaved plants in the alley grasslands Village Plum Orchard might have attracted more birds than Romulus Orchard or Salt Box Orchard (Table 4.8).

4.103 The orchard hedgerows would have provided potential habitats for invertebrates and birds. Management of the hedgerows is likely to have a major influence on their invertebrate and bird fauna. (Crocker and others 1998) found that the larger, less managed hedgerows had more birds than the more heavily managed hedgerows around Herefordshire cider orchards. There were no differences in bird numbers in hedgerows surrounding sprayed and unsprayed orchards, although breeding success was not investigated and might have been influenced by pesticide drift from air-assisted spraying of fruit trees in sprayed orchards. In terms of species richness, the relationship between bird species and hedgerow size has been found elsewhere, with a greater number of bird species occurring in larger hedgerows (Macdonald and Johnson 1995, Parish and others 1994). Hedgerows composed of more woody species had more bird species (Macdonald and Johnson 1995, Parish and others 1994) or higher numbers of birds (Crocker and others 1998) than hedgerows with fewer woody species.

4.104 The response of invertebrate species to hedgerow management is complex. Abundance of some groups such as Hymenoptera have been negatively affected by regular cutting, however some insects feeding on plants can be more abundant on annually trimmed hedgerows (Maudsley 2000). Berries and other fleshy fruit produced by hedgerow plants are important for birds and invertebrates (Snow and Snow 1988, Jefferson 2004). Abundance of some bird species, such as song thrush (*Turdus philomelos*) is correlated with increased berry abundance (Defra 2001). Management can have a major effect on berry crop, significantly lower amounts being produced on annually trimmed hedgerows compared to less frequently trimmed hedgerows (Croxton and Sparks 2002). Overall, it seems likely that the orchards where hedgerows were larger, richer in woody species, and unmanaged or trimmed every few years, such as those at Lady Close Orchard and Half Hyde Orchard, had the greatest potential as bird and invertebrate habitat rather than orchard boundaries that were shorter, less species-rich and annually trimmed, for example those around Village Plum Orchard. However the condition of the hedgerows has implications for the maintenance of the bird and invertebrate fauna. Most of the hedgerows were in unfavourable condition (Table 4.9) and hedgerow restoration would be needed to achieve the full potential of hedgerows that were in unfavourable condition as bird and invertebrate habitats.

Management and Biodiversity Action Plan status of orchard habitats

4.105 The division of the study orchards into two main groups, traditional and intensive, related to management, has been described in Chapters 2 and 3. The traditional orchards among the study orchards illustrated the usual habitat features of priority BAP orchards (Maddock 2010), such as the presence of older trees with veteran tree features (Table 4.5), and the wide-spaced planting pattern and large trees (Table 2.5, Table 4.5). The orchard floor was fully grassed, without bare ground along the tree rows, which is the normal signature of intensive management. In contrast, the intensive orchards had small, closely-planted trees, which were relatively young, and had bare ground along the tree rows, associated with intensive management with inorganic fertilisers and pesticides. Tidnor Wood Orchards was an interesting case of an orchard that had been intensively managed in the past, but where management had since been relaxed. The trees here were developing veteran tree features and the orchard floor was fully-grassed at the time of survey.

4.106 The other feature typical of traditional orchards is their agricultural biological diversity, represented by the number of fruit varieties and the genetic variety underlying them. The traditional orchards had more fruit varieties than the intensive orchards in the study (Table 4.7). Agricultural biological diversity is not an explicit part of the overall UK BAP but the international Conference of Parties to the Convention on Biological Diversity has identified conservation of agricultural biological diversity as a major theme because of the value of genetic resources for food and agriculture (Conference of Parties to the Convention on Biological Diversity 1996). From the UK perspective, the UK Government is a signatory to the Global Strategy for Plant Conservation 2001. The Strategy includes a target for conserving crop diversity (Cheffings and others 2004). The traditional orchards in the study were managed organically, without pesticides, and for such orchards, genetic variety could play a key part in future plant breeding of disease-resistant varieties (Morgan and Richards 2002) and, for both orchard types, the breeding of varieties that can thrive in a changing climate.

4.107 The orchard floor habitats in the orchards mostly were not priority BAP habitats in their own right, except for the very small area of lowland meadow in Henhope Orchard. All the orchards however had priority BAP hedgerows, in contrast to the windbreaks of introduced broad-leaved or conifer species planted around some orchards elsewhere, for example in Kent and Cambridgeshire (Heather Roberston pers. obs.).

Table 4.13 Biodiversity Action Plan habitats in each orchard

Orchard	Biodiversity Action Plan priority habitat
Henhope Orchard (T)	Traditional orchard, lowland meadow, hedgerow
Tidnor Wood Orchards (T)	Traditional orchard, hedgerow
Lady Close Orchard (T)	Traditional orchard, hedgerow
Half Hyde Orchard (T)	Traditional orchard, hedgerow
Romulus Orchard (I)	Hedgerow
Salt Box Orchard (I)	Hedgerow
Village Plum Orchard (I)	Hedgerow

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Orchard bryophytes

Survey and analysis methods

4.108 All seven orchards were visited by Dr Jonathan Sleath for the purpose of recording bryophytes. Effort was concentrated on recording epiphytic bryophytes on fruit trees, but in some sites bryophytes occurring on bare soil under the rows of trees were also recorded. Standard fruit trees were more difficult to survey than the smaller half-standard or bush trees and the epiphyte flora of orchards with standard fruit trees (Henhope, Lady Close and Half Hyde orchards) may be under-recorded as a result. Nomenclature of bryophyte species follows Hill and others (2008).

4.109 The findings were assessed with regard to species richness, presence of species of special interest and the ecological characteristics of the species, in particular attributes described by Hill and others (2007) in their report entitled *BRYOATT: attributes of British and Irish mosses, liverworts and hornworts*. The attributes chosen were those derived from Ellenberg's work in Europe (Ellenberg and others 1991), as modified and extended by the authors of BRYOATT.

Bryophyte species composition and richness

4.110 The epiphytic species found in each site are shown in Table 4.14. A total of 33 epiphytic species / taxa were found (*Hypnum cupressiforme* var. *resupinatum* was treated as a separate taxon to *Hypnum cupressiforme*). The orchards managed in a traditional way had the most epiphytes and Tidnor Wood Orchards had the richest flora. Salt Box and Romulus orchards had no epiphytes on fruit trees. The one record from Salt Box Orchard came from the veteran oak tree shown on Map 2.7.

Table 4.14 Bryophytes occurring as epiphytes in each orchard

	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Species name / Survey date	**20/9/06**	**1/1/07**	**31/5/07**	**28/3/07**	**28/3/07**	**7/2/07**	**7/3/07**
Amblystegium serpens	√	√	√	√			√
Brachytheciastrum velutinum	√			√			
Brachythecium rutabulum	√	√	√	√			
Bryum capillare	√	√	√	√			√
Bryum dichotomum		√					
Ceratodon purpureus	√	√					
Cryphaea heteromalla	√			√			
Dicranoweisia cirrata	√	√		√			√
Didymodon insulanus	√	√					
Fissidens bryoides var. *bryoides*				√			
Frullania dilatata		√	√				
Grimmia pulvinata		√					√
Homalothecium sericeum	√	√	√	√			√
Hypnum cupressiforme	√	√	√	√		√	
Hypnum cupressiforme var. *resupinatum*	√	√	√				√
Kindbergia praelonga	√	√		√			
Leskea polycarpa		√					
Metzgeria furcata	√		√				
Orthotrichum affine	√	√		√			√
Orthotrichum diaphanum	√	√		√			√
Orthotrichum lyellii	√	√					
Oxyrrhynchium hians				√			
Radula complanata				√			
Rhynchostegium confertum	√	√	√				
Schistidium crassipilum		√					
Syntrichia laevipila			√				
Syntrichia latifolia		√					
Syntrichia papillosa		√	√	√			
Syntrichia virescens		√					
Tortula muralis		√					
Ulota crispa	√						
Ulota phyllantha	√			√			
Zygodon viridissimus var. *viridissimus*	√	√	√				
Total species number	**20**	**24**	**12**	**16**	**0**	**1**	**8**

Notes: T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

4.111 The richness of epiphytes in the different traditional orchards was not obviously related to age of the trees, except where these were planted in the last few years. For example, in Lady Close Orchard, only the old trees had epiphytes, not the ones planted in the last 7 years. Among more mature trees, increasing age of tree was not matched by increasing number of epiphytes. The old trees in Lady Close Orchard were the oldest among all the trees in the traditional orchards at 80 to 100 years of age, yet only had 12 epiphytes, while

Tidnor Wood Orchard had the 'youngest' mature trees (predominantly about 40 years of age) and had the most epiphytes (24 species).

4.112 The ranking of the number of trees per orchard does match the ranking for number of epiphytes in the traditional orchards. Tidnor had the most trees and epiphytes, while Lady Close had the fewest trees and epiphytes, with Henhope and Half Hyde having intermediate numbers of trees and epiphytes (see Table 2.5 and Table 4.14). It should be noted though, that Tidnor Wood Orchards had mostly half-standard trees, which were easier to search than the larger standard trees of the other traditional orchards.

4.113 The pattern of tree numbers and bryophyte richness does not extend to the intensive orchards. Village Plum had the second largest number of trees among all sites, and the fewest epiphytes on fruit trees among sites with epiphytic bryophytes. Romulus and Salt Box orchards had the largest and third largest number of trees respectively, yet had no epiphytes on the fruit trees.

4.114 The lack of epiphytes in Salt Box and Romulus orchards was probably not related to the intensive management practiced in these sites. Stevenson and Rowntree (2009) found that intensive orchards of half-standard apples in Norfolk did have diverse bryophyte floras on the trees. This is consistent with the picture for half-standard trees in Tidnor Wood Orchards, which were intensively managed until about 5 years ago, yet had the richest epiphyte flora. The trees in Salt Box and Romulus orchards were relatively young (15 years old or less) and may not have been colonised yet. Trees in Norfolk which were more than about 30 years old had many bryophytes while trees younger than about 30 years of age had few or no epiphytic bryophytes (Stevenson and Rowntree 2009). This contrasts somewhat with one of the traditional orchards studied by Lush and others (2009) in Devon, which had 10 species on 20 year-old dwarf apple trees. However, the micro-climate here could have been a factor as it was probably wetter than that of the Herefordshire orchards. The pattern in intensive orchards is slightly more complicated than just age being the decisive factor. Stevenson and Rowntree (2009) noted that bryophytes on fruit trees were removed by tar oil sprays, which were in use until the late 1960s, so colonisation had largely occurred over the last 40-50 years, a period also coinciding with declining levels of air pollution (Lush and others 2009). Older trees may be more suitable than younger ones even though time available for colonisation is not much different, say, because of their bark could be rougher and easier to colonise. It might be that apple variety (cultivar) is also an influence – for instance, the smooth, shiny bark of the Michelin and Dabinett trees in Salt Box and Romulus orchards may have hampered colonisation. Stevenson and Rowntree (2009) found that fruit variety did have a significant effect on bryophyte numbers on different varieties of trees of the same age.

4.115 In Village Plum Orchard, the trees were 20 years old or less and did have some epiphytes. However, the orchard is composed of a different fruit type, ie plum not apple. Interestingly, in Broadway Orchard in Gloucestershire, a traditional orchard studied by Lush and others (2009), smaller plum trees had more species than larger, presumably older, trees. The young trees sampled here were in a thicket of suckering plum stems and may have had a moister micro-climate than the older trees (Robin Stevenson pers. comm.). Fruit tree type might also have an impact. Stevenson and Rowntree (2009) noted that plum is poorer host than apple. Lush and others (2009) found fewer species on plum than apple trees in the same orchard, while Porley (2005) found fewer species on damson, which is related to plum, than apple.

4.116 Species found on bare soil in a sub-set of sites are shown in Table 4.15. The intensive orchards had several bryophytes occurring on bare soil, a habitat characteristic of intensive orchards managed with herbicides sprayed on the ground along the tree rows. This bryophyte habitat in intensive orchards appears to have never been recorded in any detail before this survey. The species found were similar to those of local arable fields, which have also been surveyed by Dr Jonathan Sleath. Both habitats share the common characteristic of bare soil, for at least part of a year.

Table 4.15 Bryophytes recorded on bare soil and as epiphytes

Species name	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Barbula convoluta				G		G	
Brachythecium rutabulum	(E)	(E)	(E)	E		G	G
Bryum argenteum						G	G
Bryum dichotomum		(E)			G	G	G
Bryum rubens						G	G
Bryum ruderale						G	
Bryum violaceum						G	
Funaria hygrometrica					G		G
Kindbergia praelonga	(E)	(E)		E	G	G	G
Lunularia cruciata						G	G
Oxyrrhynchium hians				E	G	G	
Pseudocrossidium hornschuchianum							G
Tortula muralis							G
Tortula truncata							G

Notes: G = recorded on bare soil at this site, E = recorded as an epiphyte only, (E) = recorded as an epiphyte at this site, bare soil not examined. T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

4.117 The bryophytes growing on the ground seemed able to tolerate spraying by herbicide, which was done below the trees in each row in all three intensive orchards studied. Bryophytes had even become abundant in these strips at Village Plum Orchard (see Plate 2.14). They may have benefited from reduced competition from grasses and broad-leaved herbs, which were susceptible to herbicides. Brown (1992) reported several studies in which herbicides seemed to favour bryophytes at the expense of angiosperms, though none of the chemicals were the same as the herbicides used at Salt Box and Village Plum orchards.

4.118 Bryophytes on trees in intensive orchards may benefit from reduced competition from lichens, as lichens seem to be deleteriously affected by fungicide sprays (Bartok 1999). Alstrup (1992) observed that the competitive pattern between lichens and bryophytes appeared to have been altered where lichens had been treated with fungicide, although no data were presented. Release from competition may help to explain abundance of epiphytic bryophytes in Norfolk intensive orchards (Stevenson and Rowntree 2009), and, perhaps historically at least, at Tidnor Wood Orchards.

Bryophyte species of special interest

4.119 One epiphyte recorded at Tidnor Wood Orchards, *Syntrichia virescens*, is recognised as nationally scarce by the Joint Nature Conservation Committee (JNCC, undated), the Government's adviser on nature conservation at the UK and international level. However, *S. virescens* is probably rather under-recorded as it is easily confused with another species, *Syntrichia intermedia*. BRYOATT lists the latest number of records of bryophyte species in 10 by 10 kilometre squares across England, Scotland and Wales. *S. virescens* has 137 10 km square records which means it is now just outside the formal definition of nationally scarce (16-100 10 km squares). Two species recorded in the orchards that are only occasionally found across the county are *Syntrichia papillosa* and *Cryphea heteromalla*. The *S. papillosa* population found at Half Hyde Orchard was the largest seen to date in the county by Dr Jonathan Sleath, who is also the British Bryological Society's County Recorder for bryophytes in Herefordshire.

Ecological characteristics of orchard bryophytes

4.120 Ellenberg and others (1991) developed several scales for major ecological factors which affect plant distribution, such as light and moisture. These scales have been adapted and extended for bryophytes by Hill and others (2007). Each species is assigned an indicator value on the scale according to its apparent preference for particular conditions, for example on the scale for light, a bryophyte found in very shaded situations has a value of 1, while a species found in full light has an indicator value of 9. Examination of the species composition in a habitat in terms of indicator values can help describe the ecological characteristics of the habitat. It should be noted however that some species can survive in a wide range of conditions, say of light, so the assignment of a single indicator value to a species should be treated with some caution.

4.121 To illustrate the proportions of epiphytic species in Ellenberg indicator classes, in total and by orchard, the frequencies of species in each class in each orchard were calculated. Some sites and classes had very few species, and so any assessment of ecological characteristics was difficult. To improve the robustness of the results, Ellenberg classes were amalgamated to increase species numbers in classes and generalized descriptions of conditions were attached to these groups of classes (Table 4.16). However, results for sites with few species overall, particularly Village Plum, should be treated with extra caution. Analysis of Salt Box and Romulus was of course not possible given their lack of epiphytic bryophytes.

Table 4.16 Proportions of epiphytic bryophytes in Ellenberg indicator classes in 5 orchards

Ellenberg indicator type (numeric value in brackets)	Henhope (T) %	Tidnor (T) %	Lady Close (T) %	Half Hyde (T) %	Village Plum (I) %	Totals
Light						
Shaded (4 & 5)	35.0	20.8	33.3	37.5	37.5	31.3
Moderately well-lit (6)	50.0	54.2	58.3	50.0	25.0	50.0
Well-lit (7 & 8)	15.0	25.0	8.3	12.5	37.5	18.8
Moisture						
Dry (1 & 2 & 3)	10.0	20.8	8.3	12.5	37.5	16.3
Well-drained (4)	50.0	45.8	66.7	37.5	50.0	48.8
Moist (5 & 6)	40.0	33.3	25.0	50.0	12.5	35.0
Reaction						
Moderately acid (4 & 5)	40.0	20.8	25.0	31.3	25.0	28.8
Basic (6)	35.0	33.3	41.7	43.8	12.5	35.0
Strongly basic (7 & 8)	25.0	45.8	33.3	25.0	62.5	36.3
Nitrogen						
Moderately infertile (3 & 4)	55.0	45.8	50.0	37.5	62.5	48.8
Moderately fertile (5)	30.0	25.0	25.0	43.8	25.0	30.0
Highly fertile (6 & 7)	15.0	29.2	25.0	18.8	12.5	21.3
Number of epiphytic bryophytes	N = 20	N = 24	N = 12	N = 16	N = 8	N = 80

Notes: T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

4.122 As might be expected, given that orchards are composed of open-grown trees, overall, the orchard trees had no epiphytic bryophytes of very shaded conditions (0 to 2), or full light (9), and the bulk of species were typical of moderately well-lit conditions (value 6) across all the orchards, followed by species of rather more shaded conditions (4 and 5). None of the orchards had scrub swamping and heavily shading the trees and where there were relatively close-spaced trees, as at Village Plum Orchard, tree canopies were thinned through pruning. Perusal of species values in Hill and others (2007) shows that at Village Plum Orchard the most frequent light value was 8 (a value attached to light-loving plants). Bryophytes growing on the ground seemed characteristic of rather higher light conditions, as 64% of them had Ellenberg indicator values for light of 7 or 8, compared to only 18% with these values among the epiphytes (Table 4.16).

4.123 The relative proportions of species in each group of classes in each orchard suggest that more epiphytic species in Tidnor Wood Orchards were indicators of higher light levels than those in the other traditional orchards. This is quite surprising in that the tree canopy was very dense in places in the 1999 aerial photographs of Tidnor and the canopy was still dense in some areas at the time of survey (see Plate 2.5), although thinning is now underway. However, over the period of management under an intensive regime, tree canopies may have been more heavily pruned, and the half-standard trees themselves may have had smaller, thinner canopies than the standard trees in the other traditional orchards.

4.124 Ellenberg moisture values range from 1 (extreme dryness) to 12 (submerged in water). The epiphytic bryophytes in the study orchards had values ranging from 1 to 6 (moist soils or bark), with the most common value overall being 4 (well-drained substrates), followed by 5 and 6 (moist substrates). Most bark habitats available on the fruit trees were likely to have been well-drained, as run-off of rain should have been relatively rapid from vertical and inclined branches and trunks. Again, of the traditional orchards, more bryophytes in Tidnor Wood Orchards seem to have been indicators of drier conditions as well as lighter conditions, perhaps for the same reasons as suggested in the preceding paragraph. Half Hyde Orchard differed from the other orchards in that it had a higher proportion of indicators of moist substrates than well-drained ones, compared to the other orchards, perhaps due to a history of lighter pruning than the pruning done in other orchards (see Chapter 3).

4.125 Reaction values developed by Ellenberg relate to acidity or alkalinity, typically measured by pH. The range is from 1 (extreme acidity) to 9 (free calcium carbonate). Overall, the orchards had more basic or strongly basic indicators, though the indicator make-up in each orchard varied. Bryophytes of Henhope and Half Hyde orchards suggested slightly more acidic conditions than other orchards, while Tidnor species had a stronger basic character. Porley (2005) suggested that damson bark is acidic and Lush and others (2009) thought that bryophytes on plum in their study indicated the bark was acidic. It is not possible to say whether Village Plum bryophytes were responding to bark pH as so few species were recorded. Species of both basic and acidic conditions were recorded.

4.126 Nitrogen is used as a general indicator of fertility by Hill and others (2007). The Ellenberg scale goes from 1 (extremely infertile sites) to 7 (richly fertile sites). The general picture in the study orchards was of more indicators of moderately infertile conditions than other conditions. Henhope had the greatest proportion of indicators of these infertile conditions among the traditional orchards. Tidnor may have received artificial fertilisers in the past and Village Plum Orchard is annually or intermittently fertilised with nitrogenous fertilisers, but at very low levels (see Chapter 3). Neither site seemed to show any influence from these applications, though the problem of drawing conclusions from the small species list at Village Plum Orchard should again be noted.

4.127 Apart from the examination of the epiphytic bryophyte composition in terms of Ellenberg values, another interesting facet of the ecology behind species composition was noted at Tidnor Wood Orchards. Of particular interest was the occurrence of *Leskea polycarpa,* which is common along the River Wye on silt-encrusted riverside trees, but is rarely found away from watercourses. It was found around the bases of the fruit trees away from any areas that flood. Stevenson and Rowntree (2009) also noted the unusual occurrence of *Leskea polycarpa* in Norfolk intensive orchards, although they attributed its presence to high humidity levels associated with spraying. The regular clearance of ground vegetation to create bare ground along tree rows in such orchards, including in Tidnor Wood Orchards up until about 2002, may have led to soil particles being deposited on the trees, perhaps by rain or spray splash, particularly around the tree trunks. Soil particles were noticed on the bases of older trees at Tidnor, and could explain the occurrence of other species including *Tortula muralis*, *Schistidium crassipilum* and *Grimmia pulvinata*, which are not typical epiphytes. *Fissidens bryoides*, which was found at Half Hyde, is also not usually found growing as an epiphyte, being more typical of bare soil. The habitat survey described above found that there was localized bare ground at Half Hyde Orchard due to trampling by cattle, which might explain the occurrence of *Fissidens bryoides* as an epiphyte at this site, if this bare ground led to a similar microhabitat on the trees as that of the atypical epiphytes at Tidnor Wood Orchards.

Orchard lichens

Survey and analysis methods

4.128 Lichen surveys of 5 orchards were carried out by Dr Cliff Smith and Joy Ricketts in 2006-2007 and Cliff Smith visited the other 2 orchards in 2009 (see Table 4.17 for survey dates). Three records for Village Plum Orchard were contributed by Heather Colls, of the Herefordshire Fungus Group. Survey effort was concentrated on the epiphytic lichens of fruit trees, but a few species of other habitats were also recorded in some sites, as shown in Table 4.17 below. Nomenclature follows Smith and others (2009). The findings were assessed with regard to species richness, presence of species of special interest and the ecological characteristics of the species, in particular the sensitivity of individual species to amounts of nitrogen in the environment, especially ammonia.

Lichen species composition and richness

4.129 The lichens found at each site are shown in Table 4.17. In total, 48 species were recorded, 45 of these occurred as epiphytes on fruit trees, though not always in this habitat at each site. *Hypogymnia physodes* and *Lecanora conizaeoides* were not recorded as epiphytes at Tidnor Wood Orchards although were found as epiphytes at other orchards. *Buellia griseovirens, Lecidella scabra* and *Placynthiella icmalea* were not found as epiphytes in any of the orchards (Table 4.17).

Table 4.17 Lichens recorded in each orchard

	Henhope (T)	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Romulus (I)**	**Salt Box (I)**	**Village Plum (I)**
Species / Date of survey	04/8/06	02/11/07	10/7/07	02/11/07	02/11/07	13/01/09	13/01/09
Amandinea punctata	√	√	√	√	√		√
Arthonia radiata				√			
Bacidia rubella			√				
Buellia griseovirens		F					
Caloplaca cerinella			√				
Candelariella reflexa	√		√	√			
Candelariella vitellina	√						
Chaenotheca brachypoda			√				
Cladonia chlorophaea	√						
Cliostomum griffithii	√	√	√				
Diploicia canescens			√				
Evernia prunastri	√		√	√			√
Flavoparmelia caperata	√		√	√			√
Fuscidea lightfootii	√	√	√	√	√		
Hyperphyscia adglutinata			√				
Hypogymnia physodes	√	L	√	√			√

	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Hypogymnia tubulosa	√						
Hypotrachyna revoluta	√						
Lecanora chlarotera	√	√	√	√	√	√	√
Lecanora conizaeoides	√	F					
Lecanora expallens	√		√	√			
Lecidella elaeochroma		√	√				√
Lecidella scabra			G				
Lepraria incana	√		√				
Lepraria lobificans		√	√				*√
Melanelia fuliginosa subsp. glabratula	√		√				
Melanelixia subaurifera	√		√	√			
Melanohalea exasperata			√				
Opegrapha atra			√	√			
Parmelia sulcata	√		√	√			√
Pertusaria amara			√				
Phaeophyscia orbicularis		√	√	√			
Phlyctis argena	√		√				
Physcia adscendens	√		√				
Physcia aipolia			√	√			*√
Physcia tenella	√	√	√	√			√
Physconia grisea		√	√				
Placynthiella icmalea	F						
Porina aenea			√				
Punctelia jeckeri	√		√	√			
Punctelia subrudecta	√		√				*√
Ramalina farinacea	√		√	√			√
Scoliciosporum chlorococcum	√						√
Teloschistes chrysophthalmus				√			
Usnea subfloridana	√		√	√			
Xanthoria candelaria	√			√			
Xanthoria parietina	√	√	√	√			√
Xanthoria polycarpa	√	√	√	√			√
Total number of species	**30**	**14**	**37**	**22**	**3**	**1**	**15**
Total number of epiphytes	**29**	**11**	**36**	**22**	**3**	**1**	**15**

Notes: T = traditional orchard, I = intensive orchard (see Chapter 3 for management details). √ = epiphyte on fruit trees; *√ = epiphyte on fruit trees recorded by H. Colls (HVC), Herefordshire Fungus Group, as follows - *Lepraria lobificans* on 30/5/07 *Physcia aipolia* on 17/10/07 *Punctelia subrudecta* on 30/5/07. Other substrates: F = fence posts or wooden posts, G = wooden gate, L = logs.

4.130 Lady Close Orchard, a traditional orchard, had the most lichen species, even though it was the smallest orchard and had the fewest trees (Table 2.5). The three intensive orchards had the largest number of trees yet had the fewest lichen species, along with Tidnor Wood Orchards, where tree numbers were of comparable magnitude. Therefore, tree number, ie size of available habitat for epiphytic lichens, seemed to have had no positive effect on number of lichens found.

4.131 Lady Close Orchard had the oldest fruit trees, followed by Henhope Orchard and Half Hyde Orchard, while Salt Box Orchard and Romulus Orchard had trees of less than 20 years of age (Table 4.6), suggesting that age of trees could be a factor influencing species richness. Hedenås and Ericson (2000) have shown that number of epiphytic lichens increase with age of aspen (*Populus tremula*) trees, though the youngest trees in their study were estimated to be 20 years old. Studies of the early years of lichen colonization of trees are hard to find, though available evidence indicates that lichens can colonize wood substrates quite rapidly. Dettki and Esseen (1998) studied conifers ranging from 5 to 379 years of age and found that species richness of epiphytes increased quickly in young stands and reached a maximum on trees of about 100 years old. On worked wood substrates, rapid accumulation of species has been observed. A bird table in west Wales accumulated 19 species in the 11 years since it was first put in place, while a teak bench at the same location was colonized by 6 new species in 4 years (Wolseley 1999). Kershaw (1964) reported that in Welsh sites *Fraxinus excelsior* (ash) had lichens on 5-10 year-old twigs, while other tree species lacked lichens on branches until these were 12 to 15 years of age. Change in bark characteristics with tree age might have an effect on rates of colonization, but the smooth bark of the young apple trees in Salt Box and Romulus orchards would not hinder colonization by smooth bark specialists such as those listed by Coppins (2001). An example is *Arthonia radiata*, found at Half Hyde Orchard, which is adjacent to Romulus Orchard. Coppins (2001) describes *A. radiata* as a widespread species on smooth bark of branches and twigs of deciduous trees and shrubs. Thus differences in available time for lichen colonization does not seem to provide a full explanation for the very low species numbers at Salt Box and Romulus orchards, or the low figure of 11 epiphytes on trees of about 40 years of age in Tidnor Wood Orchards.

4.132 Management of some of the orchards with chemical sprays may have been an important factor affecting species richness. The effect of herbicides, fungicides and pesticides on lichens has received some attention but researchers have cautioned that much remains unknown (Vidergar-Gorjup and others 2001). Available evidence provides a mixed picture, some studies showing limited or no effects at normal use levels of these agrochemicals (Perkins and Marr 1993; Jensen and others 1999) while other studies show some lichens were affected by some chemicals (Alstrup 1992; Brown 1992).

4.133 Field experiments or observations of lichens in entire apple orchard systems (rather than studies of effects on specific lichens treated with selected chemicals) do indicate that orchards that are managed intensively can have impoverished lichen floras. Bartok (1999) compared an intensive apple orchard, a semi-intensive orchard and unsprayed traditional garden orchards. The trees in each site were about the same age though density of planting was lower in the traditional orchards. The intensive orchard received between 9 and 13 sprays a year and the semi-intensive orchard 5 sprays a year. Sprays were usually mixtures of chemicals, including insecticides and fungicides. The intensive orchard had no lichens but had abundant *Desmococcus viridis*, an alga. The semi-intensive orchard had 18 lichen species and the traditional orchards had 37 species. Henderson (2008) observed that, of 3 Yorkshire orchards, a regularly sprayed young orchard had 3 lichen species and abundant *Desmococcus*, while an intermittently sprayed orchard had 12 species and an unsprayed orchard had 34 species. Vidergar-Gorjup and others (2001) found that *Pseudevernia furfuracea* transplanted to an intensive apple orchard, sprayed 14 times in a year, showed considerable decrease in net photosynthesis, which could in part explain the die-back of the lichen in the orchard. Southon (2008) studied lichens in cobnut (hazel) 'plats', ie orchards, in Kent and found that species number did not appear to be strongly related to management intensity, although lichens in sprayed plats appeared to be damaged. However, management of cobnuts, even in these plats, may not be as intensive as that for top fruit such as apples and pears (Georgina Southon pers. comm.).

4.134 Salt Box Orchard, Romulus Orchard and Village Plum Orchard all received herbicide, insecticide and fungicide sprays during the project (see Chapter 3), while Tidnor Wood Orchards were most probably sprayed from the 1960s to around the year 2000 (see Chapter 2). Village Plum had the most species of these 4 sites but Dr Cliff Smith noted that growth of most of the lichens seen was abnormal. It seems likely that the spray regimes in the intensive orchards have had some impact on the richness of the lichen floras of these orchards.

4.135 In comparison to epiphytic lichen floras from other traditional orchards in England, the Herefordshire orchards were less rich than some sites, for example Slew Orchard in Devon had 80 lichen species in an orchard of 1.3 ha (Lush and others 2009). The Herefordshire orchards had similar species numbers to the Yorkshire orchards studied by Henderson (2008). At a national scale, historical levels of atmospheric pollution by sulphur dioxide have a great influence on epiphytic lichens (NEGTAP 2001). Hawksworth and Rose (1970) produced a map of levels of air pollution based on lichen indicators for England and Wales. At that time, the Herefordshire orchards were within a zone estimated to be affected by moderately high sulphur dioxide levels of about 35-50 micrograms of sulphur dioxide per cubic metre of air (μg m^{-3}). Historic records for sulphur dioxide concentrations in the atmosphere from recording stations in Herefordshire provide similar figures. In 1965 readings of annual mean concentrations were 54 μg m^{-3} and 63 μg m^{-3}, in 1970, 40 μg m^{-3} and 43 μg m^{-3} and in 1980 31 μg m^{-3} (UK Air Quality Archive undated). The threshold for annual mean sulphur dioxide concentrations for protection of vegetation and ecosystems is 20 μg m^{-3} (Bower and Loader 2009), so these historic levels probably did affect the epiphytic lichens in the orchards. Heavy industry and urban centres in South Wales could have had a large influence if pollution from that area was transported to Herefordshire by prevailing south-westerly winds. To the north-east of Herefordshire lies the Birmingham conurbation which could have been another possible source of pollution in the past. In contrast, Devon was in a 'clean air' zone on the map drawn by Hawksworth and Rose (1970). Yorkshire orchards have also been affected by pollution in the past and the richest sites are those furthest away from the conurbations of South Yorkshire (Henderson 2008).

4.136 In recent decades concentrations of sulphur dioxide in the atmosphere over the UK have fallen sharply. The orchards were in a zone of 0.5 – 1 μg m^{-3} on a UK map of modelled data for 2007 (UK Pollutant Deposition undated) and the mean figure recorded for Leominster, Herefordshire, in 2008 was 1 μg m^{-3} (Bower and Loader 2009). It is therefore likely that the lichen flora is now in a recovery phase.

Lichen species of special interest

4.137 The most important find of the survey was *Teloschistes chrysophthalmus*, golden-eye lichen, which was recorded on a dead branch of an apple tree in Half Hyde Orchard. This lichen is listed as Critically Endangered in Britain by Church and others (1996), Woods and Coppins (2003) and by the Joint Nature Conservation Committee (JNCC), the Government's adviser on nature conservation at the UK and international level (JNCC undated). *Teloschistes chrysophthalmus* was identified as a priority species in the first UK Biodiversity Action Plan (BAP) in 1995 but was excluded in the review published in 2007 because it was thought to be extinct in Britain. The re-discovery of the lichen at Half Hyde Orchard came too late for this review but its status will be re-assessed at the next review of the BAP (Ian Taylor, Head of Botanical Services, Natural England, pers. comm).

4.138 In descriptions of the ecology of the species, orchards are listed as one of the habitats where *Teloschistes chrysophthalmus* occurs, along with hedgerows and scrub. The lichen seems to favour well-lit, nutrient-rich, bark of small trees and shrubs in sunny, sheltered, situations (Church and others 1996; Giavarini 2008). Giavarini (2008) surveyed localities for the lichen in Ireland, and noted that high humidity and dust (presumably a nutrient source) also seem to be associated with the occurrence of the lichen. The lichen was found on bushes close to standing water and relatively close to moderately busy roads, which could produce dust. The Half Hyde locality was not close to open water but the orchard was next to a main road (Map 2.5). In addition, cattle in Half Hyde Orchard had created localized bare ground on the orchard floor, as described in the habitat survey, and may have stirred up dust close to the trees.

4.139 Two species of lichen found in the traditional orchards are listed as nationally scarce by the JNCC: *Chaenotheca brachypoda* and *Punctelia jeckeri.* Neither is considered to be threatened (Woods and Coppins 2003). *Chaenotheca brachypoda* is an inconspicuous lichen and may be under-recorded as a result. *Punctelia jeckeri* is also probably under-recorded. Another interesting species found during the survey was *Bacidia rubella*, in Lady Close Orchard. This was present in greater quantity than the surveyors had ever seen elsewhere. It is not a rare species but seems particularly associated with old wayside trees and relict woodlands (Dr Cliff Smith pers. obs.). Orchards like Lady Close can provide a better-lit habitat for such species than many unmanaged woodlands, where the understorey has become dense and created too much shade (Smith and others 2009).

Ecological characteristics of orchard lichens

4.140 Levels of atmospheric ammonia have been identified as of considerable importance in influencing the distribution and abundance of epiphytic lichens (van Herk 1999, 2004, Wolseley and others 2006a). From studies in the Netherlands, van Herk (1999) identified particular lichen species that seemed to be favoured by increased levels of ammonia (nitrophytes) and species deleteriously affected by high ammonia levels (acidophytes). Wolseley and others (2006a) found similar results in Britain. Increases in nitrophytes seems to be linked to intensification of farming, especially livestock and dairy farming (van Herk 1999; Wolseley and others 2006a; Benefield 1994, 1998; Rouss 1999; Sutton and others 2004). Van Herk (2004) reviewed the impacts of nitrogen sources more generally and suggested that other sources of nitrogen could also play a role in determining species composition, for example, nitrogen in dust. In this review, van Herk defined the terms nitrophyte and acidophyte in more detail. Nitrophytes are species needing both a relatively high bark pH (ie low acidity) and at least some additional nitrogen. Acidophytes need an acid substrate but many are sensitive to increased levels of nitrogen as well.

4.141 In an attempt to describe the Herefordshire study sites in terms of their representation of lichen indicator species, the published categorisations of species as nitrophytes or acidophytes were applied to the species found in the orchards. Some species have been labelled as tolerant or indifferent to ammonia levels in previous studies and these species have also been categorised in the orchard project. Although the Netherlands' species categorisation has already been used in the UK, conditions here are more oceanic and species may not respond in the same way as in the more continental climate of the Netherlands. This qualification needs to be kept in mind, pending further analysis of species' responses in the UK (Dr Pat Wolseley, Natural History Museum, pers. comm.). In addition, some other species have been defined as nitrophytes on a UK basis only (Wolseley and James 2002), but such study is still ongoing and categorisations have changed over time. Therefore, the following 'priority' order of references has been followed in assigning the orchard lichens to categories: van Herk (2002), Wolseley and others (2006b), Wolseley and James (2002).

4.142 To increase the number of species with a categorisation, the work on the use of Ellenberg values for lichens by Wolseley and others (2005) was also used. Ellenberg scores for lichens were developed by Wirth (as referred to by Wolseley and others 2005) for a variety of factors including nitrogen levels. Wolseley and others (2005) found that Ellenberg nitrogen scores produced very similar results as the use of nitrophyte scores. Ellenberg values for nitrogen range from 1 to 9, with 1 indicating that a species prefers low nitrogen, while 9 indicates a preference for high nitrogen. The Ellenberg values for species in Table 7.2 in Wolseley and others (2005) were used for orchard lichens as follows: species having values of 3 or below were treated as acidophytes, species with a value of 4 were treated as tolerant and species with values of 5 or above as nitrophytes. This assignment was based on an analysis of the Ellenberg values given to species that had already been defined as acidophytes, tolerant or nitrophytes in the other listed sources. Two additional sources (Edwards 2004; Giavarini 2008) were used for 2 other species without categories, namely *Teloschistes chrysophthalmus* and *Bacidia rubella*.

4.143 Using this variety of sources, the lichen species found in the orchards were assigned to categories as shown in Table 4.18. Thirty-eight species out of a total of 48 species in the orchards were categorised but no information was available from the listed references on the remaining 10 species. Romulus Orchard and Salt Box Orchard did not contain sufficient species to analyse their relationship to nitrogen and pH levels.

Table 4.18 Nitrogen and pH preferences of lichen species found in the orchards

Species	Nutrient type	Source
Amandinea punctata	N	Wolseley 2006b
Bacidia rubella	A	Edwards 2004
Candelariella reflexa	N	Van Herk 2002
Candelariella vitellina	N	Van Herk 2002
Cladonia chlorophaea	A	Van Herk 2002
Diploicia canescens	N	Wolseley 2002
Evernia prunastri	A	Van Herk 2002
Flavoparmelia caperata	A	Ellenberg (Wolseley 2005)
Hyperphyscia adglutinata	N	Wolseley 2002
Hypogymnia physodes	A	Van Herk 2002
Hypogymnia tubulosa	A	Van Herk 2002
Hypotrachyna revoluta	A	Ellenberg (Wolseley 2005)
Lecanora chlarotera	T	Wolseley 2006b
Lecanora conizaeoides	A	Van Herk 2002
Lecanora expallens	T	Wolseley 2006b
Lecidella elaeochroma	T	Wolseley 2006b
Lepraria incana	A	Van Herk 2002
Lepraria lobificans	A	Wolseley 2006b
Melanelia fuliginosa subsp. glabratula	T	Wolseley 2006b
Melanelixia subaurifera	T	Wolseley 2006b
Melanohalea exasperata	N	Ellenberg (Wolseley 2005)
Parmelia sulcata	T	Wolseley 2006b
Pertusaria amara	A	Ellenberg (Wolseley 2005)
Phaeophyscia orbicularis	N	Van Herk 2002
Phlyctis argena	A	Ellenberg (Wolseley 2005)
Physcia adscendens	N	Van Herk 2002
Physcia aipolia	N	Ellenberg (Wolseley 2005)
Physcia tenella	N	Van Herk 2002
Physconia grisea	N	Wolseley 2002
Placynthiella icmalea	A	Van Herk 2002
Punctelia subrudecta	A	Ellenberg (Wolseley 2005)
Ramalina farinacea	T	Wolseley 2006b
Scoliciosporum chlorococcum	N	Wolseley 2006b
Teloschistes chrysophthalmus	N	Giavarini 2008
Usnea subfloridana	A	Van Herk 2002
Xanthoria candelaria	N	Van Herk 2002
Xanthoria parietina	N	Van Herk 2002
Xanthoria polycarpa	N	Van Herk 2002

Notes: A = acidophyte; N = nitrophyte; T = tolerant.

4.144 No species abundance data were available for the orchard lichens, so scores that incorporated abundance could not be calculated. This contrasts with scores used previous studies, such as van Herk (1999) and Wolseley and others (2005). Instead, simple proportions of the different types of species were calculated and the results given in Table 4.19 below. Nitrogen input from livestock excretions were calculated using the factors for different types of animal given by the UK Greenhouse Gas Inventory 1990-2007, Table A 3.6.7, (Jackson and others 2009), and from stock numbers and length of grazing periods on each site (see Chapter 3). Part of these excretions will volatilise as ammonia (Jackson and others 2009) so the amount of nitrogen input may indicate the relative, local, input of ammonia to each orchard.

Table 4.19 Proportions of lichen species in 5 orchards with different nitrogen and pH preferences and relative amount of local nitrogen input from livestock

	Henhope (T) %	Tidnor (T) %	Lady Close (T) %	Half Hyde (T) %	Village Plum (I) %
Nitrophyte	33.3	54.6	42.9	50.0	42.9
Tolerant	22.2	18.2	25.0	27.8	28.6
Acidophyte	44.4	27.3	32.1	22.2	28.6
	n	**n**	**n**	**n**	**n**
Total number of species (n)	27	11	28	18	14
	Kg/ha/year	**Kg/ha/year**	**Kg/ha/year**	**Kg/ha/year**	**Kg/ha/year**
N input from livestock	44	9	114	101	0

Notes: T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

4.145 Nitrophyte species predominate in all the sites except Henhope Orchard, where acidophytes form the major proportion of species. There seems to be little relation between proportion of nitrophytes and nitrogen input from livestock grazing within the orchards. For instance, Tidnor Wood Orchards had the lowest N input from livestock but had the highest proportion of nitrophytes. Village Plum Orchard had no livestock but had a similar proportion of nitrophytes as Lady Close Orchard, which had the highest estimated input of nitrogen from livestock among the 5 sites. In terms of the surrounding landscape and possible inputs from there, Henhope Orchard was almost completely enclosed by woodland (Map 2.2), a very low intensity land use, which might help to explain its higher proportion of acidophytes. The other orchards had mixed land uses around them, including pasture, arable, intensive orchards and woodland (see Maps 2.3 to 2.8). Another factor that may influence species composition is fruit type. Fruit type is different in Village Plum orchard (plum) compared to the other orchards (apple). Plum bark may have a more acidic character than apple, as lichen floras on plum trees can contain more acidophytes than apple tree floras (Peter Lambley pers comm.). However, the lichens at Village Plum are not distinguished by having a greater proportion of acidophytes compared to the other orchards (Table 4.19).

Orchard fungi and myxomycetes

Survey and analysis methods

4.146 The orchards were visited in 2007 by members of the Herefordshire Fungus Group. The Group is made up of volunteers who are interested in recording the fungus species of the county of Herefordshire and the botanical recording area of Vice-County 36 (the two areas share almost the same boundary). Group members were not able to visit all sites with the same frequency, as shown in the timetable of visits in Table 4.20 below, and therefore sites were surveyed with varying intensity. Nevertheless, information on fungus and myxomycete (slime mould) species of orchards is so scanty that the Group's records are of considerable value in increasing the knowledge of the fungi and myxomycetes of orchards.

Table 4.20 Surveyors and timetable of visits to orchards to record fungi and myxomycetes

Orchard	Dates and recorders
Henhope	20/4/07 JW, 4/6/07 JW, 8/7/07 JW, 9/9/07 JW, 26/10/07 JW
Tidnor	20/4/07 JW, 21/4/07 JW, 4/6/07 JW, 8/7/07 JW, 26/10/07 JW, 2/11/07 CS JR DM
Lady Close	24/3/07 EB MHa, 20/4/07 EB MHa, 21/4/07 MHa, 28/4/07 MHa, 19/5/07 MHa, 16/6/07 MHa, 23/6/07 MHa, 10/7/07 JW CS JR, 18/8/07 MHa, 1/9/07 MHa, 22/9/07 MHa, 20/10/07 MHa, 2/11/07 EB
Half Hyde	7/10/07 SET, 2/11/07 CS JR DM
Romulus	2/6/07 HVC
Salt Box	11/4/07 MIS SS, 28/5/07 MIS SS, 14/11/07 MIS, SS
Village Plum	30/5/07 HVC, 17/10/07 HVC, 13/1/09 CS

Recorders: EB = Ted Blackwell; HVC = Heather Colls; MHa = Margaret Hawkins; DM = David Marshall; MIS = Mike Stroud; SS = Shelly Stroud; SET = Stephanie Thomson; JW = Jo Weightman. Both CS (= Cliff Smith) and JR (= Joy Ricketts) were primarily lichen recorders, (see lichen section above) but recorded some fungi and myxomycete species during their lichen surveys. One of these fungus species was found in 2009.

4.147 Surveyors examined the habitats found in each orchard, including the fruit trees, the orchard floor, boundary hedgerows and hedgerow trees, and microhabitats such as wood piles and sites of fires. The substrate that each species was growing on was recorded. In addition an association between the fungus and another species, or host, was also recorded if it could be determined. The host could have been living or dead, had a mycorrhizal relationship or have been parasitized by the fungus. The fungus survey was restricted to searching for fruiting bodies of macrofungi and for microfungi with features that were visible in the field. Fungi vary in their fruiting behaviour and so surveying at different times of year, and with different frequencies, will produce different species lists. Almost all fungus records for the orchards were made in 2007, but it should be noted that many fungus species are erratic in their appearance so surveying over several years would give a more complete picture of the fungi present in a site. In addition, fruiting behaviour is influenced by weather conditions. The survey results were likely to have been affected by a strange weather pattern in 2007, which began dry in the spring but then the dry spell was followed by torrential rain and floods in mid-summer, followed by drier than normal conditions into the autumn.

4.148 Myxomycete species that were visible were recorded and, in addition, Joy Ricketts collected bark samples from Tidnor Wood Orchards, Lady Close Orchard and Half Hyde Orchard to culture other myxomycetes present so that they could be identified. David W. Mitchell identified the rarer specimens found by this method.

4.149 The findings were assessed with regard to presence of species of special interest. In addition, records of associations of fungus species with plant species (hosts to fungi) and substrates on which the fungi were growing were assessed. Nomenclature of fungus and myxomycete species follows the British Mycological Society's Fungal Records Database of Britain and Ireland (FRDBI). The names are those in the FRDBI which were regarded as the accepted scientific names when the database was accessed on 1/07/09.

4.150 Myxomycete records are reported separately below. As a group, myxomycetes share some characteristics with soil amoebae and some with fungi. However, they are best regarded as part of a separate kingdom from the Kingdom Fungi, and placed in the Kingdom Protozoa (Ing 2001).

Fungus and myxomycete species composition

4.151 The fungus species found in each orchard are shown in the following tables. Each orchard has a table except Romulus Orchard where only one species was recorded (*Coprinus micaceus*). Totals of 136 fungus species and 20 myxomycete species were recorded across the seven orchards. The fungus records from the intensive orchards may be the first from these types of orchards, apart from existing records of fungus species that cause diseases of fruit trees. The myxomycete species lists (Table 4.27) are the first known published site lists for these species in British orchards. No myxomycetes were seen in Romulus or Village Plum orchards.

4.152 Abbreviations used in the fungus species tables are as follows. The letter A after a species name refers to the asexual state of the fungus (fungi can exist in sexual and asexual states). The codes I, II, and III after a species name refers to the various stages in which rust fungi can occur and the structures that contain the spores of the fungi: I = aecia, II = uredinia, III = telia. The letters 'cv.' after an associate name in fungus or myxomycete tables is an abbreviation for 'cultivar'.

Table 4.21 Fungus species composition, association and substrate recorded in Henhope Orchard

Species (FRDBI name)	**Association (host)**	**Substrate**
Agaricus arvensis	Poaceae	soil
Annulohypoxylon multiforme	*Malus* cv.	fallen branch
Armillaria gallica	*Malus* cv.	dead stump
Armillaria mellea s. str.	indeterminate	soil
Auricularia auricula-judae	*Sambucus nigra*	living tree
Barrmaelia oxyacanthae	*Ulmus* sp.	fallen wood
Bolbitius titubans var titubans	Poaceae, indeterminate	hay bale, soil
Calloria neglecta A	*Urtica dioica*	dead stem
Calocybe gambosa	*Crataegus* sp.	soil
Claviceps purpurea var. purpurea	*Dactylis glomerata*	inflorescence
Clitocybe rivulosa	Poaceae	soil
Clitopilus hobsonii	*Malus* cv.	dead twigs
Conocybe arrhenii	none	litter
Coprinellus disseminatus	*Malus* cv.	bole
Coprinopsis cinerea	Poaceae	hay bale
Coprinopsis cinereofloccosa	Poaceae	soil
Coprinus domesticus (ozonium)	*Malus* cv.	fallen branch
Coprinus sterquilinus	*Ovis aries*	dung
Coprobia granulata	*Ovis aries*	dung
Crepidotus applanatus var. applanatus	*Malus* cv.	rotting log
Crocicreas cyathoideum var. cyathoideum	*Urtica dioica*	dead stem
Diatrypella quercina	*Quercus* sp.	fallen branch
Encoelia furfuracea	*Corylus avellana*	fallen wood
Exidia glandulosa	*Corylus avellana*	fallen wood
Galerina subclavata	Musci	bryophyte
Hygrocybe conica	Poaceae	soil
Hygrocybe psittacina var. psittacina	Poaceae	soil
Hygrocybe virginea var. virginea	Poaceae	soil
Hyphodontia sambuci	*Sambucus nigra*	living tree
Hypholoma fasciculare var. fasciculare	*Malus* cv.	stump
Hypoxylon fuscum	*Corylus avellana*	fallen wood
Laccaria laccata	indeterminate	debris
Lasiosphaeria ovina	*Malus* cv.	fallen branch
Leptosphaeria acuta	*Urtica dioica*	dead stem
Macrolepiota mastoidea	*Quercus* sp.	soil
Mollisia cinerea	indeterminate	dead twigs
Monilinia fructigena A	*Malus* cv.	fruit (apple)
Mycena adscendens	*Malus* cv.	dead twigs
Mycena flavoalba (= M. luteoalba	Poaceae	soil

Species (FRDBI name)	Association (host)	Substrate
sensu auct.)		
Mycena speirea	*Malus* cv.	dead twigs
Mycena vitilis	none	litter
Nemania serpens var. serpens	*Malus* cv.	rotting log
Panaeolina foenisecii	Poaceae	hay bale
Parasola plicatilis	Poaceae	hay bale
Peniophora quercina	*Malus* cv., *Quercus* sp.	fallen branches
Peziza echinospora	indeterminate	fire site
Peziza vesiculosa	Poaceae	hay bale
Pholiota squarrosa	*Malus* cv.	bole, dying tree
Phyllactinia guttata	*Corylus avellana*	fallen leaf
Pilobolus crystallinus var. crystallinus	*Ovis aries*	dung
Polyporus squamosus	*Malus* cv.	fallen branch, rotting log
Psathyrella pennata	indeterminate	fire site
Puccinia punctiformis III	*Cirsium arvense*	fading leaves
Ramularia rubella	*Rumex crispus, Rumex obtusifolius*	living leaves
Rhodotus palmatus	*Ulmus* sp.	fallen trunk, fallen branch
Saccobolus glaber	*Ovis aries*	dung
Schizopora paradoxa	*Quercus robur, Malus* cv.	fallen wood, log
Stereum hirsutum	*Corylus avellana, Malus* cv., *Quercus* sp.	fallen wood, fallen branches
Stereum rugosum	*Corylus avellana*	fallen wood
Torula herbarum	*Urtica* sp.	dead stem
Trametes versicolor	*Corylus avellana, Malus* cv.	fallen wood, standing dead tree, fallen branch
Tubaria furfuracea	none	debris
Venturia inaequalis A	*Malus* cv.	fruit (apple)
Xanthoriicola physciae	*Xanthoria parietina*	apothecia
Total number of species = 64		

Table 4.22 Fungus species composition, association and substrate recorded in Tidnor Wood Orchards

Species (FRDBI name)	Association (host)	Substrate
Abortiporus biennis	indeterminate	buried wood
Agrocybe molesta	Poaceae	soil
Anthracobia macrocystis	indeterminate	fire site
Armillaria mellea s. str.	*Malus* cv.	tree bole
Auricularia auricula-judae	*Malus* cv.	debarked trunk
Bjerkandera adusta	*Malus* cv.	stump
Bolbitius titubans var. titubans	indeterminate	woodchip pile
Calloria neglecta A	*Urtica dioica*	dead stem
Chondrostereum purpureum	*Malus* cv.	living tree, dead bole & trunk, dead stump
Coniophora puteana	*Malus* cv.	log pile
Coprinopsis lagopus	indeterminate	woodchip pile
Entyloma ficariae	*Ranunculus ficaria*	fading leaf
Erysiphe alphitoides	*Quercus* sp.	living leaves
Golovinomyces cynoglossi	*Myosotis arvensis*	fading leaf
Hypholoma fasciculare var. fasciculare	indeterminate	buried wood
Lacrymaria lacrymabunda	Poaceae	soil
Lepiota cristata	none	fire site
Leptosphaeria acuta	*Urtica dioica*	dead stem

Species (FRDBI name)	Association (host)	Substrate
Macrolepiota mastoidea	*Malus* cv.	soil
Marasmius oreades	Poaceae	soil
Melampsora populnea I	*Mercurialis perennis*	living leaf
Panaeolina foenisecii	Poaceae	soil
Panaeolus papilionaceus var. papilionaceus	Poaceae	soil
Parasola conopilus	none	fire site
Parasola plicatilis	Poaceae	soil
Paxillus involutus	none	soil
Peziza micropus	indeterminate	woodchip pile
Peziza violacea	none	fire site
Pholiota gummosa	indeterminate	woodchip pile
Pholiota squarrosa	*Malus* cv.	living root
Pleurotus ostreatus	*Malus* cv.	log
Psathyrella candolleana	Poaceae	fire site
Ramularia rubella	*Rumex obtusifolius*	living leaves, fading leaves
Stropharia inuncta	none	soil
Trametes versicolor	*Malus* cv.	log pile, stump
Tubaria conspersa	indeterminate	woodchip pile
Tubaria dispersa	*Crataegus* sp.	soil
Uromyces muscari III	*Hyacinthoides non-scripta*	living leaf
Venturia inaequalis A	*Malus* cv.	fruit (apple)
Volvariella gloiocephalus	indeterminate	woodchip pile
Xanthoriicola physciae	*Xanthoria parietina*	apothecia
Total number of species = 41		

Table 4.23 Fungus species composition, association and substrate recorded in Lady Close Orchard

Species (FRDBI name)	Association (host)	Substrate
Abortiporus biennis	*Malus* cv.	rotting log
Agaricus arvensis	*Crataegus* sp., *Urtica* sp.	soil
Agaricus bisporus	*Crataegus* sp.	soil
Agaricus campestris var. campestris	*Crataegus monogyna*	soil
Agaricus cappellianus	*Crataegus monogyna*	litter/soil
Bolbitius titubans var. titubans	Poaceae	manured pasture
Calloria neglecta A	*Urtica dioica*	dead stem
Calocybe gambosa	Poaceae	soil
Clitocybe nebularis	*Crataegus monogyna*	litter/soil
Conocybe percincta	Poaceae	soil
Coprinellus micaceus	Poaceae	soil
Crocicreas cyathoideum var. cyathoideum	*Urtica dioica*	dead stem
Dacrymyces stillatus	*Malus* cv.	rotting log
Daldinia concentrica	*Fraxinus excelsior*	fallen wood
Entyloma ficariae	*Ranunculus ficaria*	fading leaf
Epichloe typhina s. lat.	Poaceae	living stem
Ganoderma australe	*Malus* cv.	cut log, soil
Hypholoma fasciculare var. fasciculare	indeterminate	log
Inocybe posterula	Poaceae	damp soil
Leptosphaeria acuta	*Urtica dioica*	dead stem
Lycoperdon pyriforme	*Malus* cv.	soil
Macrolepiota procera var. procera	Poaceae	soil
Melampsora laricis-populina II.III	*Populus nigra*	fading leaf

Species (FRDBI name)	Association (host)	Substrate
Mollisia cinerea	*Malus* cv.	rotting log
Monilinia fructigena A	*Malus* cv.	fruit (apple)
Panaeolus semiovatus var. semiovatus	Poaceae	soil
Periconia cookei	*Urtica dioica*	dead stem
Peziza micropus	*Malus* cv.	rotting bark, felled log, rotting log
Peziza repanda	*Malus* cv.	soil
Phragmidium bulbosum III	*Rubus fruticosus* agg.	living leaf
Phragmidium violaceum III	*Rubus fruticosus* agg.	living leaf
Postia tephroleuca	*Crataegus* sp.	rotting log
Psathyrella candolleana	Poaceae	soil
Puccinia sessilis I	*Arum maculatum*	living leaf
Ramularia ari	*Arum maculatum*	living leaves
Ramularia rubella	*Rumex obtusifolius*	living leaves, fading leaves
Schizothecium tetrasporum	*Oryctolagus cuniculus*	dung pellet
Sphaeropsis visci	*Viscum album*	dead twigs
Sporormiella intermedia	*Oryctolagus cuniculus*	dung pellet
Stilbella erythrocephala	*Oryctolagus cuniculus*	dung pellet
Trametes pubescens	*Malus* cv.	cut logs
Trametes versicolor	*Malus* cv.	fallen tree, log, rotting log, log pile
Tremella mesenterica	*Malus* cv.	attached branch
Venturia inaequalis A	*Malus* cv.	fruit (apple)
Volvariella gloiocephalus	*Malus* cv.	soil
Xanthoriicola physciae	*Xanthoria parietina*	apothecia
Xylaria hypoxylon	*Malus* cv.	fallen trunk
Total number of species = 47		

Table 4.24 Fungus species composition, association and substrate recorded in Half Hyde Orchard

Species (FRDBI name)	Association (host)	Substrate
Bolbitius vitellinus	Poaceae	well manured pasture
Coprinus micaceus	Poaceae	soil
Ganoderma adspersum	Angiosperm	living tree
Illosporiopsis christiansenii	Epiphytic *Physcia tenella*	Lichen thallus
Marchandiomyces corallinus	Epiphytic *Parmelia sulcata*	Lichen thallus
Xanthoriicola physciae	Epiphytic *Xanthoria parietina*	Lichen thallus
Total number of species = 6		

Table 4.25 Fungus species composition, association and substrate recorded in Salt Box Orchard

Species (FRDBI name)	Association (host)	Substrate
Crocicreas coronatum	*Urtica* sp.	dead stem
Discocistella grevillei	*Heracleum sphondylium*	dead stem
Erysiphe alphitoides A	*Quercus* sp.	living leaves
Laccaria laccata	Poaceae	soil
Lachnum virgineum	*Impatiens* sp.	dead stem
Leptosphaeria acuta	*Urtica dioica*	dead stem
Marasmius setosus	Angiosperm	dead petiole
Melampsorella symphyti I	*Symphytum* sp.	living leaf
Mycena adscendens	*Rubus fruticosus* agg.	dead stem
Parasola plicatilis	Poaceae	soil
Periconia cookei	*Heracleum sphondylium*	dead stem
Phragmidium bulbosum III	*Rubus fruticosus* agg,	dead leaf
Pirottaea nigrostriata	*Heracleum* sp.	dead stem
Polyporus brumalis	Angiosperm	dead wood
Puccinia arenariae III	*Silene dioica*	living leaf
Puccinia sessilis I	*Arum maculatum*	living leaf
Ramularia rubella	*Rumex* sp.	living leaves
Rhytisma acerinum	*Acer pseudoplatanus*	dying leaf
Rosellinia aquila	Angiosperm	rotting wood
Uromyces dactylidis I	*Ranunculus ficaria*	living leaf
Xylaria hypoxylon	Angiosperm	dead wood
Total number of species = 21		

Table 4.26 Fungus species composition, association and substrate recorded in Village Plum Orchard

Species (FRDBI name)	Association (host)	Substrate
Agaricus urinascens var. urinascens	*Prunus domestica* cv.	soil
Coprinellus disseminatus	Poaceae	soil
Coprinus comatus	Poaceae	soil
Ganoderma australe	*Prunus domestica* cv.	tree bole
Panaeolus acuminatus	Poaceae	soil
Parasola plicatilis	Poaceae	soil
*Trametes versicolor**	*Prunus domestica* cv.	living tree
Total number of species = 7		

Note: * Found in 2009

Table 4.27 Myxomycete species and habitat recorded in 5 orchards

Species	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Habitat
Arcyria cinerea		√	√	√		*Malus* cv. bark
Arcyria pomiformis		√	√	√		*Malus* cv. bark
Cribraria violacea		√				*Malus* cv. bark
Enerthenema papillatum		√				*Malus* cv. bark
Fuligo septica var. septica		√	√			Lady Close: log pile (*Malus* cv.) Tidnor: rotting branch
Licea operculata		√				*Malus* cv. bark
Lycogala terrestre		√				Soil associated with *Malus* cv. tree
Macbrideola cornea		√				*Malus* cv. bark
Mucilago crustacea var. crustacea					√	Living stem of *Rubus fruticosus* agg.
Paradiacheopsis fimbriata		√	√	√		*Malus* cv. bark
Paradiacheopsis rigida		√				*Malus* cv. bark
Paradiacheopsis solitaria		√		√		*Malus* cv. bark
Perichaena chrysosperma		√	√	√		*Malus* cv. bark
Physarum auriscalpium			√	√		*Malus* cv. bark
Physarum cinereum	√					Straw litter of Poaceae
Physarum decipiens			√	√		*Malus* cv. bark
Physarum limonium			√			*Malus* cv. bark
Reticularia lycoperdon	√					Fallen wood from *Corylus avellana* and *Malus* cv.
Trichia contorta var. contorta		√	√			Lady Close: rotting bark of *Malus* cv. Tidnor: *Malus* cv. bark
Trichia varia		√				Cut logs of *Malus* cv.

Notes: T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

4.153 The numbers of fungus species recorded in each site are not comparable because sites were visited with different frequencies and weather conditions prior to visits could have influenced the number of species found. Also, bark samples for culturing myxomycetes were not collected from all orchards.

Fungus species of special interest

4.154 The British Mycological Society have carried out a preliminary assessment of threatened British fungi and produced a Red Data List, which follows the IUCN guidelines on threat categories (Evans 2007). Taxonomic difficulties and lack of information about current distributions are particularly problematic for fungi and more work is required before the list becomes an official Red Data List. One species on the preliminary assessment list was found in Henhope Orchard, namely *Coprinus sterquilinus*. This species is classed as Vulnerable on the Red List. The FRDBI contains only 20 post-1960 records (the cut-off date used in the Red List for qualifying records). The only record for Herefordshire is that made at Henhope Orchard. The species is associated with dung of various mammals. At Henhope Orchard it occurred on sheep dung.

4.155 The rarity of fungus species in Britain can be further assessed to some extent even if levels of risk are not clear. Dr Malcolm Storey used the number of records of a species in the FRDBI as an indication of rarity in the orchard survey described by Lush and others (2009). There is a strong bias in the records towards larger and better-known species and probably also to interesting or rare ones. Also the records are influenced by a strong 'recorder effort' effect. A keen recorder can produce a large number of records for a species in one relatively restricted geographic area, although the species actually may be more widely distributed, but has not been searched for elsewhere. Nevertheless, the database contains over one and a half million records and is probably the best guide available, at least to the rarity of British macrofungi. Dr Storey regarded a rare macrofungus as one with less than about 100 records (in 2004) and this criterion is adopted for all fungi in the current survey (FRDBI accessed on 1/07/ 2009). However, it should be noted that the number of records in the FRDBI has been increasing over time, meaning that a 'rare' species perhaps should be defined in 2009 by a higher threshold number of records, say 150 records. The threshold of 100 adopted here is therefore relatively strict compared to the threshold in Lush and others (2009).

4.156 There are 10 qualifying species among the fungus records collected in the orchards, including *Coprinus sterquilinus*, all of them recorded from traditional orchards. The species found and the number of records in Britain and Ireland for each of the other species are given below. Notes in the FRDBI on the ecology of each qualifying species and on the frequency of occurrence in Herefordshire are also used in the following account.

4.157 Henhope Orchard had the most rare species, including the one nationally threatened species of fungus. The other species found here were: *Barrmaelia oxyacanthae* (29 records), *Coprinopsis cinereofloccosa* (39 records), *Galerina subclavata* (31 records) and *Saccobolus glaber* (78 records). *Barrmaelia oxyacanthae* grows on wood, generally elm (*Ulmus* species) but also ash (*Fraxinus excelsior*). At Henhope it was found on fallen elm wood. There are 5 Herefordshire records, including the one at Henhope, but three of these were made before 1900. *Coprinopsis cinereofloccosa* occurred on soil in grassland at Henhope, as is the case in other sites in Britain, including in parkland habitats. It can also be found on woodland soils, including conifer woodland soils. The record for Henhope is the only Herefordshire record. *Galerina subclavata* is usually associated with mosses, as at Henhope, in grassland and parkland and also in woodland, where mosses grow on leaf litter or dead wood. The only Herefordshire record is that from Henhope Orchard. *Saccobolus glaber* is another species which grows on animal dung, including that of cattle, horses, rabbits and deer, or, as at Henhope, of sheep. There are 5 records for Herefordshire, including Henhope, although it is probably more common in the area than this number of records suggest (Joy Ricketts pers. obs.). The species was last recorded 30 years ago.

4.158 Lady Close Orchard had 3 rare fungus species present: *Conocybe percincta* (78 records), *Inocybe posterula* (58 records) and *Sphaeropsis visci* (15 records). There are 6 Herefordshire records of *Conocybe percincta*, the most recent record, apart from Lady Close, was made in 1972. The species is found on dead or dying organic matter, such as straw, old stumps, leaf mould, woodchips, conifer needle litter, as well as soil associated with trees or herbaceous plants, as at Lady Close (see Table 4.23). *Inocybe posterula* has been found 3 times in Herefordshire, including in Lady Close Orchard. It is generally found on soil, associated with trees, in woodlands or parklands, or among the litter layer in woods, including conifer woodland. It is sometimes found with grasses in areas with trees, as at Lady Close. Records for *Sphaeropsis visci* in the FRDBI are all recent, the earliest were made in 1996. There are 8 records for Herefordshire, including Lady Close. The species has always been found associated with mistletoe (*Viscum album*). The fungus can occur on dying or dead mistletoe on fallen branches, but also on living mistletoe on trees. It is probably under-recorded, as mistletoe often occurs in inaccessible tree canopies.

4.159 Half Hyde Orchard had 2 rare fungus species associated with epiphytic lichens (ie lichenicolous fungi), namely *Illosporiopsis christiansenii* (30 records) and *Marchandiomyces corallinus* (66 records). These species may be under-represented in the FRDBI, as they are generally recorded by lichenologists rather than fungi surveyors. Note that the Half Hyde records were not on the FRDBI at the time the comparison was made in 2009 so there were 31 and 67 records respectively for the two species nationally including Half Hyde. There are 15 other Herefordshire records for *Illosporiopsis christiansenii*. The lichen species on which the fungus is growing is sometimes identified in the FRDBI records. Those lichens associated with *Illosporiopsis christiansenii* appear to be mostly nitrophytes as defined by van Herk (2002) and Wolseley and others (2006b). These are lichens that respond positively to increases in ammonia in the atmosphere. The ammonia often derives from agricultural intensification in the surrounding area. Nitrophytes associated with *Illosporiopsis christiansenii* include *Xanthoria parietina*, *Physcia tenella* (as at Half Hyde) and *Physcia adscendens*. There are no other Herefordshire records for *Marchandiomyces corallinus* apart from Half Hyde Orchard. In contrast to *Illosporiopsis christiansenii* it is mostly associated with acidophyte lichens, ie those negatively affected by increased ammonia levels. Lichen associates include *Hypogymnia physodes*, *Parmelia saxatilis*, *Usnea* species and *Lecanora conizaeoides* which are all acidophytes (van Herk 2002, Wolseley and others 2006b). However, the lichen with the fungus at Half Hyde was *Parmelia sulcata*, which is defined by Wolseley and others (2006b) as 'tolerant' of both ammonia enriched conditions or low ammonia situations.

Myxomycete species of special interest

4.160 There is no formal list of the conservation status of myxomycete species in Britain (Chris Cheffings, Joint Nature Conservation Committee, pers comm.). However, Professor Bruce Ing, the leading authority on the distribution of British myxomycetes, has made informal assessments of the rarity of the species found in this country (Ing 1995, Ing 2001). Of the species found, several are uncommon or rare according to Ing (1995). Uncommon species are *Licea operculata*, *Paradiacheopsis rigida* (both in Lady Close), *Physarum auriscalpium* and *Physarum decipiens* (both in Tidnor and Half Hyde). All are found on the bark of living trees as are the two rare species: *Cribraria violacea* (Lady Close) and *Physarum limonium* (Tidnor). However, Ing (2001) noted that the bark habitat is poorly recorded as yet, so these species may be less rare than currently thought. David Mitchell (pers. comm.) noted that *Physarum decipiens* and *Physarum limonium* are apple bark specialists and he has also reported that apple bark is one of the most productive for cultured myxomycetes (Mitchell 1978).

Habitat assemblages of orchard fungi

4.161 Fungi have not yet been described by means of standard ecological characteristics as have bryophytes (Hill and others 2007) and vascular plants (Hill and others 2004). One simple way of examining pattern in species occurrence, adopted in this report, is to categorise fungus species by the broad habitat type where a particular fungus was found, as done by Lush and others (2009), and express the results as proportions of the total species assigned to habitats. This avoids the problem of unequal recording effort in the survey. It should be emphasized that the habitat category to which a species is assigned purely means where the fungus was found during the survey, it does not imply that a species is confined to that habitat. However, the results give an indication of which habitats were most productive of records in each orchard during the survey. Only 4 orchards had enough records to make such a categorisation worthwhile.

4.162 The relative proportions of numbers of fungus species, expressed as percentages, in the main habitat categories in these orchards are shown in Table 4.28 below, while Table 4.29 and Table 4.30 show subsets for dead and live wood types and cultivated fruit trees (apple) compared to other trees not grown for fruit ('non-fruit' trees) growing in the orchard or in the orchard hedgerows or along boundary fences. The categories are all based on the substrate and association (host) details collected by the surveyors and described above in Table 4.21 to Table 4.26. Note that percentages are rounded so these may not add to 100% across categories by site. The score for each species occurrence was always one, even if it occurred in more than one habitat. Where a species occurred in more than one of the habitat categories in the table, the score was equally divided between each category, for example 0.5 for each of 2 categories where one fungus species occurred in both categories.

Table 4.28 Proportions of numbers of fungus species in main orchard habitat assemblages

Habitat	Henhope (T) %	Tidnor (T) %	Lady Close (T) %	Salt Box (I) %
Woody plants: living and dead material, including wood, leaves, epiphytes and soil substrate with tree / shrub hosts	52	51	54	33
Herbaceous plants: living and dead material and soil substrate with herbaceous hosts	30	32	39	62
Dung	6	0	6	0
Fire sites	3	12	0	0
Other: undifferentiated debris and plants, and soil substrate with unknown hosts	9	5	0	5

Notes: T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

Table 4.29 Proportions of numbers of fungus species in fruit tree habitats and non-fruit tree habitats

Habitat	Henhope (T) %	Tidnor (T) %	Lady Close (T) %	Salt Box (I) %
Fruit trees: living and dead material, including wood, leaves, epiphytes and soil substrate with tree / shrub hosts	55 (27)	83 (24)	60 (30)	0 (0)
Non-fruit trees: living and dead material, including wood, leaves, epiphytes and soil substrate with tree / shrub hosts	45 (22)	17 (5)	40 (20)	100 (14)

Notes: number in brackets is component % of the subset in the woody plant category in Table 4.28. Some fungi had unknown woody hosts and are not included. T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

Table 4.30 Proportions of numbers of fungus species in different wood habitats

Habitat	Henhope (T) %	Tidnor (T) %	Lady Close (T) %	Salt Box (I) %
Live wood	14 (5)	11 (4)	8 (2)	0 (0)
Attached dead wood, including standing dead trees	14 (5)	19 (7)	0	26 (5)
Fallen dead wood, no longer attached to trees	72 (26)	70 (26)	92 (22)	74 (14)

Notes: number in brackets is component % of the subset in the woody plant category in Table 4.28. T = traditional orchard, I = intensive orchard (see Chapter 3 for management details).

4.163 In the traditional orchards, Henhope, Tidnor and Lady Close, the main habitats where fungi were found were the woody habitats, or soil associated with woody plants, whereas in the intensive orchard, Salt Box, the main habitats were herbaceous plants or soil associated with these plants (Table 4.28). There were a few minor habitats for fungi, particularly fire sites and animal dung. These habitats were of varied occurrence in the orchards. Amongst woody habitats, the cultivated fruit trees were the main habitats in the traditional orchards (Table 4.29). Tidnor had the greatest proportion of fungus species in these habitats, as might be expected, given the large area occupied by fruit trees here (Map 2.3) in relation to the relative length of woody boundaries containing other trees and shrubs (Table 4.9).

4.164 No fungi were recorded from fruit tree habitats in Salt Box Orchard. This absence could be due to the trees being relatively young, at about 10 years old. Such trees could be less susceptible to a wide range of fungi, including wood decay fungi, than older trees or the time since the trees were planted has been insufficient for a fungus assemblage to develop. Alternatively, it might be due to the regular use of fungicides to control fruit tree diseases and use of herbicides to suppress herbaceous competitors to the fruit trees. There seems to be relatively little published information on the effects of fungicides and herbicides on non-target fungi in orchards or elsewhere. A full review of this topic was beyond the scope of this report but overall, fungicide effect studies appear to show a complex picture, with some types of fungi being affected by some fungicides. For example, Foster and McQueen (1977) reported that fungi varied in sensitivity to benomyl. Effects of captan and dodine (two fungicide active ingredients used in Salt Box Orchard) on beneficial fungi have been studied, though none of the fungi included in these studies were recorded in the current survey. Beneficial fungi are those which aid control of plant pests or enhance plant nutrition, such as mycorrhizal fungi found in plants roots. Studies have indicated a variable effect of these fungicides on these fungi, some being deleteriously affected and others not being affected (Campbell 1989, Sterk and others 2003, Luz and others 2007, and studies reviewed on-line in 2009 by Plant Health Care Inc.). Herbicides may also affect fungi in variable ways, for instance, some soil fungi are susceptible to, while others show tolerance of, phosphinthricin, also known as glufosinate ammonium, the active ingredient of the herbicide used in Salt Box Orchard (Ahmad and Malloch 1995, Pampulha and others 2007). There may be indirect effects on fungi due to spraying, for example, machinery use could compact the soil or lack of ground cover because of herbicide use both could reduce the fungi species growing in the orchard.

4.165 In all the orchards, fallen dead wood contributed most to the fungi records, compared with live wood and dead and decaying wood attached to trees (Table 4.30). This may, in part at least, be due to fallen wood being easier to search. No fungi on live wood were found in Salt Box Orchard, and species numbers were few on live wood in the other orchards. Henhope and Lady Close had dead wood left in situ in the orchard but the orchard floors of Tidnor and Salt Box were mostly cleared of fallen dead wood on a regular basis to facilitate machinery access (see Chapter 3). However, stacked dead wood and woodchip piles provided alternative dead wood habitats for fungi in Tidnor Orchards.

4.166 The traditional orchards were similar to each other in their relatively low proportions of fungi associated with herbaceous vegetation, contrasting with the greater proportion of species found in this vegetation in Salt Box Orchard (Table 4.28). Orchard grasslands elsewhere have been shown to have rich fungi floras, particularly of ‘waxcap’ fungi (Smart and Winnall 2006, Lush and others 2009). However, none of the surveyed orchards, with the exception of Henhope Orchard, had any of the taxa that make up the ‘waxcap’ group as defined by Evans (2003): Clavariaceae (club and coral fungi), Hygophoraceae (waxcaps), Entolomataceae (pink-gilled agarics) and Geoglossaceaea (earth-tongues). The group is generally associated with old grasslands that have not been agriculturally improved with inorganic fertilisers and are on nutrient-poor soils (Evans 2003, Spooner and Roberts 2005).

4.167 Grasslands at Tidnor, Lady Close and Salt Box were mostly species-poor with regard to flowering plants, which often indicates past agricultural improvement with fertilisers (see the orchard habitat survey above). Salt Box was arable about 10 years ago (Chapter 2) and the orchard has been fertilised with inorganic fertilisers (Chapter 3). Tidnor was managed intensively, most likely including fertiliser inputs, up to about 5 years ago (Chapter 2). The medium to high soil phosphorus level in the topsoil here (ADAS soil index 3, Table 2.3) supports this view. Most soils which have received high inputs of inorganic fertilisers have a soil index of 2 or more (Natural England 2008). The grassland at Lady Close Orchard may not have been disturbed by ploughing for many years, as suggested by the long history of the orchard on this site (Chapter 2), but the soil phosphorus level in the topsoil (ADAS soil index 2, Table 2.3) suggests past improvement with inorganic fertilisers. Therefore the lack of waxcaps is not unexpected at these three sites.

4.168 Henhope Orchard had 3 *Hygocybe* species; *H. conica*, *H. virginea* and *H. psittacina*. *H. conica* and *H. virginea* are waxcaps that are relatively tolerant of fertilisers and may appear after 10-20 years if fertiliser use ceases (Spooner and Roberts 2005). Fertilisers have not been used at least since the current owner took over management about 20 years ago (Chapter 2). The character of the herbaceous vegetation suggests inorganic fertilisers were used at some time further back in the past (see the orchard floor habitat survey above) but the composition of the sward also suggests recovery is underway, or that fertiliser use was not uniform, as the habitat survey showed that there was patchy occurrence of broad-leaved herbs in the sward and one area of unimproved grassland. In addition, soils at Henhope had very low phosphorus levels (ADAS soil index of zero, Table 2.3), which should aid the return of a grassland that will be richer in fungi.

Numbers of species of special interest among all species groups surveyed

4.169 The bryophyte, lichen, fungus and myxomycete surveys showed that the traditional orchards all had species of special interest, ranging from nationally endangered, rare and scarce species to species uncommon in Herefordshire (Table 4.31). While frequency of fungus and myxomycete survey visits and lack of comprehensive sampling of bark for myxomycetes most probably affected the numbers of special species found, it is interesting to note that the orchard with the oldest trees, Lady Close, had the highest number of species of interest, followed by Half Hyde and Henhope orchards, where most of the trees were around 50-60 years old (Table 4.6). All these orchards had representatives from each group of species, except that no special myxomycetes were recorded at Henhope. The orchard where intensive management has been relaxed relatively recently, Tidnor, had rather fewer species of special interest, and none from the fungi and lichen groups. No species of special interest were found in the intensive orchards (Table 4.31).

Table 4.31 Numbers of species of special interest in each orchard

	Species of special interest				
Orchard	**Bryophytes**	**Lichens**	**Fungi**	**Myxomycetes**	**Total**
Henhope (T)	1 (lo)	1 (ns)	1 (pv) 4 (r)	0	7
Tidnor (T)	1 (ns)* 1 (lo)	0	0	1 (rm) 2 (u)	5
Lady Close (T)	1 (lo)	2 (ns)	3 (r)	1 (rm) 2 (u)	9
Half Hyde (T)	2 (lo)	1 (ce) 1 (ns)	2 (r)	2 (u)	8
Romulus (I)	0	0	0	0	0
Salt Box (I)	0	0	0	0	0
Village Plum (I)	0	0	0	0	0

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Species of interest: lo = bryophyte locally occasional in Herefordshire, ns = nationally scarce bryophyte or lichen, ce = critically endangered lichen, pv = fungus classed as vulnerable on provisional Red List, r = rare fungus ie less than 100 records in FRDBI, rm = rare myxomycete according to Ing (1995), u = uncommon myxomycete according to Ing (1995).
* formal JNCC category, now regarded as less scarce (Hill and others 2007).

Conclusions on orchard habitats and species

4.170 Orchard management played a major role in determining the features of the habitat mosaic of fruit trees, orchard floor and hedgerows in the study orchards. The traditional orchards contained larger and older fruit trees with a greater abundance of veteran tree features than the intensive orchards, which were managed for high fruit productivity, and which utilised densely-planted bush trees. Fruit crops in the intensive orchards were obtained from one or two fruit varieties, while the traditional orchards contained larger numbers of fruit varieties. The traditional orchards qualified as priority BAP habitats.

4.171 Orchard floors in the traditional orchards were fully grassed while those in the intensive orchards had bare ground under the tree rows, due to management by herbicides. The species-richness of the grasslands varied among the orchards, but most of the grassland was species-poor, probably because of past re-seeding or treatment with inorganic fertilisers and herbicides.

4.172 All the orchards had hedgerows, most of which were dominated by native woody species and which were priority BAP habitats. The majority of the hedgerows were not in favourable condition, particularly because of gaps in the woody structure of the hedgerows and the abundance of herbaceous plants indicating nutrient enrichment and disturbance. This result is similar to the results of a compilation of local surveys across England, where the majority of hedgerows were in unfavourable condition and gaps and nutrient and disturbance indicators were the main reasons for unfavourable condition.

4.173 A brief review of habitat and management effects on invertebrates and birds concluded that these two species groups were likely to be favoured by the veteran tree features in the traditional orchards and by the absence of pesticide applications in these orchards. The species-poor grasslands found in most of the orchards was probably of rather limited value to invertebrates. The relatively high broad-leaved herb cover in the grass alleys in the intensive orchards may have had benefits for invertebrates, such as insect pollinators, and for birds, particularly if the grassland mowing regime allowed plants to flower and set seed. The bare strips, and the patches of herbaceous plant colonists in these strips, in the intensive orchards may have provided foraging habitat for granivorous birds.

4.174 More birds and bird species would have been likely to have occurred in the larger and less frequently trimmed hedgerows around the orchards. The greater berry crops on such hedgerows would have had relatively greater benefits for invertebrates and birds than the smaller berry crops on shorter, more frequently trimmed hedgerows.

4.175 The bryophyte, lichen, fungus and myxomycete surveys showed that the traditional orchards all had species of special interest, ranging from nationally endangered, rare and scarce species to species uncommon in Herefordshire. No species of special interest were found in the intensive orchards. Frequency of fungus and myxomycete survey visits and lack of bark sampling in some sites may have affected the numbers of such species found across the orchards.

4.176 The traditional orchards in the study provided habitats for a good variety of epiphytic bryophytes although no rarities were found. Among traditional orchards, the site with the largest number of trees, Tidnor, had the most species, although the trees in this orchard were smaller than in the other sites and were possibly easier to search. Few species were found in the intensive orchards. Tree age may have been the most important factor affecting bryophyte colonization in the intensive orchards rather than intensity of management. Trees in these orchards were considerably younger than most of the trees in the traditional orchards. However, relative tree age among mature trees in the traditional orchards did not seem related to richness of epiphytic bryophytes. Analysis of ecological indicator values suggested that the epiphytic bryophytes found were generally typical of moderately well-lit and well-drained substrates. Indicators of acidity and alkalinity suggested conditions provided by the fruit trees for epiphytic bryophytes were generally basic and moderately infertile.

4.177 The lichen survey found 45 species that were epiphytic on fruit trees, ranging from one species in the least diverse orchard to 36 species in the richest orchard. One Critically Endangered lichen and 2 nationally scarce species were recorded. Tree number did not seem to influence richness of epiphytic lichens. The largest number of species was found in the orchard with the oldest trees but age of trees alone did not seem to fully explain the low species richness of some orchards. Intensive management of 4 orchards with pesticide sprays, either during the project period or in the past might have reduced their species complement. Overall, the traditional orchards were less rich than some other traditional orchards in England, and may have suffered in the past from atmospheric pollution by sulphur dioxide. Lichens that prefer high bark pH and additional nitrogen (nitrophytes) predominated, in terms of relative species numbers, in most orchards analysed, while species requiring acid substrates and which are sensitive to increased levels of nitrogen (acidophytes) dominated in only one orchard. The nitrogen input from livestock grazing the orchards seemed not to be related to the proportions of nitrophyte and acidophyte species. However, surrounding land use might have had some influence on species composition.

4.178 The survey provided the first known published lists of non-target fungi in intensively managed orchards in Britain and the first myxomycete lists for orchards in Britain. It is unfortunate that the weather in 2007 was not favourable for many fungi so the records and conclusions have to be seen as interim. Fungus species were found in a variety of habitats within the orchards. Woody habitats contributed most species to the list in traditional orchards while in the intensive orchard, Salt Box, herbaceous vegetation produced the most fungus species. Compared with live wood and dead wood still attached to trees, fallen dead wood contributed most species in all the orchards analysed. No species were associated with fruit trees in Salt Box orchard, possibly because trees were only about 10 years old or possibly because of the use of fungicides and herbicides in this orchard. Grassland fungi from the waxcap group were only found at Henhope Orchard. Grassland here may become richer in fungi over time with continuation of the current low-intensity management.

Topics for further work on orchard habitats and species

4.179 More research into the life spans of fruit trees and the time taken to develop particular veteran tree features would be valuable, to be able to develop prescriptions for age structures in orchards in the landscape which would provide continuity of habitat for species such as saproxylic invertebrates. More information about the effects of relaxing intensive orchard management on wildlife would be helpful, such as potential natural lifespans and eventual sizes attained by fruit trees on dwarfing rootstocks, and colonization by species groups such as lichens. Study of the controlling factors in mistletoe occurrence would be useful, in particular in relation to tree age and tree features, such as the state of the bark as a substrate for mistletoe colonization and the role of fruit variety.

4.180 In traditional orchards, an understanding of the impact of shading and nutrient enrichment from livestock grazing on sward species-richness would be useful and investigation of ways of increasing plant resources for invertebrates, such as insect pollinators, and birds would be helpful in traditional and intensive orchards. More knowledge of the botanical characteristics of the bare strips in the intensive orchards and their value for invertebrates and birds, and any interactions with pesticide use would be helpful. Quantifying impacts of pesticide use more generally on orchard invertebrates and birds would be valuable as well as increasing the understanding of the mechanisms behind such impacts, for instance, the significance of indirect effects of pesticide use on the invertebrate food supply of insectivorous birds.

4.181 Greater knowledge of the impact of hedgerow trimming frequency, gaps at the base of hedgerows and abundance of eutrophication and disturbance indicators on species inhabiting hedgerows would be beneficial.

4.182 The information in the literature about species from bryophyte, lichen, fungus and myxomycete groups in orchards is limited and while the current project increased this knowledge, more survey is required of all groups, including surveys of species in intensive orchards, which have not received much attention as yet. A better understanding of the impact of intensive orchard management on these species groups is needed, particularly in relation to non-pest species.

4.183 Knowledge of factors controlling bryophyte colonization and diversity in orchards is still limited. Four important factors deserving further study are tree age, bark type, fruit variety and management regime.

4.184 Further survey of lichens in orchards is needed as there is limited existing information. Research into the influence of orchard management on lichens, including pesticide spray regimes, is required. Further analysis of nutrient preferences of individual species would be helpful to understand the impact of different sources of nitrogen, including nitrogen from livestock within orchards and from surrounding land uses. Research on the effect of fruit type and variety on the character of lichen floras would be useful, as such differences may interact with impacts of nitrogen deposition.

4.185 More fungi and myxomycetes survey work is needed in orchards, given the sparseness of current information and the likely possibility of finding more species of special interest in traditional orchards. The effect of management on fungi and myxomycetes needs research, in particular the effect of management with fungicides and herbicides on non-target fungi in intensive orchards. A full literature review of existing information on this topic would be a useful first step.

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5 Orchards and resource protection

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Introduction

5.1 The way that orchards are managed has implications for the protection of air, water and soil resources. This chapter is limited to consideration of these natural resources rather than any wider range of such resources, which could include, for example, plant genetic resources. Climate regulation is covered in the first part of the chapter, with regard to long-term carbon storage by orchard habitats, carbon accumulation and net annual carbon sequestration in the orchards. Orchards may be carbon 'sinks', where carbon accumulated is greater than carbon emitted, or 'sources', where emissions outweigh carbon accumulation. The chapter does not cover direct climate regulation by the trees, such as shading and evaporative cooling. A short supplementary section covers an attempt at estimating carbon storage, and net annual carbon sequestration, by orchard hedgerows.

5.2 The second part of the chapter covers impacts of orchard management in relation to potential effects of diffuse pollution of adjacent habitats, both terrestrial and aquatic, and the impact of orchard management on soil quality.

Carbon storage and rate of accumulation by orchard habitats

Scope of the carbon storage and annual accumulation assessment

5.3 Two main elements make up the carbon storage assessment for the study orchards, the carbon stored in fruit trees and in the soil. Soil contains the largest stock of terrestrial organic carbon in the biosphere (Jobbágy and Jackson 2000). Assessment of the amount of carbon stored in orchard soils is therefore of major significance for estimating the contribution of orchards to carbon storage. The organic carbon in the soil derives from the remains of living organisms or material produced by them. Carbon is stored and accumulated in a relatively permanent form in the wood of living fruit trees in an orchard, thus the trees are another important part of the overall carbon storage capacity of an orchard. Data were available to assess carbon storage in all 7 of the study orchards but not carbon accumulation rates, for which detailed management information was required. This information was only available for the 6 main study orchards (see Chapter 3).

5.4 The carbon storage or stock types identified in the Inter-Governmental Panel on Climate Change (IPCC) methodology for carbon inventories of different land uses also includes dead wood and litter (Paustian and others 2006). Dead wood is wood which is either standing dead or lying dead on the ground, and is counted if over 10 cm in diameter. Litter is non-living biomass that is less than 10 cm diameter and can be found above or within the soil, though litter is larger than the size limit of soil organic matter of 2mm (Paustian and others 2006). Most of the study orchards did not have much dead wood, though there were some quite large pieces in Henhope Orchard and some piles of dead wood around the edges of Tidnor Wood Orchards. Half Hyde Orchard however, had a significant amount of dead wood, therefore an estimate of the carbon in dead wood is made for this orchard. The potential carbon stock in litter in the orchards has not been estimated as the grazing or mowing management of the orchard floor vegetation has limited litter accumulation.

5.5 Non-woody plants, such as the herbs and grasses on the orchard floors, and plants parts, such as the leaves of the fruit trees, contain an above-ground carbon stock but it is subject to rapid turnover as most of the above-ground plant parts die each year and then grow again the following year. The carbon stock above-ground in these non-woody elements is not included in the estimates made below. Scope for long-term accumulation of herbaceous biomass above ground in grazed or mown systems, such as the orchards, is limited. However, the potential of different vegetation types for adding to soil carbon through material originating from non-woody and woody plant parts is discussed in the section below on annual carbon accumulation rates.

5.6 Measurement of actual annual carbon accumulation rates in soil or fruit trees was beyond the scope of the project but rates have been chosen based on published rates for other sites, land uses or habitats, modified by information gained from the assessment of carbon storage in the orchards, their land use history and the age of the orchard trees. In addition, an indication of the potential of the hedgerows around the orchards to store and accumulate carbon is given, based on the existing literature. These estimates for annual carbon accumulation by orchards and hedgerows are then set against estimated emissions of greenhouse gases from orchard management to assess net carbon sequestration.

Soil carbon in orchards

5.7 The overall soil sampling method, analysis and results for the orchard soils are described in Chapter 2. The results quoted below are for the single soil sample from each orchard, each sample being made up of pooled sub-samples collected in the field. For the purposes of carbon calculations the significant data are the soil organic carbon amounts, expressed as percentages. Soil organic carbon is the type of soil carbon referred to throughout the chapter. Inorganic carbon in the form of compounds such as calcium carbonate is not included. Soil was sampled by David Marshall at two depths (0-15 cm and 15-30 cm) in each orchard. Carbon percentages in the top 30 cm of soil were calculated using the average of the carbon percentages at the two depths. For comparison purposes with other studies, the 0-15 cm depth samples were used to calculate carbon storage in this upper layer of soil in the orchards. When making these comparisons it should be noted that there was more soil carbon stored in this upper layer of 0-15 cm than in the 15-30 cm layer in all orchards except Romulus Orchard, although there was only a slight difference between carbon amounts in the two layers in this latter orchard.

5.8 To translate carbon percentages into carbon per unit volume of soil, measurement of soil bulk density is required (Emmett and others 2010). Funded by the project, Professor Douglas Godbold and Faisal Kahn, of Bangor University, measured soil bulk density, using bulk density rings, in each orchard in 2007. Their results are shown in Table 5.1. Using percentage of soil carbon and soil bulk density, the soil carbon in the top 30 cm and top 15 cm of soil across the whole area of each orchard and by hectare was then calculated, to the nearest metric tonne (Table 5.1).

Table 5.1 Soil carbon storage in the study orchards in the top 15 and 30 cm of soil

Site	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Site area (ha)	4.5	10.3	1.8	2.5	6.6	5.4	6.2
Soil C % 0-15 cm	3.07	2.49	2.49	3.83	1.39	2.15	1.80
Soil C % 15-30 cm	1.80	1.62	1.39	2.78	1.51	1.80	1.04
Average soil C % 0-30 cm	2.44	2.06	1.94	3.31	1.45	1.97	1.42
Soil bulk density g cm^{-3}	1.02	0.76	1.06	1.12	0.95	0.80	0.72
Total soil C tonnes (0-15cm)	212	293	71	161	131	139	120
Soil C tonnes / ha (0-15cm)	47	28	40	64	20	26	19
Total soil C tonnes (0-30cm)	335	484	111	278	273	256	190
Soil C tonnes / ha (0-30cm)	75	47	62	111	41	47	31

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.9 The size of each orchard obviously had a major effect on the total amount of carbon stored in the soil. The largest orchard, Tidnor Wood, had the biggest store of soil carbon, while Lady Close, the smallest orchard, had the smallest soil carbon store, both for the 0-30 cm layer and the upper 15 cm of the soil. Soil carbon per unit area was greatest among the traditional orchards, with the exception of Tidnor Wood, which had close to the amount of carbon in the soil in Salt Box Orchard, an intensive orchard.

5.10 The soil depths sampled in the orchards were unlikely to have included all the soil carbon, but probably included the major part of the total soil carbon. Jobbágy and Jackson (2000) report that in temperate deciduous forest, on average 73% of soil carbon occurs in the top 40 cm of soil, and 52% in the top 20 cm of soil. Cropland shows a similar pattern, with averages of 64% in the top 40 cm and 41% in the top 20 cm of soil.

5.11 Several factors, including temperature, rainfall and soil texture influence the amounts of carbon stored in soils (Jobbágy and Jackson 2000). The following comparisons with other habitats and land uses are therefore restricted to examples from places with temperate climates and, for specific UK sites, mineral soils. With regard to soil texture, sandy soils usually hold less soil carbon than clay soils. Clay helps to stabilize soil organic matter and maintains a higher level of organic carbon over time than sandy soils even under the same management regime (Johnston and others 2009). For example, the Defra report of project SP0523 (Defra 2003a) gives “typical” levels of soil carbon of 1.2% for sandy soils, 1.5% for silty soils and 1.8% for clay soils.

5.12 Soil textures in the study orchards were estimated by David Marshall for the 15-30 cm layer in each orchard. Applying the more general categorisation of texture in the Defra report (2003a) to the soil texture categories in Table 2.3, all sites except Village Plum would be classed as clay or deep silty soils, while Village Plum’s soil would be categorised as sandy. In line with the general difference in soil carbon with texture, Village Plum’s soil had the lowest carbon content in the 15-30 cm soil layer compared to the carbon content of this layer in the other orchards (Table 5.1). Land use history also has a major influence on carbon storage and accumulation and this aspect is discussed further in the section below on annual carbon accumulation rates.

5.13 The relative amounts of soil carbon stored by the orchards have been compared to soil carbon in other habitats and land uses to gain some idea of the relative value of the orchard soils as carbon stores. Reference sources with measured bulk densities, rather than modelled figures, have been preferred.

5.14 Soil carbon content per hectare of a range of habitats and land uses have been published by Countryside Survey (Emmett and others 2010). Comparison of orchard soils has been made with the Countryside Survey (CS) results for 2007. The CS report provides figures for soil carbon in tonnes / hectare (ha) in various broad habitats, but only for the top 15 cm of soil, not the 0-30 cm layer.

5.15 Arable and horticultural soils had the lowest average soil carbon content of all the habitats recorded by CS (46.9 tonnes carbon / ha). Most of the orchards had less carbon stored per hectare in the top 15 cm of soil than this average for arable and horticultural soils (Table 5.1). Henhope Orchard had about the same amount (47 tonnes carbon / ha) but only Half Hyde Orchard had a greater amount (64 tonnes carbon / ha). In Half Hyde Orchard the soil carbon amount was nearer to the average figures for improved grassland (64.6 tonnes carbon / ha) and broadleaved, mixed and yew woodland (68.8 tonnes of carbon / ha). Of course the CS averages for England were based on a wide range of soil types, including highly organic 'peatland' soils. For example, peat soils underlie arable land in the Fens of East Anglia and grazing marsh on the Somerset Levels.

5.16 Figures of soil carbon content per unit area for habitats at individual sites that are more comparable to the orchards are hard to find in the literature. Bulk density is not often measured and depths of sampling differ. Examples found of site-specific habitat figures are given below, with a crude 'pro rata' calculation of carbon content in the 15 cm layer, based on the average carbon content per one cm of depth. This calculation is likely to be an underestimate if soil carbon content declines with every centimetre of depth. Table 5.2 shows the figures published in the selected studies and the 15 cm 'adjusted' figures. All sites appear to be on mineral soils, like the orchards, rather than being on organic soils.

5.17 Poulton and others (2003) give the most comprehensive figures found for the UK. These figures come from the long term observations at Rothamsted Farm in Hertfordshire. The Farm is on silty clay loam soils overlying clay-with-flints. The information is available as time series for several habitats recorded over the period 1881-1999. These data are also useful in deciding appropriate carbon accumulation rates and are referred to again in that section of the chapter. None of the herbaceous or grassland habitat examples from Poulton and others (2003) had received nutrient inputs in the form of organic or inorganic fertilisers. Hopkins and others (2009) give further figures for Rothamsted, for an unfertilized permanent grassland and a grassland which receives inorganic nitrogen fertiliser. Patenhaude and others (2003) recorded soil carbon in Monks Wood, Cambridgeshire, UK, an ancient woodland on poorly drained soils overlying clay. Vande Walle and others (2001) studied ancient forest on loamy and clayey soils in Belgium. Monks Wood has records of its existence dating back at least 700 years (Hooper 1973), and the Belgian site has records dating back over 1,000 years (Vande Walle and others 2001).

Table 5.2 Soil carbon storage in different habitats at several sites in the UK and Belgium

Study	Depth of measurement (cm)	Carbon content (tonnes / ha)	'Adjusted' carbon content for 0-15 cm (tonnes / ha)
Rothamsted: arable[1] (Geescroft)	0-23	29	18.9
Rothamsted: arable[1] (Broadbalk)	0-23	26	17.0
Rothamsted: arable[1] (Broadbalk winter wheat) Base year	0-23	29	18.9
Rothamsted: arable[1] (Broadbalk winter wheat) after 11 years	0-23	32	20.9
Rothamsted: arable[1] (Broadbalk winter wheat) after 106 years	0-23	34	22.2
Rothamsted: scrub 21 years old[1] (Geescroft)	0-23	37	24.1
Rothamsted: scrub 23 years old[1] (Broadbalk)	0-23	38	24.8
Rothamsted: oak with ash woodland 82 years old[1] (Geescroft)	0-23	52	33.9
Rothamsted: oak with ash woodland 116 years old[1] (Geescroft)	0-23	63	41.1
Rothamsted: mixed deciduous woodland 83 years old[1] (Broadbalk)	0-23	67	43.7
Rothamsted: mixed deciduous woodland 118 years old[1] (Broadbalk)	0-23	78	50.9
Rothamsted: ungrazed herbaceous vegetation c. 60 years old[1] (Broadbalk)	0-23	69	45.0
Rothamsted: ungrazed herbaceous vegetation c. 100 years old[1] (Broadbalk)	0-23	82	53.5
Rothamsted: grazed herbaceous vegetation c. 40 years old[1] (Broadbalk)	0-23	72	47.0
Rothamsted: unfertilised permanent grassland c. 250 years old[2] (Park Grass)	0-23	89.4	58.3
Rothamsted: nitrogen-fertilised permanent grassland c. 250 years old[2] (Park Grass)	0-23	97.5	63.6
Monks Wood: mixed deciduous woodland[3]	0-50	335	100.5
Belgium: oak – beech forest[4]	0-15	76.7	76.7 (actual)
Belgium: ash forest[4]	0-15	74.1	74.1 (actual)

Notes: [1]Poulton and others 2003; [2]Hopkins and others 2009; [3]Patenhaude and others 2003; [4]Vande Walle and others 2001.

5.18 The published studies have soil carbon contents spanning those of the orchards, though the adjusted figures are approximate and are probably underestimates as noted above. Romulus and Village Plum are in the arable soil range, while Tidnor and Salt Box are close to the scrub soil carbon figures. Lady Close soil carbon is around that of regenerating oak-ash woodland after 116 years, while Henhope soil carbon falls between that of the 83 year-old regenerating mixed deciduous woodland and carbon amount in the soil of this woodland after 118 years. Henhope soil carbon content is also close to soil carbon amounts in ungrazed and grazed herbaceous vegetation of 40-60 years of age. These habitats had a history of scrub colonisation before scrub control or grazing management was imposed. Henhope soil has less carbon than the old permanent grassland of Park Grass, either fertilised or unfertilised grassland, or ungrazed vegetation of about 100 years of age. Half Hyde soil carbon exceeds figures for all the Rothamsted habitats except soil of fertilised permanent grassland, which it equals in soil carbon content. However, the orchard has lower soil carbon content than the ancient woodland or the ancient forest. The issue of the build-up of soil carbon over time in the orchards and the role of land use history is discussed further in the section below on annual soil carbon accumulation.

Carbon storage in fruit trees

5.19 The assessment of carbon stored in the fruit trees in each orchard makes use of the tree girth measurements made by Elizabeth Slingsby during the habitat survey (see Chapter 4). The approach chosen to calculating biomass (and thus carbon amounts) of the trees from girth measurements is to use allometric equations from the literature. These equations, also known as regression models, have been developed by measuring tree dimensions and destructively sampling the trees to measure the weights of trees associated with these dimensions (Jenkins and others 2003). Biomass dry weights are then converted to carbon amounts by applying a ratio derived from measuring carbon contents of biomass. The carbon content was not measured for orchard biomass, instead the figure used for this study was the ratio of 0.48, which is given by the IPCC for broad-leaved trees growing in temperate climates (Aalde and others 2006b).

5.20 Various published regression models were assessed to see how relevant they might be to apple and plum trees and how far they apply to trees of similar sizes to the orchard trees. Two models were considered possibilities, the equation for mixed deciduous trees sampled in Cumbria, UK, by Bunce (1968) and the equation for mixed hardwoods given by Jenkins and others (2003). These latter workers produced generalizations from a wide range of published equations for different groups of tree species found in the USA and included data from other continents. Tree species for which the mixed hardwoods equation was relevant were defined by Jenkins and others (2004) to include apple and plum species. Bunce (1968) sampled 5 broadleaved species but not apple and plum. Girths at 1.3 m trunk height in his sample ranged from 9 to163 cm. The minimum girth used by Jenkins and others (2003, 2004) was 8 cm and the maximum trunk diameter for mixed hardwoods at 1.3 m was 56 cm (equals176 cm girth). Trees in both studies come close to the maximum girth of the sampled orchard trees of 184 cm (see fruit tree data in Appendix 1). Two individuals in the total sample of 160 orchard trees exceeded both 163 and 176 cm girth, all the rest were smaller than 163 cm. Three individual orchard trees were smaller than 9 cm girth and two were smaller than 8 cm girth (both of these trees had girths of 6 cm). Use of either equation was deemed acceptable given the low numbers of trees outside the size range of trees from which the models were developed.

5.21 Tree height was not used in either candidate model as Jenkins and others (2003) and Bunce (1968) found it only made a marginal contribution to the predictive capacity of their models. Another factor weighing against use of tree height in orchards is that it can be very variable, and change suddenly due to management, for example the trees in Village Plum Orchard were pruned down considerably in 2008/09 (see Plate 2.14, Chapter 2). Tree girth is a more stable character, and it should reflect such effects to some extent, by the impact that such management has on tree growth and thus on the width of the annual rings in the trunk, and in consequence, on its girth. For the purposes of the orchard study, it is assumed that girth and biomass stay closely related even for pruned trees, though such trees might take more years to reach the size of un-pruned trees.

5.22 Both Bunce (1968) and Jenkins and others (2003) used the same logarithmic model to relate tree girth or diameter at breast height to biomass but expressed it in different ways and with different parameters as follows:

Regression equation	Definitions
Bunce (1968), mixed deciduous trees $\log_e y = a + b (\log_e x)$	y = tree dry weight, kg, (trunk + branches), x = tree girth at 1.3 m. a = -5.445, b = 2.507
Jenkins and others (2003) mixed hardwoods $bm = \mathrm{Exp}(\beta_0 + \beta_1 \ln dbh)$	*bm* = total aboveground biomass (kg dry weight) for trees 2.5 cm *dbh* and larger *dbh* = diameter breast height (1.3 m) Exp = exponential function ln = log base e (2.718282) β_0 = -2.48, β_1 = 2.4835

5.23 The literature was also searched for tree girth and tree weights for orchard species. A data set was found from a study of dessert apples in New York State, USA by Collison and Harlan (1930). The mean girths (from maximum and minimum girths) of trunks of 21 McIntosh apple trees in an orchard were measured and the trees then felled and weighed. The trees were 16 years old. Regression of these data produced the following values in the form of the logarithmic model of Bunce (1968): $\log_e y = a + b (\log_e x)$, where a = -5.48864, b = 2.51562. The range in girths was quite narrow, being 64 to 84 cms.

5.24 Poulton and others (2003) used Bunce's equation for the Rothamsted study of carbon stored in regenerating woodland. They used it for a wider range of species than Bunce did, and for some trees of larger girth. When compared with other equations from the literature they found little difference in the predictions. The same procedure was followed in the current study with the three equations selected and they also produced very similar results, suggesting the models are quite robust with respect to tree species and size. An example of the comparison of biomass predictions for each regression model is given below in Table 5.3. The McIntosh apple trees in the Collison and Harlan (1930) study were described as having a history of moderate pruning. This pruning did not seem to affect the relationship between biomass and girth when the results in Table 5.3 below were compared to relationship for the trees in the other equations. This finding supports the assumption about the effect of pruning on the relationship between tree girth and tree biomass made in para 5.21 above.

Table 5.3 Comparison of three equations for calculating tree above ground dry weights and carbon content of trees in Henhope Orchard

Regression equation	Jenkins and others (2003)	Bunce (1968)	Collison and Harlan (1930)
Average biomass per tree (n = 20), kg	417.1	411.4	410.8
Total carbon content for 352 trees (0.48 of biomass), tonnes	70.5	69.5	69.4

5.25 Based on these comparisons, the results for only one model (the Bunce model) for all the orchards are given in Table 5.4. The Bunce model was chosen for several reasons. It was developed from trees in the UK, whereas the more generalized model of Jenkins and others is based on trees from a wider geographic range. In addition, the Bunce model includes a wider range of girths than the more species-specific Collison and Harlan data. The Bunce model was also used by Poulton and others (2003) for their work at Rothamsted, which provides a useful comparative study of above ground carbon amounts in woodland. It should be noted that Bunce (1968) sampled trees in winter and early spring so the trees were unlikely to have had leaves at these times of year. Note also that the orchard trees sometimes forked below 1.3 m, so girths could not always be measured at this height. In these cases girth was instead measured immediately below the fork (see Chapter 4, habitat survey method).

5.26 Another element of the relatively permanent carbon store provided by the fruit trees are coarse roots. These are assumed to contain the same proportion (0.48) of carbon as above-ground biomass (IPCC figure from Aalde and others 2006b). As no destructive sampling was done in the orchards, the biomass of coarse roots was estimated from values in the literature for proportions of root biomass compared to above ground biomass of trees. Vande Walle and others (2001) give figures ranging from 16% to 17.6% of above ground biomass being root biomass for broadleaved trees in Belgium, while Patenaude and others (2003) quotes a figure of 28.5 % of above-ground biomass for roots of broadleaved trees in Monks Wood. However, a more conservative figure was used for the fruit trees because apple trees are reported to have sparse root systems (Jackson 2003). No information was found on plum stem and root proportions. The root proportion estimate for the fruit trees was assumed to be 14% and was taken from measurements made on Cox's Orange Pippin and Worcester Pearmain apple trees grown in an orchard in Kent for 18 years (Moore 1978). These trees were on semi-vigorous M7 rootstocks and had a light pruning regime. It should be recognised however that 'root to shoot' proportions can vary widely within species, for instance due to tree age and soil type (Moore 1978; Palmer 1988; Jackson 2003).

5.27 As mentioned above, most of the orchards did not contain much dead wood, though there are some quite large pieces in Henhope Orchard. Half Hyde Orchard however had a significant amount, as there were 42 standing dead trees and 20 fallen dead trees. According to the orchard owner, the trees died about 5 years ago after being damaged by sheep. An estimate of the carbon in these trees was made using a factor in a report by the United Nations (2008). This report includes ways of estimating carbon stocks in standing dead wood. Live above-ground biomass is multiplied by an appropriate factor, depending on decay state of the dead wood, to give dead wood biomass. The factor for the decay state of "small branches no longer present" is 0.9, and this was used for the fruit trees. This figure is quite conservative given the current relatively intact state of the trees (David Marshall pers. obs.). The average biomass of live trees in Half Hyde Orchard was multiplied by 0.9, and this average biomass per dead tree was multiplied by the number of dead standing and lying trees. This approach follows the finding of Mäkinen and others (2006) that lying dead wood did not lose mass faster than standing dead wood. Root biomass of dead trees was then calculated from the root /shoot proportion. The root proportion of 0.14 (14%) of shoot biomass (see paragraph 5.26 above) was used to estimate carbon in coarse roots of dead fruit trees. A carbon proportion of 0.5 of biomass was assumed. This follows the IPCC generic figure (Lasco and others 2006) and Mäkinen and others (2006). The latter authors found that the carbon proportion in dead wood was around 0.5 irrespective of decay state. The carbon stored in each orchard above and below ground in fruit trees, including dead trees in Half Hyde Orchard, is given in Table 5.4.

Table 5.4 Carbon storage in fruit trees in each orchard, including dead trees at Half Hyde Orchard

Site	Henhope (T)	Tidnor* (T)	Lady Close** (T)	Half Hyde† (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Site area (ha)	4.5	10.3	1.8	2.5	6.6	5.4	6.2
Tree numbers	352	2480	100	187	4407	2966	4073
Tree density / ha	78.2	240.8	55.6	74.8	667.7	549.3	656.9
Total carbon above-ground, tonnes	69.5	299.8 (298.9 + 0.9)	13.5 (13.1 + 0.4)	57.5 (39.3, live + 18.3, dead)	111.4	65.7	100.2
Total coarse root carbon, tonnes	9.7	42.0 (41.8 + 0.1)	1.9 (1.8 + 0.1)	8.0 (5.5, live + 2.5, dead)	15.6	9.2	14.0
Total fruit tree carbon, tonnes	79.2	341.8 (340.7 + 1.1)	15.5 (14.9 + 0.5)	65.5 (44.8, live + 20.7, dead)	127.0	74.9	114.2
Above-ground carbon, tonnes / ha	15.5	29.1	7.5	23.0 (15.7, live + 7.3, dead)	16.9	12.2	16.2
Coarse root carbon, tonnes / ha	2.2	4.1	1.1	3.2 (2.2, live + 1.0, dead)	2.4	1.7	2.3
Fruit tree carbon, tonnes / ha	17.6	33.2	8.6	26.2 (17.9, live + 8.3, dead)	19.2	13.9	18.4

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Numbers displayed have been rounded to one decimal place.

Sample sub-totals shown in brackets for some totals: *Tidnor Orchards, two samples of 20 trees each, one sample from the mature orchards (1960 trees), trees about 40-60 years old, one sample from Museum Orchard (520 trees), with young trees less than 5 years old, **Lady Close Orchard, two samples of 10 trees each, one sample from old trees about 80-100 years old (30 trees in total), one sample of 10 trees from young trees about 7 years old (70 trees in total).
†Half Hyde Orchard total number of trees is 187, comprising125 live + 62 dead trees (42 dead standing + 20 dead fallen).

5.28 Tidnor Wood Orchards, the largest orchard, had the greatest carbon amount stored in fruit trees, both overall and per hectare, while the smallest orchard, Lady Close Orchard, had the lowest total and per hectare amounts. Amounts per unit area were influenced by tree size / age and density of planting. The bulk of the trees in Tidnor Wood Orchards were mature, in contrast to the predominantly young trees in Lady Close Orchard. Planting distances in Lady Close Orchard was also the greatest among the orchards (Table 2.5, Chapter 2). Although Tidnor was densely planted compared to the other traditional orchards (Table 2.5), the intensive orchards were much more densely planted than the traditional orchards (Table 2.5). The trees in these orchards were relatively young compared to the trees in Tidnor or the sparser trees in Henhope Orchard, but the carbon per hectare was comparable to Henhope Orchard, particularly for Romulus Orchard and Village Plum Orchard. Half Hyde Orchard had a similar density of trees to Henhope, but the trees were on average larger and so stored more carbon per hectare than trees in Henhope Orchard. Half Hyde also stored more carbon in trees per hectare than the amounts in the intensive orchards, even though density of the trees was much less than in these orchards. However, it should be noted that part of the carbon stock in trees in Half Hyde Orchard was in dead trees, which would decay and reduce the carbon stock over time, even if they were allowed to remain on the site rather than being removed.

5.29 In comparison to above ground storage of carbon in other habitats, the orchard trees clearly have greater stores than herbaceous vegetation types. For instance, the Defra (2007a) report on project BD2302 quotes figures of 1.6 tonnes of carbon / ha for heavily grazed grassland and 2.4 tonnes / ha for less intensively grazed grassland. The fruit trees also have the capacity to increase stores through growth of woody tissue whereas the scope for relatively permanent accumulations in above-ground perennial herbaceous vegetation are limited in grazed or mown situations, as is the case in the study orchards.

5.30 The relative amounts of carbon stored in the orchard trees are lower than general published figures for carbon storage in woodlands. The IPCC 'global' figures for above-ground carbon range from 20 tonnes / ha for young forests to 120 tonnes / ha for older forests (Aalde and others 2006b). Only Tidnor and Half Hyde reach even the young forest figure for above-ground carbon per hectare. For the UK, Cannell (1999) gives figures of 62 tonnes / ha for broadleaved trees and 21 tonnes / ha for conifers – at the current age of plantings. Amounts will rise on maturity, for example Scots pine in Breckland had reached 59 tonnes / ha after 35 years (Cannell 1999). Milne and Brown (1997) list estimates of above-ground carbon / ha for a range of tree species, at different tree age spans, for trees grown in commercial woodlands in the UK. For instance, an average for broadleaves is 5.7 tonnes / ha at age 0-10 years, 12.9 tonne / ha for ages 10-20 years, 52.9 tonnes / ha for ages 40-50, 68.5 tonnes / ha for ages 60-70 and 98.9 tonnes / ha for trees over 120 years old. However, the intensive orchard trees actually compare quite well with broadleaves of similar ages, as their carbon content per hectare (Table 5.4), at the planting densities obtaining in these orchards, exceeds most broadleaved species in the relevant age span. For example, trees in Salt Box Orchard were 10 years old when recorded and have a greater carbon amount / ha than the broadleaved species in age span 0-10 and greater than that for 4 out of 6 single species or species groups in age span 10-20 years (Milne and Brown 1997). This superiority might be expected, as one of the goals of intensive orchard production is quick growth and early cropping of trees. However, the mature trees in the traditional orchards have much lower carbon content / ha than the broadleaved species of similar ages described above (Table 5.4). This is not surprising, as the natural stature of the fruit trees is so much smaller than that of forest trees of equivalent age in commercial woodlands, and the planting density is likely to be greater in these woodlands.

5.31 In terms of carbon estimates for specific sites, Patenaude and others (2003) gave a figure of above-ground carbon in understorey and canopy woody species in Monks Wood of 97 tonnes / ha, while in Belgium, Vande Walle and others (2001) recorded 123.6 tonnes / ha for oak – beech forest and 118.1 tonnes / ha for ash forest, all contained in above-ground woody plants parts. Poulton and others (2003) estimated even larger amounts in regenerating woodland at Rothamsted (using the Bunce regression model). Mixed deciduous woodland after 120 years had 256.8 tonnes of carbon / ha, and oak with ash woodland of 118 years of age had 142.08 tonnes / ha. Tree density in both cases exceeded that of all the orchards, being 1,712 stems / ha for the mixed woodland and 1,985 stems / ha for the oak with ash woodland.

5.32 Three estimates of carbon storage were found for trees in more open situations, which are more akin to orchard conditions. Cannell (1999) provides figures for 'free growth' of 3 species, with canopy cover of around 60%. Estimates of carbon amounts per hectare were calculated from Cannell's data and are given in Table 5.5.

Table 5.5 Carbon amounts in broadleaved trees grown in open conditions from Cannell (1999)

	Wild cherry	Oak	Poplar
Age of trees (years)	45	100	25
Carbon (tonnes) in above-ground wood per tree	1.08	2.0	0.46
Density of trees / ha	92	63	156
Total above-ground carbon tonnes / ha	99.4	126	71.8

5.33 Oak and poplar grown under these conditions had more carbon / ha than trees of these species of similar ages but grown in commercial woodlands. Oak and poplar in woodlands store 90.1 tonnes / ha and 43.2 tonnes / ha respectively (Milne and Brown 1997). 'Free growth' wild cherry had a greater amount of carbon / ha that the average of the woodland broadleaves of similar age (52.9 tonnes / ha) given by Milne and Brown (1997). Another land use similar to orchards is agroforestry, where timber trees are grown in combination with crops or grassland. Schroeder (1993) reported an average of 63 tonnes of above-ground carbon / ha for agroforestry land use in temperate climates, considerably more than the carbon amounts per hectare in the orchard trees. In agroforestry the trees are usually quick-growing species, such as poplar, which are likely to reach larger sizes than orchard trees. Thus orchards compare less favourably with trees grown in other open situations than with trees in woodlands.

Relative carbon storage in soils and fruit trees in the orchards

5.34 The relative proportions of carbon in soil and in the fruit trees are shown in Table 5.6, to indicate whether soil or trees are more significant. Sometimes in woodlands a greater proportion of carbon is held above-ground in trees than in the soil, as at Rothamsted in the regenerating woodlands (Poulton and others 2003). In Monks Wood in contrast, when considering the 0-50 cm soil layer, soil carbon greatly exceeds carbon in trees. When the ‘adjusted’ figure for 0-15 cm soil layer only is used, the carbon amount in trees plus roots is similar to soil carbon amount (Table 5.2 above and Patenaude and others (2003)).

Table 5.6 Relative proportions (%) of total stored carbon stored in soil and fruit trees in the orchards

Site	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Soil carbon (0-30cm) %	80.9	58.6	87.8	80.9	68.2	77.3	62.5
Fruit tree carbon %	19.1	41.4	12.2	19.1	31.8	22.7	37.5

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.35 The soil carbon stored in the orchards always exceeded the carbon amounts in the fruit trees. Tidnor Wood Orchards had the largest proportion of carbon in the trees compared to the soil and the next highest proportions were in the three intensive orchards. The relative importance of soil storage versus storage in trees may reflect the impact of different land use histories, which are discussed further in the section below on carbon accumulation rates.

Carbon accumulation rates in soils and fruit trees

Approach to estimation of accumulation rates

5.36 Measurement of annual carbon accumulation rates was beyond the resources of the project and indeed seems to have been rarely attempted in a comprehensive way for orchards elsewhere, or for other habitats. However, some estimates of carbon accumulation rates have been made below, from information collected for the study sites on land use history and orchard management, from the data on carbon storage above and below ground, and from assumptions based on the literature. Total carbon accumulation rates depend on the complex, dynamic, relationships between different temporary or semi-permanent organic carbon pools. Photosynthetic carbon capture from the atmosphere is followed by carbon being moved into different plant parts, which in turn contribute to soil carbon pools. Managed habitats are not closed systems so there is an added dimension of carbon being removed from the habitat through human activity. Estimates of rates are made below for the main accumulation locations and an indication given of the likely significance of human activity on orchard carbon accumulation rates.

Soil carbon accumulation rates

5.37 The organic carbon stored in the soil results from the accumulation of the decaying remains of once-living material or organic material produced by living organisms. Long-term studies of mineral soils in temperate climates suggest that for tens or hundreds of years, the pace of accumulation can exceed decomposition, resulting in a continuous increase in organic carbon in the soil (Harrison and others 1995, Poulton and others 2003). The ‘turnover time’ between input to the soil and the complete decay of different kinds of organic carbon varies from months to thousands of years, and turnover time may increase with soil depth in temperate areas (Dawson and Smith 2006, Trumbore 2000). The longevity of some soil carbon fractions is illustrated by soils under arable land at Rothamsted. The 0-23 cm soil layer was found to contain organic matter with a measured radiocarbon age of 1,330 years, suggesting that a proportion of organic matter in soils is extremely resistant to decomposition (Jenkinson 1990). However, in a particular habitat, an overall equilibrium level seems to become established after a time, whereby accumulation and decomposition rates are more or less evenly matched (Hopkins and others 2009, Johnston and others 2009).

5.38 Land use history plays an important role in the soil carbon levels of the current era (Dawson and Smith 2006, Smith 2005). Soil disturbance and clearance of vegetation rapidly lower soil carbon, for example clearance of woodland followed by cultivation for arable crops (Thomson 2008). Change from grassland dominated by perennial herbaceous plants to arable crops also lowers soil carbon levels (Johnston and others 2009). If the woodland and grassland are re-established, soil carbon increases again towards the former equilibrium (Conant and others 2001, McLauchlan and others 2006, Thomson 2008). Thus orchards which are on sites that have been disturbed in the relatively recent past would be likely to be accumulating carbon, whereas the soil carbon of old orchards on undisturbed ground may be at equilibrium. This is the assumption made for the study sites with respect to the ground vegetation, ie not including the fruit trees. In consequence, sites with a history of disturbance have been assigned a soil carbon accumulation rate appropriate for conversion of arable to grassland. This rate is applicable to the contribution to soil carbon accumulation from ground vegetation in the orchards. Input from trees is discussed later. The rate for input from ground vegetation in the orchards was based on adjustments of two measurements made in the Rothamsted work at the Broadbalk site. Figures were derived from ‘adjusted’ amounts of soil carbon in the top 30 cm of soil. These estimates were calculated by taking the amount recorded in the 0-23 cm layer and adding the average amount per cm of the 24-69 cm layer for an additional 7 cm. The two estimates used were the original soil carbon content of arable land (31.02 tonnes / ha in the top 30 cm of soil) and the soil carbon content of grazed, permanent, herbaceous vegetation (78.24 tonnes / ha in the top 30 cm of soil) measured 118 years later (Poulton and others, 2003, Table 5.2). The yearly rate of soil carbon accumulation over the period of change was calculated to be 0.4 tonnes of carbon per hectare per year.

5.39 Table 5.7 summarises the known land use history of each of the six main study orchards based on information provided by orchard owners. Further detail is given in Chapter 2. Three sites, Henhope, Lady Close and Half Hyde, appear to have been grassland for at least 50 years and so the soil carbon levels were regarded as in equilibrium. This is a conservative, low, estimate of time taken to reach equilibrium, based on literature that suggests that carbon is gained relatively quickly by grasslands after a disturbance of the soil (Conant and others 2001, McLauchlan and others 2006). The disturbance caused by re-seeding part of Half Hyde Orchard in the 1970s has been ignored. These sites also have the highest soil carbon storage amounts, which could support the view that these sites have not been disturbed for some time. Two of the other orchards, Tidnor and Salt Box, seem to be clearly in the category of sites accumulating soil carbon. Both sites have soil carbon storage amounts per hectare similar to levels seen elsewhere in scrub developed on arable soils (see paragraph 5.18 above). Tidnor Wood Orchards have been subject to disturbance, in part because of woodland clearance, followed by removal and re-planting of the orchard that occupied the former woodland area, and partly through past arable cultivation. Salt Box was in arable cultivation before the orchard was planted. The possible degree of disturbance at Village Plum Orchard in the past is less certain. New trees were planted on land that was previously part pasture and part orchard about 40 years ago. Most of the current orchard trees are replacements for these trees present four decades ago, although part of the orchard was more recently planted into grassland. The soil carbon storage per hectare amount is the lowest of all the sites, probably partly due to the sandy character of the soils. However, disturbance associated with orchard planting and re-planting is also a possible cause. Grubbing out of trees causes soil disturbance and preparation for new planting can include ploughing (D. Marshall pers. obs.). The site has been assumed to have suffered some disturbance and has been placed in the category of sites accumulating soil carbon. Although Romulus Orchard was not included in the carbon accumulation study, its soil carbon storage amount fits the pattern of recent disturbance and low soil carbon. Romulus was in arable cultivation before the fruit trees were planted in 1994 and had soil carbon amounts similar to the other orchards with a history of disturbance, see Table 5.1. This low amount of soil carbon contrasts with soil carbon in Half Hyde Orchard, which was adjacent to Romulus Orchard, but which had a higher amount of soil carbon and had been subject to less soil disturbance.

5.40 In the intensive orchards, another factor has to be considered in deciding the potential for soil carbon accumulation from ground vegetation. The ground along the tree rows was regularly sprayed with herbicide to keep it clear of herbaceous vegetation, because this could compete with the trees (Robinson 1975). Studies have shown that herbicide use along tree rows lowered soil organic matter in the tree rows compared to levels under the grass alleys between tree rows, but not as much as cultivation along tree rows (Merwin and others 1994, Robinson 1975). The closest analogy to the tree row soils might be ‘zero tillage’ arable soils. Under this management, the soil is not ploughed but instead weeds are controlled with herbicide (Derksen 2002). Such management might be expected to increase soil carbon levels compared to ploughed arable soils. However, a recent review found mixed results for carbon accumulation due to zero tillage, the overall difference from several studies combined was not significantly different to zero carbon accumulation (Bohgal and others 2007). Thus the assumption is made for the orchard study that the sprayed tree rows do not accumulate carbon. In fact, this assumption can be set against a background of falling levels of soil carbon in arable soils in Great Britain (Emmett and others 2010) so actually the assumption of zero accumulation in tree rows could be seen as having a ‘neutral’ effect rather than a negative effect compared to management by cultivation.

5.41 The area sprayed with herbicide at Salt Box and Village Plum orchards is regarded by orchard managers as 33% of the area covered by trees (“tree acres”). The tree-covered area is smaller than the site area, being 5.06 ha and 4.98 ha for Salt Box and Village Plum respectively. The actual sprayed area may vary through time, depending on the vigour of weed control, for instance compare Plates 2.12 (Salt Box) and 2.14 (Village Plum), in Chapter 2, taken in 2009. In these two sites the trees in the rows are about the same distance apart but when the photographs were taken the sprayed zones differed in width. For simplicity, the assumption was made that the sprayed area was 33% of the “tree acres”, meaning that the area accumulating carbon was reduced by this amount.

5.42 Tidnor used to be managed intensively according to the current owner and aerial photographs taken in 1999 show clear evidence of bare ground along the tree rows. However, by the time the project was carried out, the site was fully grassed and managed as a traditional orchard, so no reduction of soil carbon accumulation by ground vegetation due to tree row management has been made. Reduced carbon accumulation by soil in the tree rows may have influenced the soil carbon storage levels at Tidnor, Salt Box and Village Plum orchards, which were lower than in the other orchards (Table 5.1).

5.43 The results for the estimation of annual accumulation rates of soil carbon from ground vegetation in the different orchards are given in Table 5.7. The assumption that soil in traditional orchards was at equilibrium with respect to their grassland vegetation means that only the intensive orchards, and the previously intensively-managed Tidnor Orchards, which all have undergone recent disturbance, contribute to soil carbon via the ground vegetation. The drawback of including current soil accumulation rates only from sites which have recently been disturbed is that it under-values past accumulation in sites where an equilibrium in soil carbon levels has been reached. The continued existence of traditional orchards like Half Hyde Orchard ‘protects’ that past build-up of carbon ‘capital’. Study of soil accumulation in orchards over longer time spans would give a more balanced picture of overall soil carbon accumulation during the lifetime of the orchard.

5.44 The presence of trees as well as grassland in orchards adds another component to carbon input to soil, and here the assumption is made that orchard trees are contributing to carbon accumulation in the soil through leaf fall and root turnover, as is the case in forests (Cannell and Milne 1995). Carbon in coarse roots is treated as part of the above-ground estimation of carbon accumulation in trees explained below. The contribution by fine roots to orchard soil carbon is unknown and has not been estimated. Root turnover is difficult to study and no suitable analogs could be found. An attempt to indicate soil carbon from leaf fall is made below, but only for leaf biomass estimated for the trees of the age they had reached at the time of the project. This amount was not averaged through time for the period since trees were planted, given the uncertainties surrounding even estimating a ‘snapshot’ of carbon accumulation due to leaf fall.

5.45 The assumption was made that accumulation of carbon in soil through leaf inputs from fruit trees was not in equilibrium with decay rates, but was still greater than decay rates, at least in the short term. This assumption was based on the ages of the trees in the orchards. There were considerable numbers of young trees in most orchards (Table 4.6, Chapter 4). These trees will increase their leaf input as they grow larger. In Henhope and Half Hyde orchards, where young trees were less abundant, there had been some relaxation of pruning, thus allowing trees to increase in size and leaf input to the soil. A biomass estimate for leaves of 2% of average tree weight was made based on the average of figures for leaf biomass for different tree species given in Vande Walle and others (2001) and Patenaude and others (2003). The regression model used to calculate orchard tree weight was based on trees without leaves (Bunce 1968), therefore the average tree weight predicted by this model was regarded as 98% of the total tree weight, with leaves making up the remaining 2%.

5.46 The total biomass of fallen leaves will not reach the relatively stable soil carbon pool, some part will rapidly decay on the ground surface, and some proportion will be present in short-term carbon pools such as litter. Other workers have given estimates of the proportion of leaf biomass from herbaceous and woody plants that reaches the long-term soil carbon pool (Andrén and Kätterer 1997, Hirsch and others 2004, Huggins and others 1998). This proportion is known as the humification coefficient. A rate of 0.2 has been chosen as the most appropriate from the literature. It is the rate used for leaves of peach and olive in orchards and for holm oak leaves (Reichstein and others 2002, Sofo and others 2005). For the orchards, this rate is applied to leaf biomass and the resulting amounts are treated as the positive accumulation rate of soil carbon due to leaf input (Table 5.7). However, the amounts of soil carbon accumulated in the project year from leaves were small. Only in Tidnor Orchards, with their high tree numbers and half-standard trees, did leaves contribute more than one tonne of carbon to the soil per year.

Table 5.7 Estimates of annual soil carbon accumulation rates in the orchards

	Henhope (T)	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Site area ha	4.5	10.3	1.8	2.5	5.4	6.2
History of land use	Grassland prior to orchard. Traditional orchard trees & grassland for c. 60 years	Part woodland, part parkland (grassland with trees) c. 40 years ago. Intensive orchard with arable then grass between trees for c. 40 years	Orchard for at least 150 years with grassland probable. For some time in recent decades, only a few trees remained in grassland before orchard restoration in 2000	Half of site had orchard trees and grass for c. 45-50 years, half re-seeded grassland around existing orchard trees c. 30 years ago	Grassland then arable prior to intensive orchard of 10 years age	Main part intensive orchard for c. 40 years, part grassland 6 years ago prior to intensive orchard
Tree row ground management	None	None (but cleared in past)	None	None	Cleared with herbicide	Cleared with herbicide
Area of bare ground in tree rows ha	0	0	0	0	1.69	1.67
Rate of soil carbon accumulation for conversion from arable to grassland, tonnes / year	0	4.12	0	0	1.48*	1.81*
Rate of soil carbon accumulation for conversion from arable to grassland tonnes / ha / year	0	0.4	0	0	0.275*	0.292*
Total carbon from leaves reaching stable soil carbon pool in project year, tonnes / year	0.284	1.224	0.055	0.160	0.268	0.409
Total carbon from leaves reaching stable soil carbon pool in project year, tonnes / ha / year	0.063	0.119	0.031	0.064	0.050	0.066
Total carbon accumulation from soil + leaves in project year, tonnes / year	0.284	5.344	0.055	0.160	1.752	2.221
Total carbon accumulation from soil + leaves in project year, tonnes / ha / year	0.063	0.519	0.031	0.064	0.324	0.358

Notes: * rate reduced due to herbicide management of tree rows. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Carbon accumulation rates of fruit trees

5.47 The approach taken to estimating annual accumulation of carbon by growth of the fruit trees in each orchard had to rely on averaging the carbon stored in fruit trees to date, as no measurements of annual increases in carbon accumulated by the trees were done. The choice of period over which to average the carbon stored per year has been conservative in that the storage amount has been divided by the period to which the oldest age class of trees belonged. Where two age classes were separately recorded, as at Tidnor and Lady Close, these periods have been used to calculate the relevant amounts of carbon accumulated per year. The two results for each age group in these orchards were then added to give one total for the site as a whole. Only live trees are included in the assessment, the dead trees in Half Hyde Orchard are excluded. For simplicity, in all orchards the small amount of biomass accumulated by trees when in the tree nursery, before they were planted out, is included in the average accumulation rate but the unknown period of time in the nursery is not included in the length of lifetime used to calculate amount of carbon stored per year.

5.48 The method used to estimate carbon accumulation has the drawback that it averages carbon accumulation per year rather than reflecting rates of carbon accumulation in any particular year. Trees do show changing patterns of growth through time, with maximum growth in early to middle age and a slowing of growth as the trees become senescent (White 1998). Thus the results are not representative of accumulation in a particular year, unlike the estimation of greenhouse gas emissions due to management (see below). However, management has to be carried out in most years and in terms of emissions might often produce similar amounts of emissions irrespective of the age of the trees, for example through the regular grazing of livestock or the spraying of tree rows. The other issues related to using averages are that no losses due to tree mortality are factored in, nor are replacements by younger trees. The decision to use the age of the oldest age class will lead to an underestimate in yearly accumulation of carbon because some trees will be younger than this age.

5.49 The estimates of carbon accumulation rates are given in Table 5.8 below. The orchards with the largest numbers of trees, Salt Box, Village Plum and Tidnor, have the largest accumulation rates. On a per hectare basis, Salt Box has the greatest accumulation rate, followed by the other intensively managed orchard, Village Plum. Salt Box has a lower tree density than Village Plum, but the trees in Salt Box were mostly younger, which could explain why the overall carbon accumulation rate was greater.

5.50 The age that the trees had reached when girth measurements were made does seem likely to affect the average carbon accumulation rate across the period up to the date of the measurements. If a tree is young it is likely to have a high average accumulation rate, while over a longer period average rates might fall as the tree's growth slows down with increasing age and the onset of senescence. To gain a rough indication of what accumulation rates might be across the whole lifetime of the trees, a set of estimates has been made based on the maximum likely ages the trees might reach. These life-spans were based on views of the orchard managers as to the likely lifetime of their orchards before removal as a consequence of falling production. Orchards of those approximate ages within the data set have then been used to estimate relevant average accumulation rates of the younger tree populations in the other orchards.

5.51 The old trees in Lady Close Orchard are about 100 years old and have been used to estimate life-span carbon rates per tree per year for the other traditional orchards, Henhope, Tidnor and Half Hyde and for the full tree population at Lady Close. The trees in these orchards have been assumed likely to last for 100 years and have the same average carbon accumulation rate per tree per year as the 100 year old trees at Lady Close Orchard. The mature trees at Tidnor provided the estimate for Salt Box, as Tidnor was a previously intensively managed orchard and had reached about 40 years of age. This is somewhat above the age of 30 years which is around the age that orchard owner thought that the trees in Salt Box orchard might reach at the end of their life span. However, the owner noted that productive trees could potentially reach 40 years of age, based on observations of a similar orchard nearby. The trees at Village Plum Orchard were regarded by the owner as largely at the end of their lives so the amount for the average carbon accumulation for the period to date has been used again to represent the amount accumulated over the lifetime of the trees. Rates of carbon accumulation per tree from the model orchards have been multiplied by number of trees in each orchard to give predicted totals for each orchard. The results are shown in Table 5.8. Salt Box would still have the greatest accumulation rate on this basis, suggesting that apple trees would be capable of accumulating more carbon than plum per year across the whole life-span of the trees, probably because apple trees are capable of growing larger than plum. These estimates are very rough but serve to indicate that over a life-span of an orchard, carbon accumulation rate could be different to that of a period up to the present, and should be taken into account in any further work examining carbon accumulation versus carbon expenditure in orchard habitats.

Table 5.8 Estimates of annual carbon accumulation rates of fruit trees in each orchard

	Henhope (T)	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Number of trees. Two numbers are given for sites where age classes were recorded separately	352	1960 & 520	30 & 70	125 (live only)	2966	4073
Density of trees per hectare	78.2	240.8	55.6	74.8	549.3	656.9
Period in years of lifetime to date* used to average carbon storage per year. Two periods are given for sites where age classes were recorded separately	70	48 & 5	100 & 8	50	11	21
Rate of carbon accumulation including coarse roots, per tree, across lifetime of tree to date, kg / year	3.22	3.62 (old) 0.41 (young)	4.98 (old) 0.86 (young)	7.16	2.29	1.34
Possible rate of carbon accumulation, including coarse roots, per tree, across whole lifetime of tree, kg / year	4.98	4.98	4.98	4.98	3.62	1.34
Rate of carbon accumulation, including coarse roots across lifetime of trees to date, tonnes / year	1.132	7.310	0.210	0.895	6.806	5.439
Possible rate of carbon accumulation, including coarse roots, across whole lifetime of trees, tonnes / year	1.751	12.340	0.498	0.622	10.741	5.439
Rate of carbon accumulation, including coarse roots across lifetime of trees to date, tonnes / ha / year	0.252	0.710	0.116	0.358	1.260	0.877
Possible rate of carbon accumulation, including coarse roots, across whole lifetime of trees, tonnes / ha / year	0.389	1.198	0.276	0.249	1.989	0.877

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details. *lifetime to date is time since planting, up to and including 2007.

5.52 Compared to estimates made by other workers for different tree species, the orchard trees accumulate low amounts of carbon per year. Nowack (1994) found accumulation rates of 1 kg carbon / tree / year to 93 kg carbon / tree / year for open grown urban trees of various sizes. Cannell (1999) gives figures of 34 kg carbon / tree / year for open grown wild cherry over 45 years and 29 kg carbon / tree / year for open grown oak over 100 years. Compared to figures for urban trees of different ages and growth rates given by the US Department of Energy (1998), rates for the orchard trees would be equivalent to carbon accumulation rates of trees in the 10 year old age class (slow 2.49 kg / year, fast 8.75 kg / year) and sometimes just equivalent to trees in the 20 year old age class (slow 4.9 kg / year, fast 18.6 kg / year). On a per hectare basis, where tree density is a factor, the orchard trees mostly have lower rates than examples given by Cannell (1999). The average carbon accumulation rate for open-grown poplar across 25 years was 4 tonnes / ha /year, while open-grown oak trees across 100 years accumulated on average 1.8 tonnes / ha / year. Accumulation by trees in Salt Box Orchard is similar to latter figure, for the whole estimated lifespan of the trees, but the accumulation rates of trees in the other orchards are well below these rates. Size of tree attained through time and potentially lower natural growth rates are not the only factors that may be involved in producing these lower rates for orchard trees. Two important management activities, pruning and fruit harvesting, could play a role and are discussed in the next section.

Carbon exports: prunings and fruit

5.53 Orchards are designed to produce heavy yields of fruit and are pruned to enhance fruit production. Pruning has a dwarfing effect on trees (Ferree and Schup 2003, Miller and Twerkoski 2003) and prunings are usually removed from orchards. Carbon allocated by each tree to fruit is removed each harvest time. To get some idea of the magnitude of these potential carbon exports, information from orchard managers on the scale of pruning and the fate of prunings was collected, along with fruit yields at the time of the project. No pruning had been done recently at Lady Close or Half Hyde, although Half Hyde had been pruned a few years previously. It is likely that Lady Close had been pruned at some time in the past. However, the lack of recent pruning caused these two sites to be excluded from the calculations. Weights of prunings were not measured so a proportion of the tree biomass that was assumed to be pruned was taken from data in the orchard study by Moore (1978). This study also provided the root / shoot proportion of biomass used in paragraph 5.26 for total biomass estimation. The annual dry weight of prunings per tree of the orchard apple trees used in the study (Worcester Pearmain and Cox's Orange Pippin) was on average 31% of the annual accumulation of the combined dry weight of tree roots, branches and trunk. The amounts of pruning in the Herefordshire orchards was estimated using this assumption but were adjusted to take account of the proportion of trees actually pruned each year in each orchard (Table 5.9).

5.54 The estimates of total carbon and carbon per hectare that could reach the stable soil carbon pool, if prunings were not burnt, are shown in Table 5.9. In a similar way as amounts of carbon reaching the long term soil pool from leaves were calculated (paragraph 5.46), the amount of soil carbon that might arise from prunings left on the ground was estimated but with a humification coefficient of 0.35, taken from the peach and olive orchard study by Sofo and others (2005). These estimates only apply to the time of the project and so any net accumulation in the soil may only be short-term. Some mulching of chipped prunings has been done at Village Plum Orchard. Mulching of prunings could add a modicum of carbon to the stable soil carbon pool in all orchards if this disposal method was widely used (Table 5.9). The potential for soil carbon accumulation from pruning material left on the ground has not been included in the overall carbon accumulation estimates for the orchards, which are compared below to carbon in emissions from the orchards. Some estimates of potential greenhouse gas emissions from the burning of prunings have been made in the emissions section below. However, these estimates have not been included in calculations of net carbon sequestration by the orchards.

5.55 Carbon allocated to fruit by the trees was removed from all the orchards except Lady Close, where fruit was left un-harvested at the time of the project, although fruit would very probably been collected in the past. Estimation of carbon in fruit from yield data for the time of the current project at Lady Close was therefore not possible. Carbon content of fruit was not measured so estimates from the literature were used. Averages for dry matter content of apples and plums was taken from several sources (apple: Salunkhe and Kadan 1995, Campeanu and others 2009; plum: Walkowiak – Tomczak and others 2008, Vitanova and others 2004). Dry matter content was less than 20% for both fruits and in the case of plum appeared to be for the flesh only without the plum stone. A standard 50% of the dry matter was assumed to be carbon in the absence of any information from the literature. The overall estimate for carbon in plums was modified to take account of plum stones. Plum stones are quite woody so figures in the reference sources for weight of plum stones compared to whole fruit were used and converted to dry matter by assuming 50% of the stone was dry matter (following the assumption for woody material in Moore 1978) and 50% of this dry matter was assumed to be carbon. The results for carbon exported in fruit are given in Table 5.9. The amounts of carbon in fruit have not been included either in overall estimates of annual carbon accumulation by the orchards when these are compared to carbon emissions from orchards, or in emissions estimates. This approach follows the IPCC's treatment of annual crops (Lasco and others 2006).

Table 5.9 Estimates of carbon in annual prunings and the fruit crop for the orchards at the time of the project

Estimates for time of project	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Proportion of trees pruned per year (total number of trees in orchard)	10% (352)	20% (2480)	0% (100)	0% (125 live trees)	50% (2966)	100% (4073)
Treatment of prunings and dead wood	Fuel + burnt + retained	Fuel + burnt + retained	None	None	Burnt	Burnt + mulched
Total weight of carbon in prunings of the proportion of trees pruned, tonnes / year	0.035	0.453	0	0	1.055	1.686
Prunings carbon weight tonnes / year / hectare	0.008	0.044	0	0	0.195	0.272
Prunings carbon weight which could reach stable soil pool if mulched / left in situ, tonnes / year	0.012	0.159	0	0	0.369	0.590
Prunings carbon weight tonnes which could reach stable soil pool if mulched / left in situ, tonnes / ha / year	0.003	0.015	0	0	0.068	0.095
Yield of collected fruit, tonnes / year. Average where available. (year(s) of figures)	41.5 (2006-2007)	239 (2005-2008)	0 (2007)	18 (2007)	230 (2006)	66 (2007)
Carbon in collected fruit. Carbon content 8% for apple, 9.4 % for plum (including stone), tonnes / year	3.320	19.120	0.000	1.440	18.400	6.204
Carbon in collected fruit. Carbon content 8% for apple, 9.4 % for plum (including stone), tonnes / ha / year	0.738	1.856	0.000	0.576	3.407	1.001

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.56 Fruit contains a great deal of water. According to the reference sources above, water content is 84 % for apples and 81 % for plums on average, so carbon is present in a very dilute amounts compared to carbon in wood. However, the estimated carbon amounts removed in fruit in one year at the time of the project were substantial compared to the average rate of carbon accumulated in trees per year, exceeding in each site with data the average accumulation per hectare per year that trees had accrued to date (Table 5.8). With regard to the time of the project at least, the removal of carbon / ha in fruit from Salt Box exceeded the carbon accumulation rate of 1.8 tonnes / ha / year for open-grown oak derived from Cannell 1999, while the amount of carbon in fruit removed each year from Tidnor was equal to the accumulation rate of this open-grown oak. The findings about carbon removal in fruit parallel those of Poulton and others (2003), who noted that the carbon removed by harvesting wheat continuously at Rothamsted equalled that accumulated on site by regenerating woodland. The key reason for lower average carbon accumulation rates in cropped habitats is that management is concentrated on production of short-lived plant parts rather than on accumulating carbon in long-lived plant structures or in the soil. Annual harvesting of fruit necessitates considerable loss of the overall amount of carbon fixed by an orchard during the year.

Relative importance of carbon accumulation pools in each orchard

5.57 The approximate proportions of carbon in each pool where carbon accumulates annually in the orchards is shown in Table 5.10 below, including the short-lived pool of fruit and the more long-lived pools. Estimates were based on accumulation per year in trees up to the project date. Carbon in fruit outweighs accumulations in other pools, except for Lady Close, where no fruit collection or pruning was done. If accumulation rates are based on the estimated whole lifetime of trees, instead of the time up to the project date, results are similar in terms of relative importance of each pool. Note that in terms of carbon storage, soil is more important than the fruit trees (Table 5.6), in contrast to estimated annual carbon accumulation rates. Soil accumulation rates could have been under-estimated or there might have faster accumulation rates in soil in the past, perhaps before an equilibrium content was established. Particularly for orchards that have been managed traditionally for decades, soil accumulation rates over the whole lifetime of the orchard could give a more realistic annual soil accumulation rate than the equilibrium rate assumed for these orchards in the current study. Further research will be necessary to obtain better information on carbon storage amounts and accumulation rates in soil compared to trees over the whole lifetime of an orchard.

Table 5.10 Proportions of carbon (%) in short-lived and long-lived pools where carbon accumulates annually in each orchard

	Henhope (T)	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Annual carbon accumulation % in soil from conversion of arable to grassland	0.0	12.8	0.0	0.0	5.3	11.7
Annual carbon accumulation % from leaves reaching stable soil carbon pool	5.9	3.8	20.8	6.4	1.0	2.6
Annual carbon accumulation % in fruit trees over lifetime to date	23.7	22.7	79.2	35.9	24.3	35.0
Potential annual carbon accumulation % from prunings if they reached stable soil carbon pool	0.7	1.4	0.0	0.0	3.8	10.8
Annual carbon % in collected fruit during project year	69.6	59.3	0.0	57.7	65.7	39.9

Notes: Yearly accumulation in fruit trees is based on estimates for trees up to the date of the project, not the whole lifetime of the trees. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.58 At present, the UK Greenhouse Gas Inventory does not include carbon stock changes in consideration of possible inclusion of orchards in the Inventory. As shown, carbon accumulation can be relatively rapid in intensive orchards, and undisturbed older orchards may store reasonable amounts of carbon in soils and trees. For Inventory purposes, the carbon value of orchards needs to be set against carbon stock reductions through losses of orchards. In England overall loss has been severe, illustrated by the decline in orchard area across England of 63% since 1950 (Robertson and Wedge 2008). Conversion of orchards to other land uses, particularly arable, will lose the carbon accumulated by the trees and be likely to reduce the carbon stored in the soil.

Greenhouse gas emissions and net annual carbon sequestration by orchards

Approach to estimation of greenhouse gas emissions

5.59 To work out net annual carbon sequestration, annual gains in carbon accumulated by orchard habitats are assessed against amounts of carbon compounds, or carbon equivalents in 'greenhouse gases', emitted each year into the atmosphere because of management of the orchards. The primary aim of this analysis is to assess whether orchards have a positive or negative impact on levels of the greenhouse gases responsible for global warming. The focus of the estimation of greenhouse gas emissions in the orchard study is on the annual emissions due to direct management of the habitat. Natural sources of greenhouses gases have been ignored, in line with the approach taken by the annual UK Inventory of greenhouse gas emissions (MacCarthy and others 2010). The UK Inventory, which is required by the provisions of the Kyoto protocol, covers only human-generated emissions. Emissions are expressed by weight in the following section, either kilogramme (kg) or tonne (1000 kg). Full management details are required for working out net annual carbon sequestration. These details were only available for the 6 main study orchards, not Romulus Orchard (see Chapter 3).

5.60 A crucial decision in emission studies concerns the choice of boundary around the factors to include. Carbon emissions are linked in chains of activities, for example, energy-related emissions could include energy expended in searching for oil deposits, drilling, extraction, transport, refining, product transport and fuel energy expended in manufacture of agricultural machinery, as well as energy expended by fuel use in the orchard at the end of the chain. The boundary in the orchard study is drawn tightly around emissions on-site and does not include 'embedded' emissions from preceding activities. Embedded emissions which are ignored include emissions from manufacture and transport of fertilisers and pesticides, emissions due to manufacture of machinery and emissions associated with livestock management off-site, such as provision of winter-housing. As far as the fruit product harvested from the orchard is concerned, the boundary is the field gate, so that emissions due to transport of product away from the site, processing and any other later activities are ignored. The emphasis is on habitat management emissions, not total emissions related to fruit production.

5.61 The UK Inventory divides emissions by economic sector, for instance, the energy sector and industrial processes sector. This is not equivalent to the habitat-focused assessment desired for the orchards. The most relevant sector for the orchard study is agriculture, in that it concerns the emissions produced by direct land management. However, the energy expended by machinery in field operations is segregated in the UK Inventory into the energy sector. This expenditure is an important part of the carbon costs of managing habitats so is included in the orchard estimates along with the 'agricultural' emissions.

5.62 Greenhouse gases covered by the UK Inventory include 6 that contribute directly to global warming and several that have an indirect impact. Only the relevant gases for the agriculture sector among the direct gases are assessed for the orchard study, namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The latter two can be compared in 'carbon dioxide-equivalent' terms to CO_2 emissions by multiplication by standard factors and incorporated in this way to an overall assessment of carbon costs. No CO_2-equivalence is available for indirect gases in the UK Inventory and they are not included in the orchard study.

5.63 No measurement of annual emissions was done in the orchards so emission assessment relies on calculations using standard factors available in the IPCC guidelines for national greenhouse gas inventories, Volume 4: agriculture, forestry and other land use (Eggleston and others 2006), and in the latest UK Inventory report (MacCarthy and others 2010). These factors are combined with management information for each orchard to give estimates of greenhouse gas emissions, using the methodology outlined in the IPCC guidelines and UK Greenhouse Gas Inventory (Eggleston and others 2006, MacCarthy and others 2010). The use of standard factors is not ideal as emissions from individual sites may vary. For instance, N_2O emissions can vary due to local environmental factors including soil moisture and temperature (Machefert and others 2002), and CH_4 emissions vary due to diet of livestock (Monteny and others 2006). However, the standard factors were the only ones available. The way that the emissions were estimated and the assumptions involved are fully explained below, to allow future studies to be compared to the results for the orchards.

Sources of emissions and emission factors

5.64 There are four main sources of emissions from orchard management: fuel use by machinery, enteric fermentation by livestock, and direct and indirect emissions from agricultural soils due to nitrogen inputs by livestock manure and inorganic fertilisers. The scale of these emissions can be assessed based on the management details collected for each orchard (Chapter 3). Relevant details are repeated below for convenience. The standard factors for conversion of CH_4 and N_2O to CO_2-equivalents, ie the Global Warming Potential (GWP) of these gases compared to CO_2, are 21 and 310 respectively (MacCarthy and others 2010).

Fuel use

5.65 The tractor use hours recorded for various orchard management operations in each orchard formed the basis of the calculation (Table 3.3, Chapter 3). Information on fuel use by hand-held machinery, such as chain-saws, was patchy and so this category of machines was not included in the estimates. Tractor use hours were treated as the source for fuel consumption estimates, except for Lady Close Orchard where total fuel use was provided by the orchard manager. Precise calculation of fuel use from tractor use hours is not straightforward. The energy input needed to carry out specific farm operations appears to be independent of tractor power (Williams and others 2006). When fuel use for particular farm operations has been worked out by different people they have produced different results (Williams and others 2006, Downs and Hansen 1998). Therefore an overall average fuel consumption per tractor hour was used for the orchard study. The chosen average (8 litres per hour) was taken from financial planning advice for working out costs of orchard management (Ministry of Agriculture, Food & Fisheries, British Columbia, 2002).

5.66 The estimates for total fuel use in each orchard were then multiplied by an emission factor to produce the amount of CO_2-equivalent (CO_2e) that would have been produced by burning this amount of fuel. The emission factor was taken from the UK Government's guidelines on greenhouse gas conversion factors (Defra 2009a). The factor includes emissions of CH_4 and N_2O, in contrast to IPCC factors where only CO_2 is considered (Garg and others 2006). Emissions of CH_4 and N_2O can vary, for example due to the technology used. However, the UK emission factor uses an average of such CH_4 and N_2O emissions (Defra 2009a). The overall factor for diesel (gas oil), based on net calorific value of the fuel, is 3.0289. Thus the calculation for each orchard is:

Total greenhouse gas emission CO_2-equivalent (CO_2, CH_4, N_2O), kg / year	=	tractor use (hours / year)	x	8 (litres fuel / hour)	x	3.0289 (emission factor per litre of fuel)

Enteric fermentation

5.67 Livestock produce methane (CH_4) during the digestive process. Cattle have a high rate of CH_4 emission due to their ruminant digestive system (Dong and others 2010). The simplest estimation method is used for the orchard study, whereby the different types of livestock are allocated a specific emission factor per head. These factors are taken from the UK Greenhouse Gas Inventory (MacCarthy and others 2010) and the relevant ones are as follows: Sheep 8 kg CH_4 / head / year, mature beef cattle 49.8 kg CH_4 / head / year, heifers 48 kg CH_4 / head / year, calves 32.8 kg CH_4 / head / year. The result is adjusted to account for the proportion of time an orchard is grazed. The calculations for each orchard for each livestock type are:

Total CH_4 emission, kg / year	=	Number of livestock	x	Fraction of year grazed (number of days/365)	x	Emission factor (kg CH_4 / head / year)

5.68 Note that the total CH_4 emissions for Half Hyde Orchard is the sum of the CH_4 emissions of the three cattle types present on the site (mature cattle, heifers and calves). The CO_2-equivalent emission produced by enteric fermentation is calculated as follows:

Total greenhouse gas emission, CO_2-equivalent, kg / year	=	Total CH_4 emission, kg / year	x	21 (GWP for CH_4)

Direct nitrous oxide emissions from fertilisers and livestock excretion

5.69 The estimation of the direct emission of N_2O from agricultural soils is limited to inorganic fertilisers and livestock excretion. It does not include any N_2O emission due to biological nitrogen fixation by plants as this source has been excluded by the IPCC because of lack of evidence of significant emissions from this source (De Klein and others 2008). Nitrous oxide is produced naturally in soils through processes of nitrification and denitrification by microbes living in the soil. In most soils, increasing available nitrogen (N) increases the production of N_2O (De Klein and others 2008). Therefore nitrogen added to orchard soils through fertilisers and livestock manures as part of orchard management is assumed to increase N_2O emissions from the soil above natural levels.

5.70 The emissions of N_2O from inorganic fertilisers is estimated by first working out how much nitrogen has been added, using the standard nitrogen proportions for particular types of fertilisers. Fertilisers were only used at Salt Box and Village Plum orchards (see Chapter 3 for details). Ammonium nitrate (211 kg per year) and Croplift foliar feed (13 kg per year) were applied at Salt Box Orchard. Nitrogen content of 33.5% in ammonium nitrate (Stiles and Reid, undated) produced a total of 70.7 kg of nitrogen applied to Salt Box in this fertiliser. Croplift contains 20% nitrogen (Yara product information, undated) so total input from this fertiliser was 2.6 kg / year. Total nitrogen input to Salt Box was the sum of the amounts in each fertiliser, ie 73.3 kg / year. Nitrogen fertilisers used at Village Plum Orchard were ®Nitram (ammonium nitrate), potassium nitrate and ®Bortrac. Nitrogen content of 34.5% in ®Nitram (GrowHow product information 2008), 13% in potassium nitrate (Stiles and Reid, undated) produced a total nitrogen input of 73.11 kg / year, while ®Bortrac's nitrogen content of 20% (Yara product information, undated) produced a total input of 0.5 kg / year. The combined nitrogen input at Village Plum was therefore 73.61 kg / year.

5.71 The emission factor for calculating the amount of nitrous oxide-nitrogen (N_2O-N) derived from nitrogen fertiliser is 0.01 kg N_2O-N / kg N input from the fertiliser. The N_2O-N is then converted to N_2O gas emitted by multiplying by 44/28 (De Klein and others 2008), and the GWP of N_2O applied. The calculations are:

Total N_2O-N emission, kg / year	=	Nitrogen input from fertiliser (kg / year)	x	Emission factor (kg N_2O-N / kg N input / year)

Total greenhouse gas emission, CO_2-equivalent, kg / year, from fertilisers	=	(Total N_2O-N emission, kg / year x 44/28)	x	310 (GWP for N_2O)

5.72 Livestock add nitrogen to the soil through depositing urine and dung. The nitrogen content of this manure is estimated by using standard nitrogen excretion factors for different types of livestock. These factors are taken from the UK Greenhouse Gas Inventory (MacCarthy and others 2010) and the relevant ones are as follows: Sheep 10.2 kg N / head / year, mature beef cattle and heifers 79 kg N / head / year, calves 38 kg N / head / year. The total amount of N input is adjusted to account for the proportion of time an orchard is grazed. Livestock grazing only occurred in the traditional orchards. The calculations for each orchard for each livestock type are:

Total N input, kg / year	=	Number of livestock	x	Fraction of year grazed (number of days/365)	x	Nitrogen excretion factor (kg N / head / year)

5.73 The total N input for Half Hyde Orchard is the sum of the N inputs of the two cattle types, defined by the UK Inventory, present on the site (mature cattle plus heifers and calves). Once the N input has been calculated, an emission factor is used for calculating the amount of nitrous oxide-nitrogen (N_2O-N) derived from the nitrogen input. This factor is different for cattle and sheep, ie 0.02 kg N_2O-N / kg N and 0.01 kg N_2O-N / kg N respectively. The N_2O-N is then converted to N_2O gas emitted by multiplying by 44/28 (De Klein and others 2008), and the GWP of N_2O applied. The calculations are:

Total N_2O-N emission, kg / year	=	Nitrogen input from manure (kg / year)	x	Emission factor for livestock type (kg N_2O-N / kg N input / year)

Total greenhouse gas emission, CO_2-equivalent, kg / year from livestock excretion	=	(Total N_2O-N emission, kg / year x 44/28)	x	310 (GWP for N_2O)

Indirect nitrous oxide emissions from fertilisers and livestock excretion

5.74 There are two indirect pathways for emissions of N_2O from nitrogen inputs from fertilisers and livestock excretion to soils. The first is volatilisation of N as ammonia (NH_3) and oxides of N (NO_x) from the N inputs to a site, followed by the deposition of these gases and their products, ammonium (NH_4^+) and (nitrate) NO_3^-, elsewhere on to soils and on to the surface of open waters. Nitrification and denitrification then convert some of these compounds to N_2O. The second indirect pathway is loss of nitrogen through leaching down the soil profile and runoff in overland water flow, mainly as NO_3^-, and subsequent emission of a proportion of the leached N as N_2O, away from the site from which it leached (De Klein and others 2008).

5.75 To estimate N_2O from the volatilisation pathway according to the IPCC methodology, the N input from inorganic fertilisers and livestock excretion is multiplied by separate factors to give the amounts of N volatilised as NH_3 and NO_x. These figures are multiplied by an emission factor to give N_2O-N amounts, see equation a) below. However, calculations for the orchards are simpler than equation a) as no site receives both inorganic fertilisers and livestock excretions. Then the N_2O emissions reaching the atmosphere are calculated from the N_2O-N amounts using equation b) below:

a)

Total N_2O-N from atmospheric deposition of N volatilised, kg / year	=	(N input from fertilisers kg / year x fraction volatilised, which is 0.1	+	N input from livestock excretion kg / year x fraction volatilised, which is 0.2)	x	Emission factor (0.01) for N_2O emissions from atmospheric deposition of N, kg N_2O-N per kg NH_3-N + NO_x-N volatilised

b)

Total greenhouse gas emission from volatilisation pathway, CO_2-equivalent, kg / year	=	(Total N_2O-N emission from atmospheric deposition of N volatilised, kg / year x 44/28)	x	310 (GWP for N_2O)

5.76 The indirect leaching pathway for N_2O emissions is calculated from the same nitrogen inputs, this time multiplied by a fraction lost in leaching and runoff and an emission factor for N_2O emission from N leaching and runoff, as shown in equation c). Then the N_2O emitted into the atmosphere is calculated from the N_2O-N amounts, as shown in equation d) below:

c)

Total N_2O-N from leaching & runoff of N, kg / year	=	(N input from fertilisers kg / year	+	N input from livestock excretion kg / year)	x	Fraction (0.3) of N input lost through leaching and runoff, kg N / kg N input	x	Emission factor (0.0075) for N_2O emissions from leaching and runoff of N, kg N_2O-N per kg N in leaching and runoff

d)

Total greenhouse gas emission from leaching & runoff pathway, CO_2-equivalent, kg / year	=	(Total N_2O-N emission from leaching & runoff, kg / year x 44/28)	x	310 (GWP for N_2O)

Biomass burning

5.77 There is some difference of approach to emissions of CO_2 from burning different types of biomass in the UK Greenhouse Gas Inventory and the IPCC Guidelines (MacCarthy and others 2010, Aalde and others 2006a). The UK reports only non-CO_2 gases from burning of annual crop residues, but for woody biomass in forests, CO_2 is reported, along with CH_4 and N_2O. The CO_2 from burning of crop residues is considered part of the annual carbon cycle. However, the IPCC guidelines are to report CO_2 when CO_2 emissions and removals are not equivalent in the inventory year. This is likely to be the case in forest wildfires, for which the UK reports CO_2 and CH_4 and N_2O. Such fires can also release carbon monoxide, an indirect greenhouse gas (Aalde and others 2006). In orchard management, prunings are often burnt (Table 5.9 above). The CO_2 in the emissions from combustion will have been captured in previous years through photosynthesis by the fruit trees. Figures for CO_2 emissions from burning prunings are estimated below but this longer-term carbon cycle should be kept in mind. Of course, releasing the carbon by burning prunings returns carbon more quickly to the atmosphere than would be the case if no pruning was done, and thus reduces the semi-permanent carbon store in the orchard fruit trees.

5.78 The amount of CO_2-equivalent emissions from burning prunings have been estimated using the IPCC methodology (Aalde and others 2006a). The greenhouse gas emissions for CO_2, CH_4 and N_2O were derived from the mass of the fuel available, multiplied by a combustion factor representing the proportion of the fuel burnt and an emission factor for kg of each gas produced by burning. The IPCC generic emission factors for each gas emitted by burning forest material from forests outside of the tropics were used. Both prescribed burning and wildfires are included by the IPCC. The emission factors were as follows: CO_2 1.569 kg / kg of dry matter burnt, CH_4 0.0047 kg / kg of dry matter burnt, N_2O 0.00026 kg / kg of dry matter burnt. The proportion of pruning material burnt was arbitrarily set at 80% which is larger than the proportion burnt by fires in temperate forests (IPCC figure of 45%) as it was assumed that prunings were burnt in a controlled way with the aim of reducing the residue as much as possible. The calculation was as follows for each greenhouse gas:

Total greenhouse gas emission, CO_2-equivalent, kg / year	=	Dry weight of prunings kg / year (Table 5.9)	x	Combustion proportion (80%)	x	Emission factor, kg greenhouse gas / kg dry matter burnt

CO_2-equivalent emissions from orchard management

5.79 The full set of estimates for the carbon dioxide-equivalent emissions from the calculations explained above are given in Table 5.11 below. The relative contributions of different sources to total emissions are shown in Table 5.12. A separate table (Table 5.13) shows the estimates for emissions from burning of prunings.

Table 5.11 Estimates of annual carbon dioxide-equivalent emissions from orchard management excluding biomass burning

Source of emissions	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Source: Fuel use (CO_2, CH_4, N_2O)						
Tractor use, hours per year	74	111	1.9	11	138.5	62
Total fuel use, litres per year	592	888	15	88	1108	496
Fuel use: CO_2 and CO_2-equivalent emitted, kg / year	1793.1	2689.7	45.4	266.5	3356.0	1502.3
Fuel use: CO_2 and CO_2-equivalent emitted, kg / ha / year	398.5	261.1	25.2	106.6	621.5	242.3
Source: Enteric fermentation (CH_4)						
Livestock type	Sheep	Sheep	Sheep	Beef cattle	None	None
Numbers of livestock	60, all adult	40, all adult	75, all adult	52 cows, 49 calves, 7 heifers, 1 bull	0	0
Fraction of year grazed	0.33	0.23	0.27	0.04	0	0
Enteric fermentation: Total CO_2-equivalent produced, kg / year	3286.4	1546.5	3383.0	3691.2	0	0
Enteric fermentation: Total CO_2-equivalent produced, kg / ha / year	730.3	150.1	1879.5	1476.5	0	0
Source: Fertilisers and livestock excretion (direct N_2O from soil)						
Total nitrogen input from livestock or fertilisers, kg / year	199.53	93.90	205.40	253.23	73.29	73.61
Total N_2O-nitrogen produced, kg / year	2.00	0.94	2.05	5.06	0.73	0.74
Total N_2O released from N_2O -nitrogen, kg / year	3.14	1.48	3.23	7.96	1.15	1.16
Fertilisers and livestock excretion: Total CO_2-equivalent produced, kg / year	971.99	457.41	1000.58	2467.16	357.03	358.59

Source of emissions	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Fertilisers and livestock excretion: Total CO_2-equivalent produced, kg / ha / year	216.00	44.41	555.88	986.86	66.12	57.84
Source: Volatilisation and leaching (indirect N_2O from soil)						
Total nitrogen input from livestock or fertilisers, kg / year	199.53	93.90	205.40	253.23	73.29	73.61
Amount of nitrogen derived from volatilisation of ammonia and nitrous oxides, kg / year	39.91	18.78	41.08	50.65	7.33	7.36
Total N_2O-nitrogen from atmospheric deposition of the ammonia and nitrous oxides, kg / year	0.3991	0.1878	0.4108	0.5065	0.0733	0.0736
Total N_2O released from N_2O-nitrogen from atmospheric deposition, kg / year	0.6271	0.2951	0.6455	0.7959	0.1152	0.1157
Volatilisation: Total CO_2-equivalent produced, kg / year	194.40	91.48	200.12	246.72	35.70	35.86
Volatilisation: Total CO_2-equivalent produced, kg / ha / year	43.20	8.88	111.18	98.69	6.61	5.78
Amount of nitrogen from nitrogen inputs lost to leaching and runoff, kg / year	59.86	28.17	61.62	75.97	21.99	22.08
Total N_2O-nitrogen from leaching and runoff, kg / year	0.449	0.211	0.462	0.570	0.165	0.166
Total N_2O released from N_2O-nitrogen from leaching and runoff, kg / year	0.705	0.332	0.726	0.895	0.259	0.260
Leaching: Total CO_2-equivalent produced, kg / year	218.70	102.92	225.13	277.56	80.33	80.68
Leaching: Total CO_2-equivalent produced, kg / ha / year	48.60	9.99	125.07	111.02	14.88	13.01
Total CO_2-equivalent produced, all emission sources, kg / year	6464.6	4888.0	4854.3	6949.2	3829.1	1977.5
Total CO_2-equivalent produced, all emission sources, kg / ha / year	1436.6	474.6	2696.8	2779.7	709.1	318.9

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Table 5.12 Relative contributions of sources of emissions to total annual emissions (percentages)

Source of emissions	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Fuel use %	27.7	55.0	0.9	3.8	87.6	80.6
Enteric fermentation %	50.8	31.6	69.7	53.1	0.0	0.0
Fertilisers and livestock excretion (direct N_2O) %	15.0	9.4	20.6	35.5	9.3	19.2
Volatilisation (indirect N_2O) %	3.0	1.9	4.1	3.6	0.9	0.04
Leaching (indirect N_2O) %	3.4	2.1	4.6	4.0	2.1	0.09

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Table 5.13 Potential carbon dioxide-equivalent emissions from annual burning of prunings

Source: Biomass burning	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Total dry weight of prunings of trees pruned, kg / year	73.1	944.3	0	0	2197.6	3512.8
Amount of dry weight of prunings consumed in fire, kg / year	58.5	755.4	0	0	1758.0	(2810.2)*
Total emission of CO_2 from burning prunings, kg / year	91.8	1185.2	0	0	2758.4	(4409.2)*
Total CO_2-equivalent (CH_4) from burning prunings, kg / year	5.8	74.6	0	0	173.5	(277.4)*
Total CO_2-equivalent (N_2O) from burning prunings, kg / year	4.7	60.9	0	0	141.7	(226.5)*
Total CO_2 & CO_2-equivalent from burning prunings, kg / year	102.2	1320.7	0	0	3073.6	(4913.1)*
Total CO_2 & CO_2-equivalent from burning prunings, kg / ha / year	22.7	128.2	0	0	569.2	(792.4)*

Notes: *Only part of the prunings at Village Plum Orchard were burnt so these figures are over-estimates. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.80 Fuel use as a source of emissions was most important in the intensive orchards, where it produced the bulk of the emissions. Direct N_2O emissions from fertilisers was the next largest source in the intensive orchards. The presence of livestock in the traditional orchards was the main factor responsible for the majority of emissions in the orchards, mostly through CH_4 from enteric fermentation, plus N_2O released from the soil, which received urine and dung from the livestock. Tidnor is an exception, where emissions from fuel use was greater than emissions from livestock (Table 5.12). Indirect release of N_2O played a small part in emissions from all orchards. The estimate of potential emissions from biomass burning was greater for Salt Box Orchard than for the traditional orchards, where a lower proportion of trees were pruned each year (Table 5.9). Only the larger diameter wood at Village Plum was burnt, smaller pieces were chipped and mulched, so actual emissions could have been lower than at Salt Box Orchard, rather than higher as suggested by the estimate in Table 5.13.

Net carbon sequestration: carbon accumulation versus carbon emission

5.81 The carbon accumulated in a year is compared below to carbon emissions from the study orchards, to see if orchards are net contributors to carbon emissions to the atmosphere, or are sinks for carbon. Two comparisons are made below (Tables 5.14 - 5.17), neither including emissions from biomass burning. The first uses the yearly accumulation of carbon by fruit trees up to the time of the project, both overall total and per hectare. The second comparison uses the potential yearly accumulation that might occur over the whole lifespan of the trees (see paragraph 5.51 above and Table 5.8 for more details about this approach). The carbon accumulation pools included in each set of comparisons are the estimates for soil carbon accumulation rate, the carbon derived from input of leaves and the average yearly carbon accumulation in the fruit trees. Note that the rate of accumulation of carbon in soil from leaves is at the time of the project, in contrast to the fruit tree averages (trunk, branches and coarse roots) which are averaged over longer periods (see paragraphs 5.44 to 5.46 and Table 5.7 for further details about carbon from leaves). The weights of emissions of CO_2-equivalent greenhouse gases have been converted to carbon weights by multiplying by 12/44 to enable a direct comparison to be made with annual carbon accumulation rates.

Table 5.14 Net annual carbon sequestration in orchards based upon yearly average carbon accumulation of fruit trees to date of project

	Henhope (T)	**Tidnor Wood (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Total yearly carbon accumulation by soil + leaves to soil + fruit trees, tonnes / year	1.42	12.65	0.27	1.06	8.56	7.66
Total yearly carbon & carbon-equivalent emitted, tonnes / year	1.76	1.33	1.32	1.90	1.04	0.54
Net yearly sequestration of carbon, tonnes / year	-0.35	11.32	-1.06	-0.84	7.51	7.12

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Table 5.15 Net annual carbon sequestration per hectare in orchards based upon yearly average carbon accumulation of fruit trees to date of project

	Henhope (T)	**Tidnor Wood (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Total yearly carbon accumulation by soil + leaves to soil + fruit trees, tonnes / ha / year	0.32	1.23	0.15	0.42	1.59	1.24
Total yearly carbon & carbon-equivalent emitted, tonnes / ha / year	0.39	0.13	0.74	0.76	0.19	0.09
Net yearly sequestration of carbon, tonnes / ha / year	-0.08	1.10	-0.59	-0.34	1.39	1.15

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Table 5.16 Net annual carbon sequestration in orchards based upon potential yearly average carbon accumulation of fruit trees over whole lifetime

	Henhope (T)	**Tidnor Wood (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Total yearly carbon accumulation by soil + leaves to soil + fruit trees, tonnes / year	2.04	17.68	0.55	0.78	12.49	7.66
Total yearly carbon & carbon-equivalent emitted, tonnes / year	1.76	1.33	1.32	1.90	1.04	0.54
Net yearly sequestration of carbon, tonnes / year	0.27	16.35	-0.77	-1.11	11.45	7.12

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Table 5.17 Net annual carbon sequestration per hectare in orchards using potential yearly average carbon accumulation of fruit trees over whole lifetime

	Henhope (T)	Tidnor Wood (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Total yearly carbon accumulation by soil + leaves to soil + fruit trees, tonnes / ha / year	0.45	1.72	0.31	0.31	2.31	1.24
Total yearly carbon & carbon-equivalent emitted, tonnes / ha / year	0.39	0.13	0.74	0.76	0.19	0.09
Net yearly sequestration of carbon, tonnes / ha / year	0.06	1.59	-0.43	-0.45	2.12	1.15

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.82 The carbon accumulation rate minus carbon emitted for the two intensive orchards, Salt Box and Village Plum, indicates net annual positive sequestration of carbon, both up to the project date and for the whole lifetime of the trees. The estimates benefit from the assumption that soil carbon is accumulating (Table 5.7), but even without soil carbon accumulation, (0.275, 0.292 tonnes / ha / year in Salt Box and Village Plum orchards respectively), the orchards would still have been accumulating carbon because of large accumulation rates due to the high density of fruit trees. In contrast, the traditional orchards, Lady Close and Half Hyde, were estimated to have net negative sequestration in both situations, so that they were overall sources rather than sinks for carbon in the atmosphere, although in relatively small amounts of less than a tonne / ha / year. Henhope Orchard was a very small source of carbon up to the project date and a small sink if the whole tree lifetime was estimated. All three sites were assumed to have no accumulation of soil carbon. However, it should be noted that the protective function of these orchards with regard to equilibrium soil carbon ‘capital’ built up in past years was not included in any orchard lifetime accumulation estimates. The estimated carbon accumulation by the fruit trees, which were all planted at relatively low densities (Table 5.4), was not able to compensate on their own for the emissions, the bulk of which were due to the livestock grazing of the 3 sites (Table 5.12). Tidnor Orchards had a high density of trees, and had been intensively managed in the past, but were traditionally managed at the time of the project. The site had positive net carbon sequestration even without soil carbon accumulation (0.4 tonnes / ha / year), despite livestock effects (Table 5.12). Inclusion of biomass burning among the emissions makes very small differences to the net figures for any orchard, and causes no changes as to whether orchards have positive or negative net sequestration.

5.83 Comparisons of the orchard results with other studies are difficult to draw as there is a lack of detail as to what factors underlay the carbon estimations in such studies, as pointed out by Lillywhite and others (2007). These authors include a wider set of carbon emission sources in their horticultural product review, and in relative terms found that intensive apple production was among the lowest for greenhouse gas emissions. Their figure was 2735 kg CO_2-equivalent / ha / year, clearly greater than the amounts for Salt Box and Village Plum (Table 5.11). Lillywhite and others (2007) found that manufacture of fertilisers was a significant factor in emissions from crop production. Emissions from fertiliser manufacture, packing and transport were not included in the current orchard study but to test if inclusion would change the picture in a major way, estimates were made for the ‘embedded carbon emissions’ in fertilisers and pesticides used at Salt Box and Village Plum orchards.

5.84 Estimates for embedded carbon in terms of Global Warming Potential of CO_2-equivalent gases in fertilisers vary (Wood and Cowie 2004, Williams and others 2006, Defra project HH3606 2005b). Estimates from Williams and others (2006) were used as follows: ammonium nitrate (including ®Nitram) 7.2 kg CO_2-equivalent / kg N, Croplift, potassium nitrate and Bortrac, mean of N fertilisers (6.8 kg CO_2-equivalent / kg N), muriate of potash

0.53 kg CO_2-equivalent / kg K, pesticides 8 kg CO_2-equivalent x dose / ha of product used x area of application. No estimate was available for magnesium sulphate but in the report of Defra project HH3606 (2005b) magnesium sulphate as a product was given a similar energy use as sulphate of potash, so the estimate of 0.1 kg CO_2-equivalent / kg product for sulphate of potash was used. Amounts of the various chemicals applied can be found in Chapter 3. Calculation of total emissions resulted in estimates of 0.4 tonnes carbon / year (0.07 tonnes / ha / year) for Salt Box and 0.2 tonnes carbon / year (0.03 tonnes / ha / year) for Village Plum, which would make only a minor difference to the net positive sequestration amounts (see Tables 5.14 - 5.17).

5.85 Some comparative estimates for different farming regimes in terms of greenhouse gas emissions are available in the Defra project report for BD2302 (2007a). On the basis of factors included in this study, improved grassland managed for dairy cattle had the greatest greenhouse gas emissions, while orchards managed with pesticides and fertilisers (but not grazed) had emissions of only 13% of those from the improved grassland regime, 38% of those from semi-improved grassland grazed by sheep and 43% of emissions from winter wheat cropping. Enteric fermentation by livestock is significant in emissions from the dairy regime and for emissions from semi-improved grasslands. Grazing by livestock undoubtedly adds to greenhouse gas emissions from the Herefordshire traditional orchards but equivalent stocking of permanent grasslands which are without trees would not be offset by any accumulation of carbon by trees. Thus livestock grazing of treeless grasslands would be likely to result in larger net carbon emissions than equivalent stocking regimes in traditional orchards. The scenario for winter wheat production used in BD2302 has nitrogen inputs from fertilisers 3 times the amount used in Salt Box Orchard and Village Plum Orchard. Thus fertiliser use in intensive orchards would result in smaller emissions from this source than emissions from arable crops on the basis of these figures. Read and others (2009) make some estimates for emissions from forestry management in the UK. Emissions are lower than those for the study orchards, across a range in management intensity from unmanaged woodland to wood biomass production stands (0.01 to 0.17 tonnes CO_2 equivalent / ha / year). The range for the orchards, expressed as CO_2 equivalent rather than carbon (Table 5.15), is 0.32 to 2.78 tonnes CO_2 equivalent / ha / year. When emissions from forestry management are set against the average estimate of about 14 tonnes CO_2 equivalent / ha / year accumulated by plantation conifers (Read and others 2009), carbon sequestration by managed forests appears to be considerably greater than sequestration by the orchard study sites.

5.86 The positive net annual sequestration of carbon by trees in intensive orchards, and any net annual sequestration by trees in traditional orchards will only last as long as the trees are in place. Most of the carbon accumulation in a year that stays on site takes place in the trees (Table 5.10 above). If these trees are burnt in the open after being grubbed out most of the stored carbon in the trees, accumulated each year over the lifetime of the trees, will return to the atmosphere. The most carbon-efficient use for the timber from grubbed trees would be to use it as a fuel-substitute for fossil fuels for power or heat generation, ideally in the local area so carbon transport costs were minimised. Another less likely use would be in long-lasting wood products but the volume of suitable timber would be small, given the small stature of the trees. The soil was estimated to contain the bulk of stored carbon in each orchard (Table 5.6) and this might remain after trees are removed but maintenance would depend on there being no soil disturbance. The process of removing the trees and then any cultivation afterwards would be likely to reduce the accumulated carbon in the soil and negate gains achieved while the orchards were present. While the project has been able to examine carbon storage and sequestration in single sites, to assess the contribution of orchards generally requires a landscape scale approach. Across a landscape, orchards may be in different stages of carbon accumulation and loss. New orchards may be accumulating carbon, even as old orchards are grubbed out and their carbon-capture ability lost. Thus across an orchard landscape, positive or negative carbon accumulation may prevail.

Carbon storage, rate of accumulation and net annual carbon sequestration by orchard hedgerows

Climate regulation by orchard hedgerows

5.87 Each study orchard is surrounded in part or entirely by hedgerows (Maps 2.2 to 2.8), a feature of orchards more generally (Lush and others 2009, Smart and Winnall 2006). Shelter for fruit trees and habitat for natural enemies of orchard pests are two advantages cited for orchard hedgerows (Rieux and others 1999, Solomon 1981). Such hedgerows have potential to store and accumulate carbon but these properties appear to have been rarely measured anywhere to date (Falloon and others 2004). As an experiment, to gauge possible significance of orchard hedgerows for climate regulation, some estimates have been made based on existing literature. Two aspects are included, carbon in the soil and in the woody above-ground plant material of the hedgerow.

Carbon storage in the soil under hedgerows

5.88 For the purposes of the current study, the soil carbon storage figures for scrub and woodland from the Rothamsted Broadbalk study (Poulton and others 2003) were adapted and applied to hedgerows. The decision on the size of the zone to be used as 'hedgerow soil' for soil carbon storage estimation was made based on a hedgerow study in France. In this study soil carbon storage was directly measured across a range of sites and at different distances from the hedgerow (Walter and others 2003). The hedgerows were part of the dense network of ancient hedgerows in the 'bocage' landscape of Brittany in France. The zone within 2 metres of the middle of the hedgerow bank had some of the highest carbon amounts and these appeared to be linked to the presence of the hedgerow. Therefore a zone of this dimension was used in the orchard estimations. Length of hedgerow in metres, multiplied by 2 m, gave the area for estimation of soil carbon storage.

5.89 Most of the hedgerows around the orchards were dominated by native woody species and probably dated from at least the time of Enclosure. Most Enclosure hedgerows were established in the period 1760-1820 (Pollard and others 1974). Some of the orchard hedgerows may have been older still. Clues lay in the woody species composition, which was often mixed, with hazel and holly present as well as hawthorn, while the ancient woodland indicators bluebell (*Hyacinthoides non-scripta*) and dog's mercury (*Mercurialis perennis*) occurred in places (see habitat survey, Chapter 4). All these hedgerows are treated as 'old' and given a soil carbon storage estimate of 85 tonnes / ha. This is the amount in the soil beneath 118 year-old woodland at Broadbalk, Rothamsted, adjusted for 30 cm depth of soil as explained in paragraph 5.38 above. In fact, this figure is not much different to the average of minimum and maximum soil carbon figures plotted for the 0-2m zone of the Brittany hedgerows (77.5 tonnes of carbon / ha in the top 30 cm).

5.90 Orchard owners identified two newer hedgerows of native species around the orchards, one at Tidnor (paragraph 4.26, Chapter 4), the other at Lady Close (paragraph 4.33, Chapter 4). In addition, the habitat survey found two shrubby hedgerows with abundant non-native woody species (boundaries 2 and 4 at Village Plum Orchard) and these hedgerows have also been categorised as 'new' as they were likely to have been recent. It should be noted that boundary 2 was classed as a mix of BAP hedgerow and hedgerow in the habitat survey (Chapter 4) but for the purposes of carbon estimation it has been treated as 'new'. Where lines of trees made up the hedgerow, these have all been treated as 'old' although sometimes non-native trees did occur in them (boundary 1 at Lady Close Orchard, see Chapter 4). For the new hedgerows the soil carbon storage figure is based on the measurement of soil carbon under scrub of 23 years of age, given by Poulton and others (2003). This scrub developed on abandoned arable land at Broadbalk, Rothamsted. Using the same procedure as outlined in paragraph 5.38 above, the figure for soil carbon was 'adjusted' for 0-30 cm depth, resulting in a storage amount of 43 tonnes soil carbon / ha.

Carbon storage estimates for soils of new and old hedgerows around each of the orchards are shown in Table 5.19.

Carbon storage in the woody hedgerow species

5.91 The regenerating woodland site studied at Broadbalk is described by Poulton and others (2003) as 'perhaps best regarded as a very wide hedgerow'. This site has been used to estimate carbon storage by woody hedgerow species in the orchard hedgerows. Data are available for two common species of classic shrubby hedgerows, namely hawthorn *Crateagus monogyna*, and hazel, *Corylus avellana*. Data are also available for 3 common hedgerow trees; ash, *Fraxinus excelsior*, oak, *Quercus robur*, and sycamore, *Acer pseudoplatanus*. All these species occur in the orchard hedgerows. The data have been used to estimate 'typical' carbon storage by a hedgerow or line of trees, the precise species composition of which will be different in the individual orchard hedgerows. The number of stems of each species in Broadbalk, the proportion that they occupy of total basal area of stems and biomass are given by Poulton and others (2003) for the years 1969 and 2001. Biomass was estimated by Poulton and others (2003) using the same model as for the orchard fruit trees, that described by Bunce (1968). It should be noted that the Broadbalk biomass figures are relatively high for woodland habitats but Poulton and others (2003) suggest that per unit area, wide hedgerows with trees are better than woodland blocks at sequestering carbon, probably because light interception is greater.

5.92 The carbon stored by hawthorn and hazel when estimated at Broadbalk for 1969 is used as a basis for estimating carbon stored by the shrubby orchard hedgerows. In 1969 the two species were at their peak of abundance in Broadbalk. Both species, particularly hawthorn, are abundant in the orchard hedgerows. Together, the two species accounted for 34.5% of the biomass at Broadbalk, and thus of the carbon stored, amounting to 45 tonnes of carbon / ha. Use of this amount in estimates of the biomass of a whole hedgerow is conservative, and perhaps represents carbon stored by a rather gappy hedgerow. The height of each orchard hedgerow is used as a rough indicator of the amount of carbon that might be expected in hedgerows of different sizes. The tallest type is assumed to have the full carbon storage figure, while reductions are made for hedgerows of smaller stature as shown in Table 5.18 below. For estimating carbon stored in lines of trees, the sum of ash, oak and sycamore biomass at Broadbalk in 2001 is used, when the trees were at their largest during the study. The three species accounted for 64% of the woody biomass at this time, representing 166 tonnes of carbon / ha. Again this is conservative for a line of trees, unless it too is quite gappy.

Table 5.18 Assumptions for above-ground storage of carbon in hedgerows

Hedgerow size range (metres)	Type of hedgerow	Assumed carbon storage above ground tonnes / ha
> 6	Line of trees	166
> 3 to 6	Tall hedgerow	45
< 2 to 3	Medium hedgerow	22.5
2 or less	Short hedgerow	11.25

Note: Hedgerow heights taken from habitat survey, see Chapter 4.

5.93 Using these assumptions about above-ground storage, the height-type of each orchard hedgerow was determined. The total area for that hedgerow was calculated by multiplying the hedgerow width and length from the habitat survey (see Chapter 4 and Appendix 1) to give an area in hectares (Table 5.19). The appropriate carbon storage figure for that height type was then multiplied by this area to give the total carbon stored in woody species in each hedgerow. The estimates for the total carbon stored in each orchard hedgerow, in above-ground woody plants in hedgerows, and in the soil beneath hedgerows, are shown in Table 5.19 below.

Table 5.19 Carbon storage estimates for hedgerows around the orchards

	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Romulus (I)	Salt Box (I)	Village Plum (I)
Hedgerow area (length of boundary x width of woody species component), ha	0.27	0.11	0.2	0.09	0.19	0.12	0.22
Total soil carbon in zone 2 m x boundary length, in 0-30 cms soil layer, tonnes	6.8	9.2	7.7	5.5	14.7	10.1	14.3
Total carbon stored above-ground, tonnes	45.4	3.8	20.1	14.7	17.9	2.4	7.2
Total carbon storage, tonnes	52.2	13.0	27.9	20.2	32.6	12.5	21.5

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.94 The hedgerows are estimated to make some relatively small contributions to total soil carbon in the top 30 cm of soil in the orchards (see the orchard soil estimates in Table 5.1). Note that the area of land included in hedgerow soil carbon storage should really be subtracted from the orchard soil storage area as these two areas overlap. However, when the consequent reduced carbon storage in orchard soils was added to hedgerow soil storage, overall soil amounts were greater for 4 orchards and within 95% of the soil carbon amounts in the other three orchards.

5.95 Hedgerow carbon storage above-ground adds quite substantially to above ground carbon in some orchards, notably Henhope and Lady Close (Tables 5.4 and 5.17). This is because of the presence of lines of trees among the boundary types of these orchards, with their greater assumed carbon content compared to shrubby hedgerows.

Carbon accumulation by hedgerows, greenhouse gas emissions and net annual carbon sequestration

5.96 No direct measurement of annual carbon accumulation rates by hedgerows were made so figures from the literature were used as a basis for estimates. The soil carbon accumulation rate for new and 'alien' shrubby hedgerows was assumed not to be in equilibrium and a rate was taken from the amount accumulated per year by the change of arable to scrub over 23 years at Broadbalk, Rothamsted (Poulton and others 2003). For old hedgerows and all tree lines, an assumption that soil carbon levels were in equilibrium was also rejected. The amount accumulated in the soil per year by regenerating woodland at Rothamsted over 118 years was used instead. The optimistic assumption of continued accumulation was chosen because modelling of carbon in soil at Rothamsted suggests the soil of the woodland there will not reach equilibrium there for 766 years (Harrison and others 1995) and that actual accumulation has been occurring in all measurements to date for over 100 years (Poulton and others 2003). It appears that woodland soils in the UK may take a very long time to reach equilibrium but more research is needed. The soil carbon accumulation rates were adjusted for 30 cm depth of soil, as in paragraph 5.38 above, resulting in estimates of 0.542 tonnes of carbon / ha / year and 0.456 tonnes of carbon / ha / year for new and old hedgerows respectively. These estimates do not take into account size of hedgerow, although presumably a large hedgerow would input more to soil carbon in the forms of leaves and other plant parts than a small hedgerow. Management is also not considered, even though some hedgerows are trimmed (or 'pruned' in fruit tree management terms) while other hedgerows are not managed (see Chapter 4). However, trimming with flails results in the cut material dropping to the base of the hedgerows where it would decay and a proportion of carbon would enter the soil pool. Therefore management would probably make less difference to overall soil carbon levels than if trimmed material was removed and burnt. As with carbon storage, the per hectare accumulation estimates for carbon are calculated for the 0-2 m zone along the hedgerow boundaries. The resulting rates of annual accumulation are small (Table 5.20). Modification of soil carbon accumulation rates to take account of the overlap of hedgerow area and orchard area did not reduce the overall rate for any site, all were greater than the orchard soil rate alone.

5.97 For above-ground carbon accumulation rates, management is assumed to prevent annual accumulation of carbon, even though it is possible that main stems might thicken somewhat, despite material being regularly lost from the hedgerow canopy. For unmanaged hedgerows, the amount of carbon accumulated per hectare, per year, by regenerating woodland at Rothamsted over 120 years was used for lines of trees, ie 1.38 tonnes of carbon per hectare per year (Poulton and others 2003). In the same way as carbon storage for shrubby hedgerows was calculated (paragraph 5.92), hawthorn and hazel biomass accumulation per year up to 1969 was used for estimating carbon accumulation by tall hedgerows (0.51 tonnes carbon / ha / year), medium hedgerows (0.26 tonnes carbon / ha / year and short hedgerows (0.13 tonnes carbon / ha / year). All estimates are calculated for the area occupied by the hedgerows. Results are given Table 5.20 and show accumulation might add to fruit tree amounts to a moderate degree where lines of trees are present, such as the line of trees at Henhope Orchard.

5.98 Estimation of annual greenhouse gas emissions from hedgerow management is limited to fuel use required to trim the hedgerows. Details of hedgerow management can be found in Chapter 4. Figures for fuel use required to flail a hedgerow have been kindly provided by Dr Robert Wolton of Hedgelink and a hedging contractor. To trim a hedgerow of about average size (2 metres high and 1.5 metres wide) which is in good condition, that is, not gappy, 6 passes with the machine are needed to cut both sides and the top. Average fuel consumption is estimated at one litre of diesel per 55 m of hedgerow. In estimating fuel use for trimming the orchard hedgerows, only those hedgerows which are currently managed produce emissions through fuel use. If a hedgerow was trimmed every other year, or every 2-3 years, then the total fuel use was halved, or divided by 2.5 in the latter case, to estimate the appropriate 'yearly' figure. The calculation of carbon dioxide-equivalent greenhouse gas emissions has been made using the same emission factor described in paragraph 5.66 above. Conversion of weights of CO_2-equivalent gases to carbon weight allows an easy comparison with carbon accumulated by the hedgerows. Results are shown in Table 5.20 below.

Table 5.20 Estimated annual carbon accumulation rates, greenhouse gas emissions and net annual sequestration for orchard hedgerows

Orchard	**Henhope (T)**	**Tidnor Wood (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Hedgerow soil carbon accumulation rate in 0-2m zone, tonnes / year	0.042	0.074	0.058	0.033	0.062	0.127
Hedgerow above-ground carbon accumulation rate tonnes / year	0.377	0	0.145	0.122	0	0.000
Total hedgerow carbon accumulation rate in site tonnes / year	0.419	0.074	0.203	0.156	0.062	0.127
CO_2 & CO_2-equivalent emitted tonnes / year	0	0.031	0.008	0	0.019	0.066
Carbon and carbon-equivalent emitted tonnes /year	0	0.008	0.002	0	0.005	0.018
Net sequestration of carbon, tonnes / year	0.419	0.066	0.201	0.156	0.057	0.109

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.99 The hedgerows around each orchard all show a small amount of net carbon sequestration, either because they are unmanaged, as for example at Henhope Orchard, or because the CO_2-equivalent emissions due to hedgerow trimming are more than off-set by the estimated carbon accumulation rate. The results suggest that orchard hedgerows could add to overall sequestration for orchards and their carbon storage and sequestration potential is worth investigating further.

Conclusions for climate regulation by orchard habitats

Orchards

5.100 Soil carbon storage predominated over storage in fruit trees but amounts of carbon in soil were generally not high compared to soil carbon storage in other habitats, such as woodland and permanent grassland. Carbon storage in fruit trees in intensive orchards was comparable to woodlands of a similar age but carbon storage in fruit trees in traditional orchards was much less than storage in woodlands or open grown trees of similar age.

5.101 Soil carbon levels appeared to be significantly affected by land use history. Orchard sites that had been disturbed in the recent past, for example, by arable cultivation, had lower soil carbon levels than orchards that had remained undisturbed. The soils in disturbed orchard sites were probably accumulating carbon from ground vegetation (excluding fruit trees) each year, unlike the soils in undisturbed orchards. However, if soil accumulation rates due to inputs from ground vegetation are considered only from sites which have recently been disturbed, then past accumulation is under-valued in sites where an equilibrium in soil carbon levels was assumed to have been reached by the time of the project. The continued existence of traditional orchards on sites over many decades 'protects' that past build-up of carbon 'capital' even though no further accumulation has occurred. Leaf fall from the fruit trees will add to carbon accumulation by soil if decay rates are lower than inputs from leaf fall.

5.102 Annual carbon accumulation rates per hectare for fruit trees were estimated to be larger in intensive orchards, which had high densities of trees, than in traditional orchards. However, amounts of carbon accumulated in semi-permanent form in fruit trees each year were less than carbon amounts removed each year through fruit harvesting. Fruit production is usually the primary purpose of orchard management but necessitates removal of considerable amounts of the carbon captured by the orchard trees.

5.103 The main annual greenhouse gas emissions arising from orchard management resulted from fuel use by tractors and enteric fermentation by grazing livestock. Comparisons of carbon accumulation per year against carbon emissions, excluding biomass burning, revealed that the intensive orchards and one of the traditional orchards were carbon sinks, while the remaining traditional orchards were small sources of carbon emitted to the atmosphere, largely due to emissions from livestock-grazing management. However, emissions from equivalent grazing regimes on tree-less grasslands would not be off-set by any accumulation by trees, in contrast to livestock grazing in traditional orchards.

5.104 Positive net annual carbon sequestration will only last as long as the fruit trees are in place. When orchard trees are grubbed up at the end of the orchard lifespan, carbon-efficient ways of using the woody material to substitute for fossil fuels would be valuable, together with ensuring as little soil disturbance as is feasible after tree removal, to try to maintain any gains in soil carbon storage that had been achieved while the orchard was in place. Conversion of orchards to other land uses, particularly arable, will lose the carbon accumulated by the trees and be likely to reduce the carbon stored in the soil.

Orchard hedgerows

5.105 Orchard hedgerows have scope to be carbon sinks above and below ground. Trimming management may reduce above-ground storage and accumulation but may allow some accumulation in soil beneath the hedgerow if trimming material is not removed. Lines of trees have the greatest potential to add to the carbon capture from the atmosphere by hedgerow habitats.

Topics for further work on climate regulation by orchard habitats

5.106 Much of the estimation of carbon storage, annual accumulation and emissions in the orchard study relied on assumptions and parallels drawn from other habitat studies. More direct measurements are needed to test these assumptions and results obtained from a wider set of orchards than the current case study orchards so that the role of orchards in climate regulation can be more accurately assessed. Combined, direct, studies of carbon storage amounts and accumulation rates in different carbon pools are necessary to enable better predictions about changes that might occur with a changing climate. More precise measures of the impacts of fuel use and livestock grazing are needed as these two emission sources feature significantly in the orchard study. Ways of minimising these emissions deserve further research.

5.107 Accumulation of carbon in soils through time requires more research, possibly including chrono-sequences in orchards, wood pasture and woodlands to examine potential equilibrium soil carbon levels, including accumulation from leaf fall and woody material. Study of soil carbon accumulation in orchards over longer time spans would give a more balanced picture of overall soil carbon accumulation during the lifetime of the orchard, both before and after any equilibrium level of soil carbon is reached. The potential of hedgerows to accumulate carbon both above and below ground should be further investigated. The examination of chronosequences may be helpful in hedgerow studies as well as for the other habitats already mentioned. The study of soil carbon at greater soil depth than the depth examined in much of the existing work on the topic would be helpful as this ‘missing’ carbon may be among the most resistant to decay. Research into the impact of pruning on fruit tree growth and the implications for biomass estimation would enable better estimates of carbon lost through pruning and the impact on carbon accumulation rates.

5.108 The contribution of orchards to carbon storage, accumulation and emissions across an orchard landscape needs examination. New orchards may be accumulating carbon, even as old orchards are grubbed out and their carbon-capture ability lost. To assess the overall impact of orchards on carbon sources and sinks, the individual budgets for each orchard should be included in a landscape-wide analysis of the contribution of orchards to climate regulation.

5.109 Research into the most carbon-efficient ways to use carbon-containing products from the orchards is needed, especially with reference to pruning material and fruit trees at the end of the orchard life span.

Soil quality and diffuse pollution

Approach to the assessment of soil quality and diffuse pollution

5.110 Detailed direct measurements of soil factors, like microbial activity, or measures of factors affecting diffuse pollution, such as recording of nitrate leaching across the sites, were not within the scope of the project. Instead, a qualitative risk assessment has been made for possible impacts of management on soil quality and potential diffuse pollution problems arising from orchard management. Environmental policies and policy instruments provided the context for the work, while relevant literature was used to guide the assessment of potential impacts of orchard management. Finally, the possible influence of site-specific factors on diffuse pollution risk was examined for the orchards using indicators such as slope and distance to watercourses. Only the main 6 study orchards are covered by the soil and diffuse pollution section. Romulus Orchard is not included in the following assessment.

Orchard soil quality

Definition of soil quality

5.111 Soil quality has been widely recognised as an important concept in land management but has not proved easy to define (Gosling and Bending 2007). In this report soil quality is regarded as the ability of the soil to perform several functions:

- Act as a stable growing medium for food, forage crops and timber.
- Store, filter and transport water.
- Transform and recycle chemicals and organic matter, including provision of plant nutrients and detoxification of pollutants.
- Support soil biota which are actively involved in the functioning of the soil, such as microbes that decompose organic matter.

5.112 These functions have also been equated to various ecosystem services that are supplied by soil (Stockdale and others 2006, Defra 2005a, project SP0546). Many possible indicators have been identified with which to measure soil quality, including amount of organic matter in the soil (Gosling and Bending 2007, Defra 2005a). Given the limited scope of the Herefordshire orchard study, soil organic matter was the only direct measure available for the orchards and its potential significance is discussed below, followed by an examination of the potential impacts of orchard management on the soil biota.

Soil organic matter

5.113 The organic material in the soil derives from the remains of living organisms or material produced by them. Soil organic matter levels are closely linked to soil quality and soil organic matter is fundamental to maintaining a fertile soil (Turbé and others 2010). Soil organic matter provides plant nutrients and is the chief food source for microbes and the organisms which feed on them. Soil organic matter also improves and stabilises soil structure and increases resistance to compaction, thus allowing water and air to move more easily into and within the soil, and increases water-holding capacity of the soil (Reganold and others 2001, Johnston and others 2009, Defra 2000, project SP0306, Turbé and others 2010). In terms of value to farmers, benefits of improving soil organic matter include reduced water-logging of soil, a longer workability window, increased crop yield and reduced fertiliser requirements (GYA Associates undated). Such benefits of soil organic matter have been translated into economic benefits to farmers (Defra 2004a, project SP0310, GYA Associates undated).

5.114 In policy terms, the European Union's (EU) Thematic Strategy for Soil Protection has identified decline in soil organic matter as part of soil degradation across Europe and called for action by Member States (Commission for the European Communities 2006a). Measures to protect soil, including organic matter, are already included in EU cross-compliance conditions under the Single Payment part of the Common Agricultural Policy (CAP) (Defra 2009a) and the agri-environment part of the CAP (Natural England 2009, 2010a, 2010b, 2010c).

5.115 Soil organic matter in the study orchards was recorded and analysed as described in the soil section of Chapter 2. Yara Analytical Services converted the soil organic carbon measured by them to soil organic matter by multiplying soil organic carbon by 1.724, a standard factor used for this conversion (Adrian Dawson, Yara Analytical Services pers.

comm., Defra 2003b, project SP0511). The results are shown in Table 5.21, and are the averages of measurements made for the top 15 cm layer of soil and the 15-30 cm layer of soil. The percent organic matter is given in Table 5.21, as this form of measurement is sometimes used to refer to soil organic matter thresholds, but the amount in tonnes per hectare (ha) is also given in Table 5.21. This measure is more realistic because it takes into account soil bulk density as described in the carbon storage section in paragraph 5.8 above.

Table 5.21 Soil organic matter percentages and tonnes / ha in each orchard

Site	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Soil organic matter in 0-30 cm soil layer, %	4.2	3.55	3.35	5.7	3.4	2.45
Soil organic matter in 0-30 cm layer, tonnes / ha	128.5	80.9	106.5	191.5	81.6	52.9

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.116 Various attempts have been made to define thresholds for desirable levels of particular indicators of soil quality but it has proved to be a difficult task (Gosling and Bender 2007). However, at a Europe-wide level, the EU regards soil organic matter percentages of 0-2% as low and has linked them to the problem of soil degradation described in the Thematic Strategy for Soil Protection (Commission for the European Communities 2006a, 2006b). The depth of soil this percentage relates to is not clear, but all the orchards exceeded this amount of soil organic matter in the 0-30 cm layer (Table 5.21).

5.117 The traditional orchards, except Tidnor, had greater amounts of soil organic matter in tonnes / ha than the intensive orchards (Table 5.21). The possible reasons for these differences are discussed in detail in the carbon section of this chapter above. Land use history appears to have been important, in terms of soil disturbance and the effect this has in causing a reduction in soil organic matter. Orchard soils that had been disturbed in the recent past, for example by arable cultivation, had lower soil organic carbon contents (paragraphs 5.38, 5.39 above). Soil texture may also have been a factor affecting soil carbon amounts (paragraphs 5.11, 5.12). However, one significant on-going difference between traditional and intensive management which has implications for soil quality in orchards was the treatment of ground vegetation in the tree rows. The traditional orchards studied had fully vegetated orchard floors while in the intensive orchards the ground beneath the tree rows was cleared of vegetation by use of herbicides (see Chapter 3 management details). Studies elsewhere have shown that herbicide use along tree rows lowered soil organic matter in the tree rows compared to levels under the grass alleys between tree rows (Merwin and others 1994, Robinson 1975). Thus the capacity of these areas in the Herefordshire intensive orchards to build up soil organic matter from plant remains was likely to have been somewhat constricted.

5.118 An important physical soil property that could be affected by lack of vegetation cover and lower soil organic matter is the susceptibility of the soil to erosion. Defra project SP0519 (2004b) found that, in the upper 0-2 cm layer of soil, stability declined dramatically below a critical level of soil organic carbon, although the level was associated with soil texture and hence differed between soils. The project also found that soils under grassland were more stable than soils that had received minimum tillage or conventional tillage. Bare ground susceptible to erosion may also occur in fully grassed orchards where over-grazing by livestock occurs but this is an accidental outcome of management compared to the deliberate creation of bare ground by management with herbicides in intensive orchards. Overall, soil organic matter levels seem likely to be less favourable and soil erosion more likely in the intensive orchards compared to the traditional orchards. This situation would be likely to persist because of on-going management. Potential implications of reduced organic matter in tree rows on the soil biota are discussed below.

Soil biota and orchard management

5.119 The living organisms in the soil are linked to the ecosystem services that soils provide and are vital to maintaining soil functions (see the review by Stockdale and others 2006). For instance, Jongmans and others (2003) compared two apple orchards, one which had earthworms and one which did not (due to past pollution from heavy metals). They found that in the orchard without earthworms there was restricted incorporation of organic matter into the soil, and soil structure was poorer and compaction worse compared to the orchard with earthworms.

5.120 The differences in organic matter content of soil and presence of bare ground below tree rows in the Herefordshire study sites have potential impacts on soil biota of these orchards. Soil organic matter is the main food resource of soil organisms and there is a strong correlation between total organic matter content and soil microbial biomass (Stockdale and others 2006). Wardle and others (2001) found microbial biomass was greater in soil which was grass-covered compared to herbicide-treated tree rows in kiwifruit orchards, presumably because there was more organic matter 'food supply' in the grass-covered soil. One effect of this difference was a slower rate of litter decomposition in the herbicide-treated ground. Stockdale and others (2006) also noted that bare fallow in a grassland system reduced soil fauna such as earthworms and collembola, but not other groups such as mites. Based on these lines of evidence it is likely that the orchard sites that have suffered recent disturbance, which probably reduced organic matter levels, and orchards where herbicide-treated tree rows are present, may have reduced populations and activity of soil biota.

5.121 The study orchards differ in chemical inputs, the intensive ones receive mineral fertilisers, herbicides, insecticides and fungicides (Table 3.4), whereas no chemical inputs are made to the traditional orchards (see Chapter 3). These orchards could be regarded as being under 'organic' management although only two of them are officially certified as organic (see Chapter 3). As discussed above in paragraph 5.120, herbicides may reduce available organic matter amounts for soil biota but evidence for direct effects of these chemicals on soil organisms is mixed (Stockdale and others 2006). As described in the fungi section in Chapter 4, some soil fungi are susceptible to, while others show tolerance of, phosphinthricin (also known as glufosinate ammonium) the active ingredient of the herbicide used in Salt Box Orchard (Ahmad and Malloch 1995, Pampulha and others 2007). Herbicides may affect the 'beneficial' soil fungi. Beneficial fungi are those which aid control of plant pests or enhance plant nutrition, such as mycorrhizal fungi found in plants roots, including the roots of apple trees. Granger and others (1995) found that the propagules of mycorrhizal fungi in the soil beneath trees of an apple orchard that had been treated with a herbicide (simazine) were reduced in number compared to controls untreated with herbicide. Increase in herbicide application rate was linked to a corresponding decrease in propagule numbers. Other studies have indicated a variable effect of fungicides on beneficial soil fungi. Some beneficial fungi have been deleteriously affected by fungicides, while others have not been affected (Campbell 1989, Sterk and others 2003, Luz and others 2007, and studies reviewed on-line in 2009 by Plant Health Care Inc.).

5.122 Organophosphate insecticides, such as chlorpyrifos, which is used at Salt Box and Village Plum orchards, have been shown to have negative effects on collembola and earthworms and can change bacteria and fungi numbers (Stockdale and others 2006). Reinecke and Reinecke (2007) studied earthworms in a plum orchard and found that chlorpyrifos reduced the biomass of earthworms and inhibited activity of acethylcholinesterase in them, an enzyme necessary for the proper functioning of the nervous system. Direct effects of mineral fertilisers on soil biota have been shown to be variable, and are hard to study because fertilisers change the biomass of the plants and the resultant organic matter, thus causing indirect effects on soil biota (Stockdale and others 2006).

5.123 The impact of a complete management regime on soil organisms may be different than effects found in individual experiments using single chemical treatments, as was suggested for epiphytic lichens (Chapter 4 paragraphs 4.132 and 4.133). Some comparisons of soil biota between organic and intensively managed orchards have been made. There was evidence of greater species richness and density of soil micro-arthropods and predatory mites in organic apple orchards compared to apple orchards with chemical inputs (Doles and others 2001). The authors considered that possible explanations could be the different levels of soil organic matter and / or chemical use in the two types of orchard. In this study, organic matter was added to the soil, whereas the Herefordshire traditional orchards received no such organic amendments. However, Paoletti and others (1995) found that detritivores, earthworms, isopods and predatory carabid beetles were more abundant in apple orchards receiving no chemical or organic additions compared to apple orchards receiving mineral fertilisers and pesticides. In a further study, Paoletti and others (1998) found that microbial biomass did not differ in orchards and vineyards receiving no chemical treatment or high inputs of fungicides and insecticides but earthworm species richness and abundance were greater in low-input orchards. Overall, it seems possible that the Herefordshire study orchards that received chemical inputs may have had a less effective soil biota, although no direct data were available to assess the impacts of chemicals. Clearly, the topic needs much more research.

Orchard management and the potential for diffuse pollution

Definition of diffuse pollution and selection of potential pollutants

5.124 Diffuse pollution occurs when there is no discrete point of pollutant discharge, for example an effluent pipe, and pollution enters the environment by many different pathways (Defra 2002a). The following assessment considers three groups of potential pollutants produced by orchard management: pesticides, plant nutrients (nitrogen and phosphorus) and sediments. Agricultural management, including horticulture, is the main source of diffuse pollution in the UK. Davey and others (2008) give figures of 61% of the total nitrogen load in surface waters in England and Wales and 75% of sediment input being derived from agricultural activity. The main transfer routes of the potential pollutants considered below are drift through the air, surface flow in water and sub-surface movement in water. The possible impacts of these pollutants on water quality and habitat condition of terrestrial habitats in the vicinity of the orchards are outlined and risks of these impacts occurring are assessed. First, the policy context for the discussion of potential diffuse pollution from orchard management in the study area is described.

Policy context for diffuse pollution assessment in the orchard study area

5.125 There are several important and relevant policies related to the health of aquatic and terrestrial ecosystems and of water generally, both at national level and specific to the study area. Under the European Union Water Framework Directive (2000/61/EC), the UK Government must implement measures to control water pollution to achieve good chemical and ecological status for all rivers, lakes, estuaries and coastal waters and good chemical and quantitative status for all groundwater bodies by 2015 (The European Parliament and the Council of the European Union 2000, Defra 2002a, Davey and others 2008). More specific Directives of relevance pre-date the Water Framework Directive. Minimum standards for the quality of the public water supply are laid down in national regulations derived from the EU Drinking Water Directive (98/83/EC, Council of the European Union 1998), including limits on nitrates (50 milligrams / litre (mg / l)) and pesticides (0.5 micromilligrams / litre) (Defra 2002a). The EU Nitrates Directive (91/676/EEC) concerns the protection of surface and ground waters against pollution caused by nitrates from agricultural sources (Council of the European Communities 1991).

5.126 There are geographical expressions of these policies through the designation of Nitrate Vulnerable Zones in the UK and the identification of priority catchments in England for action to meet Water Framework Directive objectives (Defra 2010a). All the orchard study sites lie within Nitrate Vulnerable Zones (Defra 2010b) and are within priority catchments (Defra 2009c, MAGIC 2010). The action programme for the priority catchments is called the Catchment Sensitive Farming Initiative, and aims to reduce diffuse water pollution from agriculture through provision of advice to farmers and a capital grants scheme for pollution reduction measures such as watercourse fencing to exclude livestock and provision of pesticide sprayer loading and wash-down areas (Natural England 2010d). Salt Box Orchard and Village Plum Orchard are in the River Wye priority catchment, while the other sites are within the River Lugg priority catchment, which includes the River Frome. Table 5.24 shows the distance of the orchard sites to the river nearest to each orchard and the river's name.

5.127 The EU Habitats and Species Directive (92/43/EEC) requires the UK Government to maintain or restore priority habitats and species to favourable conservation status by designating and protecting Special Areas of Conservation (SAC) (Council of the European Communities 1992). At national level, statutory conservation areas may also be designated as Sites of Special Scientific Interest (SSSI) under the Countryside and Rights of Way Act 2000 (HMSO 2000). The River Wye and River Lugg are designated as a SAC (River Wye / Afon Gwy) and as SSSIs, but the River Frome is not designated (JNCC 2003, Natural England 2010e). There is a link between SAC designation and the Water Framework Directive. SACs such as the River Wye are recognised as Protected Areas under the Water Framework Directive, which specifically requires compliance with the conservation objectives of the SAC.

5.128 In the Biodiversity Action Plan (BAP) for the UK, priority habitats requiring conservation action, which includes tackling diffuse pollution problems, are listed by the UK Government (UK Biodiversity Action Plan 2007). Hedgerows comprised of native woody species are a priority habitat and occur in all the orchard sites (see Maps 2.2 to 2.8 and habitat survey, Chapter 4). Rivers are also on the list of BAP priority habitats. The Government's Environmental Stewardship Scheme funds management by farmers to conserve BAP habitats. Funded options include creation of buffers along hedgerows and watercourses and reductions in fertiliser application on fields to reduce risk of nutrient enrichment in water bodies (Natural England 2010a).

5.129 These different policy strands indicate the significance of the orchard study area, both in terms of intrinsic conservation value and the urgency of action to tackle diffuse pollution problems.

Potential risks of diffuse pollution from pesticides

5.130 Diffuse pollution from agricultural pesticides derives from the use of chemicals to protect crop plants of all kinds, including fruit trees, from competition from weeds, and from damage from fungal diseases and invertebrate pests. Pesticide diffuse pollution can be transported by surface or sub-surface water and by air in the form of spray drift and volatilization. The latter pathway refers to the evaporation of spray after it has been deposited and is sometimes known as indirect drift (Felsot 2005, Breeze and others 1992).

5.131 Several cases of water and air pathways transferring pesticides outside orchard application areas have been reported in the literature. Surface flow and sub-surface leaching of a fungicide applied to an apple orchard experiment have been detected (Merwin and others 2006). Surface run-off and ground contamination from drift deposits of an insecticide have been found outside a plum orchard (Reinecke and Reinecke 2007). Several projects have shown the movement of spray drift from orchards (Davis and others 1992, Defra 2002b, Defra 2003d).

5.132 The relative amounts lost by these pathways will depend on local conditions but Fox (1998) suggests that about 20%-25% could be lost in drift from pesticide application in orchards. Of the remainder some will be deposited directly on the ground rather than on the trees and be potentially susceptible to loss in runoff. Fox (1998) quotes a figure of 10-15% for the proportion deposited on the ground. Examples of relative amounts of pesticides lost in water are from studies of other agricultural land uses. Felsot (2005) considers that, in general, spray drift is responsible for 10% of the contaminant loads in water bodies compared to loads that are derived from surface runoff. On arable land, Defra (2002a) gives a figure of less than 0.05% of the total applied as a typical amount that will be lost in surface run-off or overland flow, unless there is very heavy rainfall within one or two weeks of application. Through-flow to streams can be as much as 9% but typically is less that 1%, while leaching to groundwater generally is less than 1% but can be up to 5% of amount applied (Defra 2002a).

5.133 Research into the movement of spray drift from orchards has shown that it can be very variable, due to factors such as wind velocity and direction, local shelter effects and size and density of the orchard canopy (Davis and others 1993, Miller 1998, Fox 1998). For example, greater drift was found from orchards early in the year when the fruit tree canopies were not expanded, compared to later in the season when leaf canopies were fully expanded (Defra 2003d). To treat the tree canopies adequately, a spray plume has to be directed upwards and outwards from an air-assisted sprayer and so the potential for drift from these orchard-sprayers is greater than from boom-sprayers which spray downwards onto arable and grass crops. Cross (2010) estimates the amount lost to drift could be 10 to 100 times that of boom-spraying. The distance travelled by drift can be considerable. Spray deposits have been noted up to 300 m from a sprayed orchard (Davis and others 1992). Reinecke and Reinecke (2007) found an insecticide (chlorpyrifos) in soil 500 m downwind of its application in their study orchard.

5.134 The amount of pesticide that reaches particular distances will also be variable not only due to local conditions but also chemical type. Insecticides can have a greater potential for drift because finer sprays are needed to achieve pest control compared to other pesticides (Davis and Williams 1993). However, amounts of spray deposited beyond the fruit tree canopy usually decline rapidly with distance (Defra 2007b). For instance, horizontal collectors on the ground in drift experiments in orchards generally received less than 0.3% of the spray applied to the fruit trees at 30 m distance from them and less than 0.1% at 60 m distance (Fox 1998).

5.135 There is an important difference between amounts deposited on horizontal collectors (which are equivalent in form to surface water) and vertical collectors (equivalent in form to trees and hedgerows). Research has shown that per unit area, deposition is an order of magnitude greater on vertical collectors (Defra 2002b). The researchers suggested that amounts found in horizontal collectors should be multiplied by a factor of 10 to estimate risk for terrestrial plants, and presumably for the organisms living on them.

5.136 The risks that pesticides pose to non-target living organisms will depend not only on the amount of a chemical that reaches particular locations but also on the toxicity of the chemical to different kinds of organisms, the rate of application and frequency and the persistence of the chemical in the environment. Of critical importance is the actual exposure of the non-target organism, for instance a chemical may be highly toxic to a group of animals but individuals of that species may not come into contact with it around the orchard due to their feeding behaviour or they ingest insignificant levels of the chemical.

5.137 The toxicity of the pesticides used in Salt Box Orchard (on cider apples) and Village Plum Orchard (on plums) are shown in Table 5.22 to illustrate the range of potential hazards for selected non-target organisms if they were exposed to damaging levels of such chemicals. The information was derived from manufacturers' product information, food assurance standards for top fruit production (Assured Produce 2006) and best practice guidance for orchard management published by Defra (2001).

Table 5.22 Potential hazards of pesticides to selected groups of non-target organisms from active ingredients of pesticides used at Salt Box Orchard and Village Plum Orchard

	Pesticide active ingredient	Potential hazards to non-target organisms
Salt Box Orchard		
Fungicide (Radspor L)	Dodine	Harmful to fish and aquatic life, harmful and irritant to humans[1]
Fungicide (Alpha Captan)	Captan	Harmful to fish and aquatic life, harmful and irritant to humans[1]
Fungicide (Systhane)	Myclobutanil	Harmful to fish and aquatic life[1]
Insecticide (Alpha Chlorpyrifos)	Chlorpyrifos	Extremely dangerous to fish and aquatic life, dangerous to bees, harmful and irritant to humans[1]
Herbicide (Harvest)	Glufosinate-ammonium	Harmful to fish and aquatic life, harmful to humans[2]
Village Plum Orchard		
Fungicide (Systhane)	Myclobutanil	Harmful to fish and aquatic life[1]
Fungicide (Indar)	Fenbuconazole	Harmful to fish and aquatic life, irritant to humans[1]
Fungicide (Signum)	Boscalid-pyraclostrobin	Very toxic to aquatic life[3]
Fungicide (Teldor)	Fenhexamid	Toxic to aquatic organisms[4]
Insecticide (Equity)	Chlorpyrifos	Extremely dangerous to fish and aquatic life, dangerous to bees, harmful and irritant to humans[1]
Herbicide (Headland Trinity)	MCPA - mecocrop-p - dicamba	Harmful to fish and aquatic life[5], harmful to humans[2]

Sources: [1] Defra (2001), [2] Assured Produce (2006), [3] BASF (2006) Environmental Information Sheet for Signum, [4] Bayer CropSciences (2010) product information for Teldor, [5] A H Marks and Company Limited (2006), Environmental Information Sheet for Headland Trinity.

5.138 The literature provides examples of measurable impacts of pesticides on non-target organisms around orchards and other crop types, through transport routes described above in paragraph 5.129. 'Bioassay' studies have shown insecticide drift can cause mortality of invertebrates, including freshwater invertebrates such as *Asellus aqauticus* (Davis and others 1993, Pinder and others 1993). Effects on plants of herbicide drift can be more subtle, with greater susceptibility among younger plants (Marrs and others 1993) and reduced biomass and fecundity rather than mortality of plants (Gove and others 2007). Drift may be filtered out by structures such as hedgerows (Defra 2003d). Hedgerows may harbour crop pollinators and natural enemies of pests (Jones 1991, Cross 2010). When broad-spectrum insecticides such as chlorpyrifos are used, increased capture of spray by hedgerows could have implications for these groups. As well as carrying potential hazards for non-target organisms, including bees, listed in Table 5.22, chlorpyrifos is also toxic to parasitoids and predatory bugs that are the natural enemies of orchard pests (Defra 2003c).

5.139 A study of the impact of water transport of pesticides at Rosemaund in Herefordshire found that feeding of bioassay freshwater shrimps was reduced and mortality increased after application of pesticides to arable fields upstream of the monitoring site. Chlorpyrifos was one chemical implicated in the effects (Williams and others 1996, Defra 2002a). Transport of the pesticides was mainly via the field drains, even for chlorpyrifos, which had been thought to be relatively immobile. It was probably carried by being adsorbed on to fine soil particles. Most of the transport to the stream occurred soon after significant rainstorms, ie periods with greater than 10 mm of rain in 24 hours (Williams and others 1996).

5.140 Chlorpyrifos is an example of a chemical with some persistence, for example it was found in the soil 6 months after the spraying event in Reinecke and Reinecke's orchard study (2007). It is also the insecticide most used on UK plums (Garthwaite and others 2008). It has been found as a residue on fresh plums in the UK Pesticide Residues Committee testing programme (Pesticide Residues Committee 2007). A very small sample size (5) of UK plums showed that 60% had residues but all at levels below the Maximum Residue Levels defined by EC Regulation 396/2005 (Chemical Regulations Directorate 2009).

Pesticide residues on fruit are another pathway by which pesticides might enter the wider environment, although this route is not usually included in diffuse pollution studies. Disposal of processing waste comprised of pressed cider apples and disposal of un-saleable fresh fruit which does not make the quality grade could be other routes for diffuse pollution to reach the wider environment.

5.141 The Pesticide Usage Survey (Garthwaite and others 2008) shows that in Great Britain cider apples (data presented with data for perry pears) and plums receive fewer applications on average, across all pesticides, than dessert apples. However frequency of application can overlap between types. For example, Village Plum Orchard had similar numbers of insecticide applications (4) as the average for dessert apples in Great Britain (3.9) and more than the average for plums (2.2), while Salt Box Orchard received 17 individual fungicide applications, compared to an average of 15.7 for dessert apples and an average of 6.3 for cider apples plus perry pears (see Chapter 3, Table 3.4). Frequency of insecticide application has been shown to have impacts on wild bees in a study of vine fields in Italy (Brittain and others 2010). The species richness of wild bees was reduced in a zone 125 metres wide around the treated area after 2 or 3 applications but not after one application. No equivalent information on the effects of frequency of pesticide application appears to be available for cider and plum orchards in the UK.

5.142 While individual studies on particular chemicals and organisms have been described in the literature, the impact of the full, yearly, and repeated regime of pesticide use on non-target organisms has received relatively little attention. Brown and others (2006), in a report for the Environment Agency and Pesticides Safety Directorate, carried out a risk analysis by crop type for England in which combined scores for toxicity of pesticides and usage on all of the main crop types on which pesticides were used were calculated to assess potential risk to aquatic organisms. The calculations were based on toxicity data for a test species of aquatic invertebrate (*Daphnia magna*) and algae (generally *Scenedesmus*). Calculations were made for different landscape types and regions. As an example of the difference in results between crop types, for clay landscapes in the West Midlands, summed annual toxicity to *Daphnia magna*, in toxic units / unit area, for top fruit was 47 times that for cereals. Intensive orchards were judged to pose the highest risk among all the crop types.

5.143 One observational study of ditches in orchards in the Elbe river valley showed that the ditches had richer invertebrate faunas in the 1950s, before the time of widespread pesticide use, than in 1978-1980. In the same study, unsprayed ditches in pastures, surveyed in 1980-1981, had a similar fauna to the orchard ditches in the 1950s (Caspers and Heckman 1982). Groups such as beetles (Coleoptera), mites (Acari) and dragonflies (Odonata) were reduced in species number in the ditches of sprayed orchards. Microhabitats in the ditches were similar, although no examination of other factors that could affect faunas, such as nutrient inputs, was carried out. The researchers also observed that fungi which colonise dead aquatic arthropods were lacking in the sprayed orchards. In another study, concerning a headwater catchment containing apple orchards and hop gardens, mortality of bioassay aquatic invertebrates in the stream was found to occur after storm events, and specific groups of sensitive organisms were not found in the natural invertebrate communities in the stream (Defra 2002a). Brown and others (2006) found that ditches around orchards in the Wisbech area were dominated by pesticide-tolerant invertebrate species, although the ditches were atypical compared to most ditches as the water in them was brackish.

5.144 A recent modelling study of pesticide risk for foraging honeybees, based on data for different crop types across Europe, examined the level of risk during the growing season as a function of the active ingredients used and the application regime (Barmaz and others 2010). Generally, risk was higher in sites cultivated with permanent crops such as olives, than sites growing annual crops such as cereals.

5.145 To summarise, the literature on pesticide impacts suggests that the management of the intensive orchards in the Herefordshire study does carry risk, compared to the avoidance of this risk in the unsprayed traditional orchards, in part because impacts can depend on unpredictable factors such as occurrence of significant rainfall events soon after spraying has been completed.

Potential risks of diffuse pollution from nitrates, phosphorus and sediment

5.146 Nitrate, which is very soluble, is the dominant form of nitrogen that causes diffuse pollution in freshwaters and derives largely from inorganic nitrogen fertilisers and from livestock dung and urine (Davey and others 2008). Diffuse pollution by phosphorus from agricultural activity is a major cause of enrichment of freshwaters in England (Natural England 2008). Agricultural activities such as manure and inorganic fertiliser applications to land contribute 22% - 28% to the total phosphorus load entering British waters (Mainstone and others 2008). Nitrate reaches non-crop habitats through surface run-off and through sub-surface flow. It can also reach groundwater through this latter path. Most of the phosphorus in agricultural soils is bound to soil particles and is mainly transported by water in solid form in particles of organic matter or minerals eroded from soil. Excess nitrate and phosphorus in water affects species abundance and diversity of aquatic organisms (Davey and others 2008). Enrichment with these nutrients can lead to algae dominating the plant community, reducing light penetration into the water and thus lowering vascular plant diversity. A high biomass of algae can also cause unpleasant tastes and odours in water and block water filtration equipment. When the algae decay, they can reduce oxygen levels in the water enough to cause fish kills (Defra 2002a). When nitrate levels are above 50 mg / l, water must be treated before it can be used as drinking water (Defra 2002a). Nutrient enrichment can also occur in terrestrial habitats adjacent to fertilised fields, such as hedgerows, and can change plant community composition and abundance of individual species (Kleijn and Snoeijing 1997, Bateman and others 2004). As well as transporting phosphorus, particles of sediment from soil erosion can cause turbidity in receiving water bodies, cutting down light available for aquatic plants. Sediment can also clog the gills of fish and crayfish, smother benthic invertebrate habitats and blanket gravels used as spawning sites by fish (Mainstone and others 2008, Davey and others 2008).

5.147 Assessment of the relative importance of nitrogen and phosphorus enrichment of water in causing deleterious ecological impacts is not straightforward. In terms of algal growth, phosphorus is most likely to be limiting growth, while nitrogen is usually in surplus (Mainstone and Parr 2002). The worst ecological effects of river eutrophication might be avoided by controlling phosphorus inputs alone but full remediation would require control of both nutrients (Mainstone 2010). A recent review has indicated that nitrates remain a problem and that the presence of high levels of both nutrients together can have greater impacts than each nutrient separately (Mainstone 2010).

5.148 In the study orchards, nitrate loss via leaching and runoff is likely to derive from inorganic nitrogen fertilisers, in the case of Salt Box and Village Plum orchards, and from animal dung and urine from livestock in the traditional orchards. Nitrogen input was estimated using management information for the orchards (see Chapter 3) and standard livestock nitrogen excretion factors (MacCarthy and others 2010). Total amounts of nitrogen input per year, and per ha per year, in each orchard are shown in Table 5.23 below. Greater total nitrogen input was estimated to occur in the traditional orchards than the intensive ones, and in terms of input per hectare, with the exception of Tidnor (Table 5.23).

5.149 As with nitrates, sources of phosphorus in the orchards also comprise inorganic fertilisers and animal dung and urine. Table 5.23 gives estimates of phosphorus input in the study orchards from inorganic fertilisers and livestock. In the intensive orchards in the current study, no inorganic phosphorus sources were applied apart from about 1 kg at Salt Box Orchard (13 kg of foliar Croplift, with 13% phosphate). No inorganic phosphorus is applied to the traditional orchards and the phosphorus source here was dung and urine from grazing livestock. Phosphorus inputs have been estimated from standard livestock excretion rates (Carvalho and others 2005) and the stocking levels and periods of grazing in the traditional orchards. Surface runoff containing particles from trampled and dunged bare ground in the traditional orchards is likely to be the main way that phosphorus could be transported away from these orchards, although sub-surface leaching could be another route for transport, as found for other agricultural grasslands managed in a similar way (Defra 2002a). Sediment losses could derive from the bare ground along tree rows in intensive orchards and from bare ground in traditional orchards but no estimates were possible.

5.150 It should be noted that nitrogen and phosphorus levels in animal excrement are affected by a number of factors such as the size of the animal, the nutrient content of feed and the efficiency of absorption into the body (Kirkham 2006, Haygarth and others 2003). The estimates in Table 5.23 are only approximations of the actual amounts of nitrogen and phosphorus inputs.

Table 5.23 Estimates of nitrogen and phosphorus inputs in the study orchards

	Henhope (T)	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Site area ha	4.5	10.3	1.8	2.5	5.4	6.2
Management: livestock grazing or inorganic fertilisers	Sheep	Sheep	Sheep	Cattle	Inorganic fertilisers	Inorganic fertilisers
Livestock numbers	60	40	75	109	0	0
Number of days in year grazed	119	84	98	14	0	0
Fraction of year grazed	0.33	0.23	0.27	0.04	0	0
Livestock Units / ha / year	0.54	0.11	1.4	0.94	0	0
Nitrogen (N)						
N input from livestock or fertilisers, kg / year	199.53	93.90	205.40	253.23	73.29	73.61
N input from livestock or fertilisers, kg / ha / year	44.34	9.12	114.11	101.29	13.57	11.87
Phosphorus (P)						
P input from livestock or fertilisers, kg / year	23.47	11.05	24.16	49.7	1.69	0
P input from livestock or fertilisers, kg / ha / year	5.2	1.1	13.4	19.9	0.31	0
P export to water, using export coefficient of 3%, kg / ha / year	0.16	0.03	0.40	0.60	0.01	0

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Livestock types: Henhope, Tidnor and Lady Close adult sheep; Half Hyde 52 cows, 1 bull, 7 heifers (young cows), 49 calves. Livestock Units (Crofts and Jefferson 1999): Adult sheep (60 kg) 0.125 LU; calf (40 kg) 0.1 LU; yearling beef (heifer) (250 kg) 0.5 LU; adult beef cattle ((550 kg Hereford animal) 1.0 LU. N excretion factors kg / head / year: sheep 10.2; mature beef cows and heifers (bull assumed to have the same input) 79; cattle less than 1 year old 38 (MacCarthy and others 2010). P excretion factors kg / head / year: sheep 1.2; mature beef cattle 17.5; heifers 14.2; calves 5.5 (Carvalho and others 2005). Export coefficient for P from Johnes (1996). Nitrogen input from fertilisers calculated as described in paragraph 5.70 above. Salt Box Orchard receives 13 kg of foliar Croplift / year, containing 13% phosphate. All P treated as total P, ie all insoluble and soluble forms of P.

5.151 Clues as to the possible fate of nitrate from fertiliser inputs in intensive orchards come from work by Merwin and others (1995). In an experimental apple orchard, different treatments of the orchard floor were compared with respect to nitrate runoff and leaching. Herbicide treatment of the tree rows, to create bare ground, led to larger losses of nitrate than from a mown grassland sward treatment. De Deyn and others (2009) found that leaching of dissolved inorganic nitrogen (ammonium and nitrate) was much greater from bare soil than vegetated soil in experimental pots, in both low and high fertility soils. Such findings suggest that the application of inorganic nitrogen to the herbicide-treated ground of the tree rows in the intensive orchards does risk greater nitrogen leaching than from fully-grassed, mown, orchards. However, where such fully-grassed orchards are grazed, like the traditional orchards in the study, the uneven distribution of dung and urine can overwhelm the capacity of plants nearby to take up the nitrate, so high nitrate leaching can occur after rainfall (Wedin and Russell 2007). The potential for nitrate loss thus seems at least to be equal from the traditional orchards compared to the intensive orchards, and perhaps greater due to the higher nitrogen inputs in the traditional orchards per hectare (Table 5.23).

5.152 Loss of sediment, and presumably phosphorus bound to it, has been found to be greater from arable land than grassland, because of the presence of bare ground in arable cropping regimes (Defra 2002c). Modelling of sediment export in the River Lugg catchment showed that sediment loss would be 669 kilotonnenes (kt) per year if the catchment was all arable compared to 230 kt / year if the catchment was entirely pasture (Defra 2002a). The bare ground in arable fields is somewhat similar to the bare ground created along tree rows by use of herbicides in the intensive orchards, although amount of bare ground and disturbance of soil is much less in intensive orchards than arable fields (see paragraph 5.40).

5.153 Erosion can also occur from grasslands. Grazing of livestock close to watercourses has caused sediment input to freshwaters from grasslands, due to trampling by livestock and loss of vegetation cover (Davey and others 2008). Over-stocking by livestock could create conditions for phosphorus and sediment loss from the traditional orchards. Calculation of Livestock Units (Table 5.23) allows some comparison of risks to be made. Livestock Units (LU) standardise the stocking level across different species or categories of livestock, and 1 LU is conventionally defined as equivalent to 1 dairy cow of 600 kg body weight (European Commission undated). Lady Close has the highest LU / ha / year, followed by Half Hyde (Table 5.23). The estimates of stocking rates for Henhope and Tidnor lie around or below those in general recommendations for stocking levels on unimproved neutral grasslands and all stocking rates in the orchards lie below a typical stocking rate of 2 LU / ha on intensive grassland (Crofts and Jefferson 1999). The grassland in Lady Close and Half Hyde orchards appears to resemble MG7 in the National Vegetation Classification, ie species-poor *Lolium perenne* leys and related grasslands (Rodwell 1992), which are characteristic of intensively managed, fertile, grasslands (see Chapter 4, Table 4.8). The habitat survey in 2008-2009 (Chapter 4) recorded localized bare ground in Half Hyde Orchard but a closed grassland sward in Lady Close Orchard. However, over-grazing had been noted in this orchard in a previous survey (see Chapter 4).

5.154 Assessment of risks that agricultural management poses for diffuse pollution of water by phosphorus has concentrated on trying to estimate catchment-level loss rates through modelling (Johnes 1996, Carvalho and others 2005). Such models have tried to estimate general proportions of phosphorus lost from different sources and entering the surface drainage network. These estimates are known as export coefficients (Johnes 1996). To give a rough idea of how the orchards might contribute to catchment input, a general export coefficient of 3% (Johnes 1996) has been applied to the phosphorus inputs to the orchards, to calculate the resulting potential loss of phosphorus from them in kg / ha / year (Table 5.23). Background rates of phosphorus export from land to rivers vary widely due to catchments differences such as underlying geology (Mainstone and Parr 2002). However, these authors have made some estimates of export rates for total phosphorus that would result in different concentrations of phosphorus in river water for a range of river systems modified by human activity. Rates of loss of 0.2 – 0.3 kg total phosphorus / ha / year from land should allow ecologically desirable concentrations of phosphorus in these rivers to exist (Mainstone and Parr 2002). On this basis, Lady Close Orchard and Half Hyde Orchard appear to have the greatest potential diffuse pollution risk for phosphorus as they have estimated loss rates greater than these levels of 0.2 - 0.3 kg / ha / year (Table 5.23).

5.155 To examine the relative importance of nutrient inputs and potential losses in the orchards compared to other agricultural land uses, information on inputs of nitrogen and phosphorus from different sources and on different land use types has been collated in Table 5.24. Average nutrient inputs have been mostly derived from the British Fertiliser Practice Survey (Defra 2010c) but some were calculated from several 'land use scenarios' of typical management regimes in Defra project BD2302 (Defra 2007a). For consistency, the same livestock excretion factors from MacCarthy and others (2010) and Carvalho and others (2005) used in Table 5.23 were used for the scenarios in Table 5.24. Nutrient content of farmyard manure and slurry given in Defra (2010d) were used for calculating the nutrient content of these applications in Table 5.24.

5.156 The small sample of fertiliser use in top fruit orchards showed that top fruit category had the highest phosphorus input among the land use types, though the average was heavily influenced by 10 sites which had 100-125 kg / ha applied to them. 64% of sample sites received no phosphorus input but do not feature in the average which only relates to land receiving fertiliser (Defra 2010c). The Fertiliser Practice Survey (Defra 2010c) does not give nutrient totals for inorganic and manure inputs combined. Occurrences of both types of input are given in the report though, and show that on grassland in particular, both types were frequently applied together. For example, 45% of grassland 5 years old or older received both inorganic and organic inputs (Defra 2010c). However, inputs from dung and urine from grazing animals were not included in any of the inputs. The land use scenarios give some idea of the input from all these sources of nutrients (Table 5.24).

Table 5.24 Examples of nitrogen and phosphorus inputs to agricultural land

Land use	Average nitrogen input kg / ha / year	Average phosphorus input kg / ha / year
Top fruit, inorganic fertiliser (of 40 samples, 36 received N, 14 received P) [1]	73	89
Winter wheat, inorganic fertiliser[1]	190	54
Grassland under 5 years old, inorganic fertiliser[1]	117	29
Grassland 5 years old and over, inorganic fertiliser[1]	92	21
Grassland, grazed not mown, inorganic fertiliser[1]	79	18
Grassland, cut for silage, not grazed, inorganic fertiliser[1]	138	32
Winter sown crops, cattle farmyard manure[1]	150	80
Grassland, cattle farmyard manure[1]	108	57.6
Grassland, cattle slurry[1]	83.2	38.4
Winter wheat scenario, inorganic nitrogen and phosphorus[2]	220	63
Pasture scenario, inorganic nitrogen and phosphorus and dung/urine from grazing dairy cattle[2]	216.7	54.3
Grassland cut for silage scenario, inorganic nitrogen, farmyard manure and slurry[2]	258	84

Notes: [1] Figures from Defra (2010c), average field rates kg / ha for Great Britain, 2009. Average relates to the total area that receives that particular nutrient, unfertilised land area is excluded. Average organic manure application rates from (Defra 2010c), multiplied by nutrient contents from Defra (2010d). Crops and grass may receive both manure and inorganic fertilisers, but combined data not available from Defra (2010c). [2] Management information, inorganic fertiliser rates, stocking rates and applications of farmyard manure and slurry from Defra (2007a); nutrient inputs from grazing animals using MacCarthy and others (2010) for N, and Carvalho and others (2005) for P. N and P content of farmyard manure and slurry from Defra (2010d). All P treated as total P, ie all insoluble and soluble forms of P.

5.157 Compared to other agricultural land uses, and other top fruit orchards, the nitrogen and phosphorus inputs to the intensive and traditional orchards are relatively low. Inputs of nitrogen and phosphorus in the intensive orchards, Salt Box and Village Plum (Table 5.23), are less than any of the examples in Table 5.24. Among the traditional orchards, only Half Hyde Orchard had a phosphorus input close to any of the examples in Table 5.24, and these are all for inorganic fertiliser inputs on grassland, so do not take into account any organic inputs from manures or grazing animals. The British Fertiliser Practice Survey (Defra 2010c) reports that 93% of fertilized grasslands were grazed, thus the two sources of inputs would usually be present on these grasslands. Similarly, nitrogen inputs from all the orchards were lower than the examples in Table 5.24, with the exception of Lady Close and Half Hyde (Table 5.23), but inputs from either grazing animals or other fertiliser types were not included in the examples in Table 5.24 which had lower nitrogen inputs than Lady Close or Half Hyde orchards.

5.158 Results from field studies into subsurface leaching of total phosphorus (Defra 2002a) provide further information for judging the impact of different types of grassland management, though the environmental conditions in the study catchments were not specified. Quoted figures for loss rates are: 0.17 kg / ha / yr from unfertilised pasture, 0.71 kg / ha / year from pasture receiving 50 kg / ha inorganic phosphorus fertiliser, 2.91 – 3.58 kg / ha / year from permanent grasslands receiving intensive cattle slurry inputs, dairy cattle and sheep grazing and cutting for silage, 3.47 – 5.03 kg / ha / year from permanent grasslands receiving 25 kg / ha inorganic phosphorus fertiliser, intensive cattle slurry inputs, dairy cattle and sheep grazing and cutting for silage. All these rates, with the exception of unfertilised pasture, are above the rates of 0.2 – 0.3 kg total phosphorus / ha / year that are considered to allow ecologically desirable concentrations of phosphorus to exist in the rivers described by Mainstone and Parr (2002).

5.159 In summary, potential risks of nutrient and sediment losses seem relatively small in the study orchards compared to other agricultural land uses. Management of the intensive orchards and Lady Close and Half Hyde orchards was probably most likely to cause diffuse pollution, due to the amounts of ground managed to be bare of vegetation in the intensive orchards and the nutrient inputs from livestock, and their capacity to create bare ground when high stocking levels are present, in the two traditional orchards.

Site factors: Topography and hydrology

5.160 The topographic and hydrological characteristics of individual study sites and their surroundings will affect the potential for water transport of diffuse pollution and will influence the impact of pollutants on other habitats. The locations of the study orchards are random with respect to topography and hydrology. However, the situations of individual sites can illustrate potential site-specific risks in the form of examples. Slope and distance to water bodies are indicators of likelihood of diffuse pollution influenced by topography and hydrology and are given for the study orchards in Table 5.25 below. The slopes of the sites were measured using contours on the digital Ordnance Survey MasterMap, and spot altitudes on digital aerial photographs on a Geographic Information System (GIS). The GIS was also used to make two distance measures for each site. The distance of each site from open water was measured from the edge of the site to water features mapped on the OS MasterMap. Distances to the nearest river, as shown on the OS MasterMap, were also measured from the edge of each site. The indicators in Table 5.25 were chosen because steeper slopes may lead to greater surface water and sediment movement and water bodies closer to the orchards would be likely to most vulnerable to water-borne diffuse pollution from the orchard.

Table 5.25 Gradient of slopes in each orchard and distance from the edge of each site to the nearest open water body and to rivers

Site	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
General slope across site (%)	13	12	9	15	5	c. 0 (ridge)
Range of slopes (%)	9-80	2-27	5-17	7-46	3-22	west-facing slope 5-16; east-facing slope 5-12
Distance to nearest mapped open water, m	345	90	45	145	0	10
Distance to river, m (river name)	1200 (R. Frome)	260 (R. Lugg)	350 (R. Lugg)	480 (R. Frome)	0 (R. Wye)	450 (R. Wye)

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

5.161 By chance, Salt Box and Village Plum Orchards, which are intensively managed, are closest to open water bodies. Salt Box Orchard is immediately adjacent to the River Wye. The western edge of Village Plum Orchard is close to Luke Brook, which drains into the

River Wye. Another hydrological factor, the volume of water in the receiving water body, may also influence the impact of diffuse pollution. A small stream like Luke Brook would be likely to be more affected than the River Wye, say by pesticide drift deposits.

5.162 In all the orchards, some of the slopes are within the range of 8-10% slopes in the study by Merwin and others (1995), described above, while slopes in some of the study orchards were steeper (Table 5.25). Merwin and others (1995) considered that their study indicated that nitrate and fungicide leaching was a possibility from orchards on moderate slopes of 8-10%. Potentially, nitrate could reach the River Wye or Luke Brook from the intensive orchards in the Herefordshire study, but the intervening grassland between tree row treatment areas and the watercourses (see buffer widths in Table 5.26 below) would be likely to limit the nitrate lost, as discussed in paragraph 5.151 above. Among the traditional orchards, where distances to water bodies are greater, any water pollution seems even less likely. However, Tidnor and Half Hyde orchards have BAP priority hedgerows in the receiving position at the bottom of the slope at each site and the hedgerow flora could potentially suffer enrichment (see Maps 2.3 and 2.5, Chapter 2, boundary 1 at Tidnor and boundary 2 at Half Hyde). Another hydrological factor that depends on the site location in the landscape is flooding. The owner of Salt Box orchard noted that the lower part of the orchard is sometimes flooded by the River Wye. Such flooding could potentially allow transport of pesticides, nutrients and sediments beyond the orchard.

Site factors: buffers for adjacent habitats

5.163 The impact of orchard management on adjacent habitats can be mitigated by buffers. Buffers are areas of land established with the aim of reducing the impact of agricultural operations on adjacent habitats (Burn 2003). With regard to diffuse pollution, buffers can reduce the impact of pesticide drift and loss of pesticides, nutrients and sediments in surface water. Ideally, a “no-observed effect concentration” for pollutants would obtain beyond the buffer. The width of buffers necessary to obtain this level has been studied by bioassay in the case of pesticide drift in research reported in the literature (Davis and others 1993, Marrs and others 1993). In practice, exact widths are difficult to specify, given the variability of factors such as wind speed that affect individual spraying events, and differences in toxicity and application rate of pesticides. Generally a range is specified in the literature. For example, Gove and others (2004) looked at the effect of glyphosate drift on woodland plants and suggested that buffers of 5-10 m width would protect these plants from the most damaging effects of drift. Davis and others (1992) did a bioassay with *Pieris brassicae* larvae exposed to orchard spraying of insecticides (cypermethrin and carbyl). At wind speeds of 2 - 3.5 metres per second, there was 50% mortality at 20-25 m distance and 10% mortality at 50 m, while beyond this mortality was no different compared to unsprayed larvae. The researchers recommended a buffer of 50-60 m, given that conditions during the experiment were not considered particularly “drift-producing”. Marrs and others (1992) studied effects of herbicide drift from a ground sprayer and suggested that buffer zones of 6-10 m would be adequate to protect established plants, but a buffer of at least 20 m would be needed to enable regeneration by seedlings.

5.164 Buffers can also reduce loss of pollutants in surface water. Grass buffers have been shown to slow and spread runoff, enhance filtration and retention of sediment and associated nutrients and pesticides (Wood and others 2007, Dillaha and Inamder 1997, Uusi-Kämppä 1997, Correll 1997, USDA 2000). Variability in effectiveness is again influenced by local factors, such as soil texture. Grass buffers are less effective at trapping fine particles, for example from clay soils, compared to coarse particles in sandy soils, and slope angle can also be important (Wood and others 2007). Trapping efficiency of buffers is generally improved by greater buffer width and wider buffers are needed to trap soluble compounds like nitrate compared to buffer widths needed to trap sediment (USDA 2000). In heavy rainfall events however, buffers can be overwhelmed by flow that becomes channelized through the buffer. Buffers can also be by-passed by sub-surface drains and surface ditches (Wood and others 2007).

5.165 Salt Box and Village Plum orchards provide examples of buffers that could reduce the effects of pesticide drift, and of other potential pollutants. The buffers are predominantly composed of closed grassland, though tall herbs and bare ground along tracks also occur in these zones. Buffer widths between the fruit trees and the adjacent boundary are shown in Table 5.26. Buffer width and boundary lengths were measured using digital aerial photographs on a GIS. Buffer width was calculated as an average and as a range of widths at 5 equidistant points along the boundary.

Table 5.26 Buffer widths around Salt Box Orchard and Village Plum Orchard

Site	Length of boundary, m	Average buffer width, m	Range in buffer width, m
Salt Box			
Boundary 1 (BAP hedgerow)	244	9	6-14
Boundary 2 (fence, part adjoining woodland)	206	9	5-20
Boundary 3 (River Wye)	188	18	12-25
Boundary 4 (BAP hedgerow)	431	13	8-26
Village Plum			
Boundary 1 (BAP hedgerow)	196	7	3-14
Boundary 2 (BAP hedgerow + fence)	336	6	2-9
Boundary 3 (BAP hedgerow)	84	4	3-7
Boundary 4 (hedgerow + fence)	229	9	5-13
Boundary 5 (BAP hedgerows, 10 m from Luke Brook)	168	6	4-7
Boundary 6 (BAP hedgerow)	276	7	4-15

5.166 There are regulations governing buffer widths required next to watercourses when air-assisted orchard sprayers are used. On a pragmatic basis, the Local Environment Risk Assessment for Pesticides (LERAP) procedure sets out what buffer zone widths for watercourse protection are required for certain chemicals, applied at particular rates (Defra and Pesticide Safety Directorate 2002). As an example, both Salt Box and Village Plum orchards conform to the buffer required for chlorpyrifos. Normally an 18 m buffer is required but at the rates used, 50% and 25% of full rate for Salt Box and Village Plum respectively, buffer widths can be reduced to 12 m for Salt Box and 7 m for Village Plum. The buffer along the River Wye at Salt Box is 12m at a minimum and on average 18 m wide. The buffer at Village Plum between the fruit trees and Luke Brook is 14 m at a minimum and 16 m on average (Table 5.26). Buffer widths between hedgerows or woodland and the fruit trees are narrower, particularly at Village Plum Orchard and there could potentially be some effects on these adjacent habitats. Even the River Wye and Luke Brook could receive spray drift in adverse circumstances, such as a sudden increase in wind speed, while orchard spraying is in progress. The rapid change in wind speed that can occur during spraying operations is illustrated by an orchard spraying study described in the literature, where wind speed varied either side of the average speed by 2 metres / sec within a 20 minute period (Davis and others 1992). The Fruit Sprayers Handbook (British Crop Protection Council 1992) recommends that no spraying be done when wind speed exceeds about 2.6 m / second, the same as the limit given for ground spraying (Defra and others 2006). Given the greater drift from orchard sprayers there seems to be little margin for error with regard to unfavourable spraying conditions.

5.167 Other mitigation measures are becoming available for reducing risk from pesticide use in orchard management although none are currently in use in the study orchards. Development of these mitigation techniques is an active research area (Cross 2010). Research has been carried out on sprayer technology and spraying practice to reduce the movement of chemicals beyond the orchard. Topics included changing the pattern of spraying on outer tree rows (Defra 2002b), a review of low-drift sprayers (Defra 2009d), methods to adjust pesticide doses to the growth state of the particular orchard to reduce amounts used (Defra 2007c) and experiments with tunnel sprayers (Fox 1998). 'Integrated' pest management (IPM) is being pursued and covers a wide range of techniques, including use of selective rather than broad spectrum pesticides, often in conjunction with monitoring of pests to ensure that spraying is only done when pest populations reach problem levels (Blommers 1994). Reduction in use of broad spectrum pesticides can encourage increases in natural arthropod enemies of pests, both predators and parasitoids (Cross and others 1999, Pekár 1999). Other management can also encourage increases in natural enemy numbers, such as planting herbaceous plants that are attractive to these invertebrates (Bostanian and others 2004). Biological control of pests is also tackled by introducing bacteria (*Bascillus thuringiensis*) and viruses such as codling moth, *Cydia pomonella*, granulovirus. However, the Pesticide Usage Survey for Great Britain (Garthwaite and others 2008) showed that, as yet, these microbial biological controls were only applied to a small proportion of orchards (less than 5%). Disruption of mating behaviour of pests is another recently developed technique, whereby pheromones are used to reduce mating success of pests such as codling moth (Cross 2010).

Conclusions for soil quality and diffuse pollution potential in orchard habitats

5.168 The traditional orchard study sites were judged to have had a greater potential to maintain higher soil organic matter status than the intensive orchards, given that these orchards had bare ground along tree rows, with implications for greater activity of soil organisms and lower soil erosion potential in the traditional orchards. Management with pesticides in the intensive orchards possibly might have possibly resulted in soil biota being less effective in provision of soil-based ecosystem services than in the traditional orchards.

5.169 The literature suggests that use of pesticides in intensive orchards poses greater potential diffuse pollution risks than their use in other agricultural land uses, due to the total toxicity and amounts of pesticide applied and the need to apply pesticides by air-assisted sprayers. Pesticide use also carries risk in terms of diffuse pollution due to unpredictable factors beyond human control, such as occurrence of rainfall events after spraying has been done, for orchards and for other crops treated with pesticides.

5.170 Risk of diffuse pollution of adjacent habitats by nutrients or sediment was judged to be likely to have been relatively low for the orchards compared to other agricultural land uses. However, the presence of bare ground along tree rows in the intensive orchards and high stocking rates in two of the traditional orchard sites could have exacerbated any loss of nutrients or sediment from these orchards.

5.171 The potential for diffuse pollution will be affected by local site-specific factors such as slope and distance of the orchard from watercourses and other sensitive habitats. Buffers in the intensive orchards may have helped to mitigate risk of potential damage from diffuse pollution from pesticides but were not likely to have removed this risk entirely.

Topics for further work on soil quality and diffuse pollution potential in orchard habitats

5.172 Greater understanding of the effects of pesticides on soil biota and the ecosystem functions they provide is needed. The effect of the whole regime of pesticides used in orchards on non-target organisms in soil and off-site habitats needs further study, including long-term effects. More information on the potential for soil erosion and nitrate loses from orchards would be helpful, along with better knowledge of the relative success of buffers in reducing diffuse pollution from orchards. Other measures that may reduce diffuse pollution of pesticides should also continue to be investigated and developed, such as use of biological control of pests and technical and operational methods of reducing spray drift.

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6 Orchards and people

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Introduction

6.1 The role of orchards in communities has been well established through the work of Common Ground, for example the organisation's active encouragement of community orchards (Common Ground, 2000). However, the Herefordshire Orchards Community Evaluation Project appears to be the first time that structured, direct, interaction with visitors and local communities has been undertaken to ascertain the importance of orchards for people who are not necessarily directly engaged with orchards. The assessment of the social value of orchards was carried out by seeking the views of a range of different groups; general visitors to Herefordshire, visitors to one study orchard (Lady Close), people making an active contribution to the conservation of another of the study orchards (Tidnor Wood), and local communities living around each of the 6 study orchards. Their opinions also provided the basis of the monetary assessments made in Chapter 7. The studies of general visitors and people more actively engaged in the two orchards are explained first. These studies were conducted through the use of questionnaires and were of a limited scale. However they provide some appreciation of the interactions between orchards and people with different levels of engagement with orchards. This is followed by the findings of an investigation of the values attached to orchards by people who live close to them. This formed the main part of the work and was conducted during local community evenings. By analysis of findings and drawing comparisons between the different groups, this chapter considers the importance of orchards for people and implications for future activity.

Assessment of the importance of orchards for visitors to Herefordshire

Background to the survey of views of general visitors

6.2 Tourism is important for Herefordshire. The County's Tourism Strategy 2002-2007 (Herefordshire Council, 2002) states, "The mission for tourism in Herefordshire is to drive forward the quality, competitiveness and wise growth of tourism in Herefordshire, supporting the economic success of the area and considering the distinct landscape, heritage and culture of the County…" (p.6). The *Visit Herefordshire* Business Plan 2007-2010 reports that there were 4.8 million visitors in 2006, spending over £290 million. (Herefordshire Council undated). The importance of orchards *per se* is not explored in significant detail in the Tourism Strategy but it recognised that the Herefordshire Cider Route has provided a focus for visitor interest in cider-making and orchards in the County. The Route encourages tourists to visit cider producers around the County to sample ciders and to see the cider-making process. The Route is supported by a website publicising cider events and cycling and driving tours of cider producers and sellers (Herefordshire Cider Route undated). The Tourism Strategy recommended that there needed to be more investment in the link between landscape, land management and visitor, including supporting initiatives that improve or maintain the orchard landscape. Some of the key attractions noted in the strategy related to orchards through cider making: Hereford's Cider Museum (14,070 visitors in 2000) and Dunkerton Cider Mill (9,000 visitors in 1999) (Herefordshire Council 2002). However, the promotion of the tourist potential of Herefordshire's orchards themselves is not included in the list of key priorities in the current Business Plan.

Views of general visitors about orchards: survey and results

6.3 A small structured survey was conducted of the views of people visiting Hereford Tourist Centre in Hereford city centre on five days during May, June and August 2007. The survey was conducted at different times of the day during weekdays. The days chosen were not statistically randomised. The intention was to help to understand the importance of orchards in Herefordshire to general visitors, particularly as part of the landscape. In addition, the contribution of orchards to the economy, environment and society and the relative value placed by visitors on different types of orchard were assessed. The contents of the questionnaire used for the survey are contained in Appendix 4. Visitors during blossom time in the Spring and harvest time in the Autumn are more likely to have a specific interest in orchards or their produce. Therefore, to discover the views of the more general visitor to the County, the survey was conducted during the summer months, to avoid these times. Up to 5 visitors were interviewed on each of the days, with survey periods lasting 2 to 4 hours. All visitors to the Centre during the survey period were asked to participate. A total of 23 people were interviewed.

6.4 The survey found that 30% of respondents lived in Herefordshire, 44% elsewhere in the UK and 26% came from overseas. The reasons for their visits were equally spread across culture, enjoying natural beauty, undertaking activities, visiting friend or family, and business. A number of other reasons were also cited, such as the availability of cheap accommodation or shopping opportunities. Interviewees were asked to rank the three landscape features most important to them as a visitor. To analyse the results the top ranked feature was allocated three points, second-ranked two points and third-ranked one point. Rivers, hills and woodlands scored significantly higher than other features (see Table 6.1) and orchards scored the lowest. Only one person (a visitor from Devon) put orchards into their top-three landscape features. Even towns, cited by two interviewees as another ‘landscape’ feature, scored higher. This somewhat surprising result possibly may have arisen because orchards are a relatively specific landscape use, and visitors implicitly considered them when making their choice of features such as hills (which may have orchards on them) or woodland.

Table 6.1 Ranking of landscape features in Herefordshire

Landscape feature	Score	Percentage of total score
Hills	30	26
Rivers	30	26
Woodland	17	15
Fields	13	11
Hedgerows	6	5
Other: General	6	5
Other: Town	6	5
Parkland	4	3
Other: Ponds	3	3
Orchards	1	1

6.5 Given the low ranking of orchards as landscape features, not surprisingly the survey showed that orchards were not very important in a visitor’s decision to visit Herefordshire. Among the visitors surveyed, 87% said that orchards were not at all important. Indeed, some people did not realise that there were orchards in Herefordshire and only 30% of the visitors questioned had even noticed an orchard during their visit. Only two people had noticed Half Hyde or Salt Box Orchards (when shown the photographs in Plates 6.1 and 6.2), despite these orchards being adjacent to the main Worcester and Brecon roads, respectively.

Plate 6.1 Half Hyde Orchard

Plate 6.2 Salt Box Orchard

6.6 However, few of the visitors had travelled down those roads to arrive at Hereford, and one came in the dark, so this is not a good indicator of the true visibility of these orchards. Furthermore, it must be remembered that this survey was deliberately timed for early summer, outside of blossom and fruit time, to capture the views of the general visitor to Herefordshire. At that time of the year the orchards will not have been as noticeable as they are in the photographs, particularly when people were travelling past in a car at speed. One respondent, a Herefordshire resident, had visited Lady Close Orchard at Bodenham and liked the visitor information there. This was the only specific orchard to have a positive impact on a visitor.

6.7 Only 13% of visitors had actually walked in an orchard with one person answering that they had not realised that the public could sometimes walk in orchards, but that they would like to walk in them. A number of visitors recommended that public access and signage be improved.

6.8 From a pre-determined list of economic, environmental and social sectors, visitors were asked to choose to which sector orchards contribute most, ie their primary contribution. Although the terms used for these sectors were not specifically defined on the questionnaire, few people had any difficulty deciding on the appropriate category. The questionnaires were completed in the presence of, or their answers were written down by, the interviewer who was therefore able to offer (non-standardized) clarification if required. By far the most important contribution was perceived to be the contribution of orchards to the local economy (see Table 6.2), followed by the contribution to nature. The role of orchards in heritage, views and leisure were not rated highly.

Table 6.2 Assessment by general visitors of the contribution of orchards to economic, environmental and social sectors in Herefordshire

Primary contribution of orchards to:	Number of votes	Percentage of total votes
Local economy	14	54
Nature	7	27
Heritage	2	7
Views	1	4
Leisure	1	4
Other	1	4

6.9 Visitors were asked to look at photographs of a traditional, bush and remnant orchard (see Plates 6.3, 6.4 and 6.5) and asked the following question: “In Herefordshire, there are broadly three types of orchard. If there was £100,000 available to support orchards in Herefordshire, please decide how you would like this to be shared between the types: Bush orchards, traditional orchards, remnant orchards.” This question was intended to elicit a proxy of relative value of each type of orchard, either to preserve or to enhance the landscape feature. “Bush orchard” was used by the survey as a simple descriptor for orchards that are managed intensively.

Plate 6.3 Bush orchard

Plate 6.4 Traditional orchard

Plate 6.5 Remnant orchard

6.10 The results are given in Table 6.3. People wanted most money to be spent on traditional orchards – but they also wanted bush orchards to be supported due to the perception of their more efficient and orderly role in fruit production.

Table 6.3 Allocation of "funding" by general visitors to different types of orchards

Type of orchard	Share of financial pot (%)
Traditional	60
Bush	25
Remnant	15

6.11 The overall conclusion is that orchards are not of particular significance themselves in encouraging visitors to come to the County. However, it is perhaps more realistic to regard orchards as part of Herefordshire's rich landscape. Herefordshire's Tourism Strategy describes this landscape as "Quintessentially English and deeply rural countryside" and goes on to include orchards as part of this landscape: "Herefordshire is arguably the most rural County in England. The landscape of rolling hills, small woodlands, hedgerows, orchards, hop yards, meadows and cultivated fields still provides a rich resource for rural tourism" (Herefordshire Council, 2002, p.26). The main reason that orchards exist is understood to be because they are part of the agricultural economy.

Assessment of the importance of orchards for visitors to Lady Close Orchard

Information about the orchard and accessibility

6.12 At Bodenham Lake Nature Reserve, in which Lady Close Orchard sits, visitors are encouraged to visit through easy car parking and access. Lady Close used to be a remnant orchard, comprised of a few old and decaying trees, but has now been restored as a traditional orchard, through the planting of young fruit trees by Herefordshire Council. Display boards on site explain about the Reserve. In Lady Close Orchard itself, there are two boards, one about orchards in general and another identifying the varieties of apple and pears that grow on the trees in the Orchard. Although the location of the Nature Reserve can be found on the Herefordshire Council website (Herefordshire Council 2011), the site is not advertised heavily because of difficulty in car access from the A49 trunk road. Despite this, Herefordshire Council's logging of cars entering the Bodenham Lake Nature Reserve shows that 12,979 cars entered the car park in the year May 2006 to April 2007, and 11,898 cars entered the car park in the previous year.

Survey of views of visitors to Lady Close Orchard

6.13 A small survey of visitors arriving at the car park was carried out on 24 May 2007. The contents of the questionnaire are contained in Appendix 5. It was designed to incorporate information to allow a valuation based upon the travel cost of visitors to be calculated. This monetary valuation is included in Chapter 7 and is used as a second estimate against which to check of the calculation of the overall tourism value of orchards. All the visitors observed arrived in cars, which mostly contained one person with a dog. Where more than one person arrived in a car, they were interviewed together and treated as a single interview. Although terms were not defined in the questionnaire, the surveyor was available to offer explanation if required. The occupants of a further five cars entering the car park did not leave their cars and therefore were not interviewed, but presumably the overall environment still attracted them to the car park.

6.14 The survey found that all visitor cars (10 in total) had come from Herefordshire, and 30% of them came from Bodenham village. The average distance driven to get to the orchard was just 2.3 miles. 60% of the groups interviewed visited the Reserve daily and 20% at least weekly. Visitors were asked to select as many reasons as they felt appropriate from a pre-determined list of reasons for visiting. Access for exercise (people or dogs) was the reason most often given for visiting, in total 38% of visitors came for this reason (see Table 6.4).

Table 6.4 Interviewees' reasons for visiting Lady Close Orchard

Reasons for visit to the orchard	Number of votes	Percentage of total votes
To exercise the dog	9	23
To observe nature	8	20
For exercise	6	15
Accessibility	6	15
Car parking	6	15
To observe the trees in the orchard	3	7
Orchard information	2	5

6.15 It was apparent that visitors were attracted to the overall facility at the Nature Reserve, of which Lady Close Orchard is only a part. 60% of people nearly always walked in the Orchard, and 70% reported that the Orchard was moderately or highly important to their visit. From observation, it appeared that most people crossed the Orchard during a circular walk incorporating the lake shore. It is interesting to note that only 20% of respondents said that they had walked in any other orchards. They did not know of other orchards that have public access.

6.16 When asked what economic, environmental and social sectors orchards in general contributed the most to, visitors to Lady Close Orchard perceived nature to be the most important (see Table 6.5). Each visitor or visitor group was asked to select only one sector from a pre-determined list.

Table 6.5 Assessment by visitors to Lady Close Orchard of the contribution of orchards to economic, environmental and social sectors

Primary contribution of orchards to:	Number of votes	Percentage of total votes
Nature	4	40
Local economy	3	30
Heritage	2	20
Views	1	10
Leisure	0	0

6.17 Despite the fact that the interviewees were walking in an orchard at the time of questioning, none said that orchards contribute most to leisure. However, this question was not specifically about their perception of the role of Lady Close Orchard, but rather about orchards generally.

6.18 The visitors' allocation of a notional pot of funding to bush, traditional or remnant orchards showed that traditional orchards attracted most support (Table 6.6). Again this was a question about orchards generally, although the visitors' answers may reflect their views on Lady Close Orchard specifically, which was probably seen as a traditional orchard rather than a remnant orchard due to the recent replanting to fill in gaps.

Table 6.6 Allocation of "funding" by people visiting Lady Close Orchard to different types of orchards

Type of orchard	Share of financial pot (%)
Traditional	56
Bush	25
Remnant	19

6.19 From the limited surveys conducted, it can be concluded that this orchard is appreciated primarily as part of a regular dog walk by local people in a varied natural environment which offers easy access and a car park. The fact that none of those questioned had searched out public access into other orchards tends to confirm that the orchard itself is not an important draw.

Assessment of the importance of orchards to sponsors of trees in Tidnor Woods Orchards

Tidnor Woods Orchard Trust tree sponsorship scheme

6.20 Tidnor Wood Orchards Trust makes specific efforts to involve people in the Orchards through its tree sponsorship scheme. The Orchards house the National Collection of cider apple varieties (Tidnor Wood Orchards CIC undated). Over 400 varieties have been planted in the Orchards during the last 7 years. Tree sponsors pay £60 to sponsor a tree for its lifetime.

Survey of views of tree sponsors

6.21 A postal questionnaire was sent to all tree sponsors in 2007. The contents of the questionnaire are contained in Appendix 6. The survey was designed to get an understanding of the motivation of sponsors, whether sponsors visit the Orchards, and views on the contribution of orchards to economic, environmental and social sectors. Of the 26 tree sponsors recorded for 2007, half came from outside the County.

6.22 The postal survey of all tree sponsors received 21 responses. 73% of sponsors had visited the Orchards and a number had come to the County specifically to visit Tidnor Wood Orchards. Only 50% had walked in other orchards. 41% of sponsors had been attracted by the innovative way that the Tidnor Wood Orchards Trust was working to protect and promote the orchards and 32% had used the sponsorship as a gift.

6.23 Sponsors ranked nature and heritage highly when asked their views on what orchards contribute the most to among economic, environmental and social sectors (see Table 6.7). Sponsors were asked to choose only one from the pre-determined list of sectors.

Table 6.7 Assessment by tree sponsors of the contribution of orchards to economic, environmental and social sectors

Primary contribution of orchards to:	Number of votes	Percentage of total votes
Nature	10	48
Heritage	8	38
Local economy	2	10
Other	1	5
Leisure	0	0

6.24 People attracted into sponsorship viewed the heritage role as being more important than the economic role. A number of sponsors mentioned the importance of the collection of apple trees and the conservation of old varieties. This is not surprising given that a specific aim of the Trust is to conserve apple varieties. However, the orchard's role in contributing to the nature sector was seen as most important. From their comments, sponsors appeared to think deeply about the role of the Tidnor Wood Orchards, specifically, for example in "raising public awareness of the value of well managed orchards for the benefit of the environment and ultimately society as a whole". One sponsor noted that it will be "important to maintain the balance between human activity and wildlife."

Evaluation of orchards by local communities

General approach to obtaining local community views

6.25 People living near to each of the six study orchards were invited to an evening meeting. Invitations to this 'community evening' were sent by letter to a sample of houses within broadly a half mile radius of each orchard (but taking into account the local roads), with the intention of attracting twenty to thirty people to attend. The invitations followed the same format and explained that the purpose of the evening was "to find out more about what the orchard means to you…..We would really value your participation in the evening and your views will help to develop our understanding of the importance of orchards". To encourage attendance, the letters also mentioned that food and drink would be provided.

6.26 For the first few meetings, people who had not responded to the invitation letter were prompted to accept their invitation by knocking on doors. However this was very time consuming so in the later evenings, when the unprompted acceptance rate was clearer from earlier evenings, the number of invitation letters was increased by increasing the sample size in the area to avoid door-knocking, yet ensure that sufficient numbers of people attended.

6.27 During these evenings, the people who lived around each orchard took part in structured discussions to consider and rank the impacts of the orchard on local people. In the introduction it was explained that the intention was to find out "What impact does an orchard have on people living near it?" The intention of using the word *impact* for the community evenings, rather than the term *value,* was to ensure that people focused upon the direct effect or influence of the orchard upon themselves as they went about their daily lives, that they could then easily define and describe, and to avoid confusion with monetary values. However in this report the two terms are used synonymously.

6.28 People sat around tables in small groups of mostly four to six people, and each table had an independent facilitator to help the discussion and ensure everyone's views were recorded (see Plate 6.6). A simple process to obtain their views was devised (described below) with help from Forum for the Future, a non-profit organization that promotes sustainable development. The process worked well in that it structured but did not stifle discussion and allowed the key impacts of each orchard to emerge in a democratic way but in a very short space of time. At each evening, people participated enthusiastically and seemed pleased to have been asked for their views on their local environment, and to have the opportunity to discuss this with their neighbours. The detailed structure of the community evenings and the process followed is described in detail in Appendix 7.

Plate 6.6 Half Hyde Orchard community evening

Format of the community evenings

6.29 The format followed for the evening was the same for each orchard, although a few minor refinements were made after it was piloted for Henhope Orchard. The structure of the community evening was designed to accomplish the following:

- to record on post-it notes all the impacts of the orchard on the attendees (good and bad things), whether experienced when they are in the orchard or when outside the orchard. It was for the individual to decide and record whether an impact was 'good' or 'bad'.
- to find out what were the most important three impacts for everyone at the evening (the social impacts) by a voting system using paper dots
- to rank these three social impacts against three economic and three environmental impacts that had already been ordered by monetary value through previous project work on these aspects. The methodology used to value the economic and environmental impacts is explained in Chapter 7.

The economic values were termed:

- profitability of the orchard
- cash flows in the local economy
- draw for tourism

The environmental values were termed:

- climate change (ie regulation)
- biodiversity
- soil and water (together)

6.30 The economic values are described in detail in Chapter 3 (orchard profitability, impact of orchard expenditure on the local economy) and Chapter 7 (value for tourism for the local economy). Chapter 4 covers biodiversity, Chapter 5 includes climate change (climate regulation by carbon sequestration in the orchards) and soil and water (soil quality and diffuse pollution). Simple explanations of the economic and environmental values were made available at the community meetings in a standardized form, shown in Appendix 8.

6.31 The methodology piloted at the first community evening, for Henhope Orchard, categorized positive and negative impacts into 'Identity and heritage', 'Quality of life' and 'Other social impacts'. It was found that this made the process too complicated on the evening so the categorization was changed for subsequent community evenings to 'Good things when in the orchard', 'Good things when outside the orchard', 'Bad things when in the orchard' and 'Bad things when outside the orchard'.

6.32 At the end of the evening, the monetary values attached to the economic and environmental values were disclosed to provide an illustration of the value of the community's choices in financial terms. The relative rankings of social values in monetary terms are used in the Triple Bottom Line accounting process in Chapter 7 of this report. Note that monetary values were revised after the community evenings but this change was judged to have had only had a minor effect on the results.

6.33 Following the evening, a report of all the findings and resultant monetary values was prepared. A short summary of the overall value of the orchard, bringing all the findings about the orchard together for local people, including the results of the community evening, was published as appropriate on the village notice board, in the parish magazine or on the parish website. As a follow-up, local historian Rebecca Roseff was commissioned to conduct in-depth taped interviews with each orchard owner and some of the neighbours to record their stories. The neighbours chosen were people who had an interesting perspective on the orchard and who were willing to share their stories. The results of her work are now stored for posterity on the oral history database at Hereford Cider Museum.

Numbers of attendees at the community evenings

6.34 A total of 138 people came along to community evenings, which were held close to each of the six orchards. Numbers attending were above or close to 20 at each evening and were considered large enough to gather a reasonable representation of views of each local community, as some of the orchards were in sparsely populated areas.

Table 6.8 Dates of the community evenings and number of attendees

Orchard	Date of community evening	Number of invitations by letter	Number of attendees
Henhope (T)	22 November 2006	30	30
Tidnor Wood (T)	1 August 2007	37	24
Lady Close (T)	18 July 2007	34	16
Half Hyde (T)	7 November 2007	70	19
Salt Box (I)	20 September 2007	59	18
Village Plum (I)	10 October 2007	62	31

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

6.35 Local people probably came along to the evenings out of inquisitiveness, or because they had a direct interest in the orchard, or perhaps a specific issue that they wanted to air. At Henhope in particular people appeared also to have been drawn by the popularity of the orchard owner in the community. The orchard owners attended the meetings for Henhope, Half Hyde and Village Plum and orchard workers or managers were also present at the Tidnor Wood, Half Hyde and Salt Box evenings. They were encouraged to be full participants in the group discussions and were happy to hear the honest views of other people. The views of those directly involved in working in the orchards did not appear to dominate discussions around the tables, with the exception of the Half Hyde Orchard evening, where one full table comprised the farmer, his family and orchard workers.

Social value of the individual orchards

6.36 The three most voted-for types of social impact which were identified by each community are summarised in Table 6.9, with the percentage share of the total voting they received through placement of dots. In arriving at the most voted-for impacts, types of impact that featured both inside and outside the orchard were not summed, to keep the *active* and *passive* impacts separate. In practice there were few overlapping types. Appendix 9 contains some examples of people's personal expressions of these impacts upon them, taken from their post-it notes, together with summary comments on the overall importance of the orchard to the local community.

Table 6.9 The three most voted-for types of social value

Orchard	First	Second	Third
Henhope (T)	Enjoying nature (27%)	Conservation (25%)	Walking (12%)
Tidnor Wood (T)	Lack of knowledge (18%)	Like it being there (17%)	Nice environment to be in (14%)
Lady Close (T)	Enjoying wildlife and nature (34%)	Walking and exercise (21%)	Education (21%)
Half Hyde (T)	View (33%)	Enjoying wildlife (18%)	Road issues (16%)
Salt Box (I)	Work/income (20%)	Enjoying wildlife (20%)	Walking (14%)
Village Plum (I)	Peace (23%)	Natural beauty (14%)	Enjoying wildlife (13%)

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

Analysis of common themes among social values

6.37 The listing of the three most popular social values for each orchard during the community evenings was specific to individual types of value, which were experienced either inside or outside the orchard. However, one or more of these three types may sometimes have been noted in the other location (inside or outside) as well, although the votes from both locations were not added up. Shortage of time during the course of the evenings precluded such analysis and any analysis of broader themes across 'good' and 'bad' values at that time.

6.38 An analysis of the more general themes that arose across the orchards during these discussions has been possible since the community evenings, using the full range of comments from local people and combining inside and outside values where this seemed appropriate.

6.39 Eight main themes emerged from the information collected. Some had clear positive and negative aspects, while others were considered as purely positive in character. Many comments were particular to only one, or a few, of the orchards, and not all themes were represented in all orchards. The themes were:

- Enjoyment of wildlife
- Visual attractiveness
- Access for activity
- Orchard management
- Tranquility
- The orchard as a land use
- Communication about the orchard
- Sense of place

6.40 The approach taken to analysing the relative significance of these themes has been to sum votes for both negative and positive features of each theme. This total is taken to represent the importance that people attached to a theme, whether it was seen as purely positive or where there were ‘bad’ things that detracted from it. Table 6.10 shows the ranking of these ‘importance’ values in each orchard and the average across orchards (1 is the highest rank, 8 is the lowest). The rankings are based on the total number of votes judged to apply to a particular theme in an orchard. Inevitably, this process was subjective and the appropriate assignation was not always clear cut.

Table 6.10 Ranking of the main social themes identified by local communities

Theme	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)	Average rank (rank order of average rank)
Enjoyment of nature	1	7	2	2	2	3	2.8 (1=)
Visual attractiveness	4	5	3	1	3=	1	2.8 (1=)
Access for activities	2	6	1	5=	3=	4	3.3 (3)
Orchard management	5	2	4=	4	1	6	3.6 (4)
Tranquility	7=	4	6	5=	5	2	4.0 (5)
Orchards as a land use	6	1	4=	3	6=	7	4.3 (6)
Communication	7=	3	7	8	6=	5	5.5 (7)
Sense of place	3	8	8	5=	6=	8	6.5 (8)

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

6.41 Enjoyment of nature within the orchards was a very strong positive feature, either in general or specifically, for instance birds, wildflowers and mistletoe were noted by people. People valued the opportunity an orchard provided to appreciate the changing seasons. Wildlife very rarely attracted negative comments. Overall, enjoyment of nature was one of the top two themes, matching the importance of ‘enjoyment of nature’ recognised during the community evenings.

6.42 The visual attractiveness of the orchards was a strong positive feature. This encompassed both large scale – the orchard in the landscape, and small scale – the beauty of blossom, fruit and berries. No comments were made concerning any detractions orchards caused to the landscape. In fact, where one orchard was considered to be obscured by a hedgerow, this was regarded by local people as a negative feature. Visual attractiveness equaled enjoying nature in overall importance among themes and appeared most obviously as “views” and “natural beauty” among the top three social values during the community evenings.

6.43 Access for activities, principally walking and exercising dogs, featured as a prominent positive feature. Conversely, for some orchards lack of access (and by implication desire for access) was a negative aspect. Examples of other minor negative features were dog mess and vandalism. In line with the overall importance of themes, “walking” appeared as one of the three top values during the community evenings for three sites.

6.44 Orchard management had strong positive and negative aspects. The most popular positive feature was the enjoyment of seeing ‘orcharding’ being done, shown by the interest people expressed in the management activities being carried on in the orchard. Other positive features were the local produce, and the varieties of fruit grown in the orchard. Examples of the negative side of orchard management were reflected in comments about spray use in some orchards, vehicle use associated with orchards leading to mud on roads, and waste of fruit.

6.45 The tranquility associated with the orchard was a positive feature of varying popularity. It was quite often mentioned, and there was seldom concern about the orchards being a source of noise.

6.46 The existence of the orchard as a land use was a popular positive feature. This was the sheer presence of the orchard, even where access to it, or views of it, were restricted. The presence of an orchard conveyed reassurance and the very fact of the orchard being there, and apparently likely to endure, was strongly appreciated. Sometimes the preference for orchard land use over other land uses, such as arable or development, was stated. Potential threats to the existence of the orchard that were identified by local people, in particular the damage that road traffic or heavy visitor use might do, were regarded in the analysis as support for the existence of the orchard as a land use.

6.47 Communications involving the orchards were seen as both positive and negative. The educational value of some orchards was noted. Negative comments were more about wanting to know more about particular orchards, including how they were managed and future plans. This indicates that more communication was desired.

6.48 Sense of place featured only in two orchards, Henhope and Half Hyde, in the way that the orchard fitted into the heritage of the local area and made people feel at home there.

6.49 This review shows that orchards have a range of impacts on local people. Appreciation of them as a place to enjoy nature and for their visual attractiveness were widely held, but there were a range of other themes that emerged from the evenings. Some of these, such as the orchard as an educational resource and the importance of the tranquil place that orchards offer, could be taken into account in future conservation work. What is also clear is that different orchards have different attributes and this review demonstrates the range of interactions that people and orchards can have.

Comparison of positive and negative social values in the orchards

6.50 To assess whether positive or negative social values predominated in the judgment of local people, the numbers of votes for ‘good things about the orchard’ and ‘bad things about the orchard’ were totalled for each orchard. The results are shown in Table 6.11.

Table 6.11 Comparison of votes for positive and negative social values

Orchard	% total votes for positive values	% of total votes for negative values
Henhope (T)*	90	10
Tidnor Wood (T)	66	34
Lady Close (T)	74	26
Half Hyde (T)	69	31
Salt Box (I)	78	22
Village Plum (I)	83	17

Notes: *The pilot community evening at Henhope Orchard did not use the ‘good thing’ and ‘bad thing’ terminology but negative impacts were identified during the process. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

6.51 The local people living around each orchard judged that all the orchards had overwhelmingly positive impacts on their lives. The two orchards with the highest numbers of positive votes were Henhope, a traditional orchard, and Village Plum, an intensive orchard. The results for these two contrasting orchards suggest that local people see positive qualities in orchards irrespective of their management regime. However, it has to be accepted that the results of the community evenings could be unrepresentatively positive if only those people favourably disposed to orchards accepted the invitation to attend an orchard meeting. Nevertheless, for those that attended the evening, the process deliberately sought to encourage people to express any negative aspects, to counter natural shyness, or politeness to their hosts, or reluctance to speak ill of the owner’s management, particularly at the meetings where the owner was present.

Comparison of social values experienced inside and outside orchards

6.52 The proportion of votes for social values regarded as belonging either inside or outside the orchards by local people were totalled for each orchard except Henhope Orchard (Table 6.12). These values could have been strongly influenced by the degree of public access to the orchards so this information is also shown in Table 6.12.

Table 6.12 Proportion of votes for social values experienced inside and outside orchards

Orchard	**Extent of public access**	**% of total votes for values inside**	**% of total votes for values outside**
Henhope (T)*	None	Not available	Not available
Tidnor Wood (T)	None (except by arrangement)	20	80
Lady Close (T)	Open access	81	19
Half Hyde (T)	None	35	65
Salt Box (I)	Public footpath	54	46
Village Plum (I)	Public footpath	82	18

Notes: *The pilot community evening at Henhope did not use this classification. T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

6.53 The results for the proportion of local people voting for social values experienced inside and outside the orchards show a more mixed pattern than that for positive and negative values. Not surprisingly, the lowest voting numbers for values inside orchards corresponds to those orchards without general access (see Table 6.12). Village Plum Orchard and Lady Close Orchard have the highest proportion of votes for values inside orchards. They are very close to the respective villages of Glewstone and Bodenham, where most of the attendees lived, and thus were 'on the doorstep' for residents. The result for values inside Half Hyde Orchard is somewhat higher than expected, given that there is no public access. This result arose because there were a number of people who worked in the orchard were at the community evening. There are no equivalent results for Henhope Orchard, but the fact that it has no public access seemed not to influence the very positive way its social values were regarded by local people (Table 6.11). Village Plum Orchard is intensively managed, but despite this votes were overwhelmingly for values within the orchard itself. The division of votes for Salt Box, another intensive orchard, was more evenly distributed for outside and inside values, even though there is public access. This may be because it is less immediately accessible than Village Plum, as it is not adjacent to a settlement.

Comparison of social values with economic and environmental values

6.54 The average ranking from the groups at each evening of the three top social values within the six predetermined rankings of environmental and economic values for each orchard is shown in Table 6.13. In most orchards, an economic value was considered the single most important value, apart from Lady Close Orchard where a social value was ranked highest.

Table 6.13 Ranking of social, economic and environmental values by local communities in descending order

Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
ECONOMIC Orchard profitability	ECONOMIC Cash flows in the local economy	**SOCIAL Enjoying nature and wildlife**	ECONOMIC Orchard profitability	ECONOMIC Orchard profitability	ECONOMIC Cash flows in the local economy
SOCIAL Conservation	**SOCIAL Like it being there**	**SOCIAL Walking and exercise**	ECONOMIC Draw for tourism	**SOCIAL Work/income**	ECONOMIC Orchard profitability
ECONOMIC Cash flows in the local economy	*ENVIRONMENT Climate regulation*	ECONOMIC Draw for tourism	**SOCIAL View**	*ENVIRONMENT Climate regulation*	**SOCIAL Natural beauty**
SOCIAL Enjoying nature	**SOCIAL Nice environment to be in**	**SOCIAL Education**	**SOCIAL Enjoying wildlife**	**SOCIAL Enjoying wildlife**	**SOCIAL Peace**
ENVIRONMENT Biodiversity	*ENVIRONMENT Biodiversity*	*ENVIRONMENT Biodiversity*	*ENVIRONMENT Biodiversity*	ECONOMIC Cash flows in the local economy	**SOCIAL Enjoying wildlife**
ENVIRONMENT Climate regulation	ECONOMIC Draw for Tourism	ECONOMIC Cash flows in the local economy	ECONOMIC Cash flows in the local economy	**SOCIAL Walking**	*ENVIRONMENT Climate regulation*
SOCIAL Walking	*ENVIRONMENT Soil and water*	*ENVIRONMENT Soil and water*	*ENVIRONMENT Soil and water*	ECONOMIC Draw for tourism	ECONOMIC Draw for tourism
ENVIRONMENT Soil and water	**SOCIAL Lack of knowledge**	ECONOMIC Orchard profitability	*ENVIRONMENT Climate regulation*	*ENVIRONMENT* Biodiversity*	*ENVIRONMENT* Biodiversity*
ECONOMIC Draw for tourism	ECONOMIC Orchard profitability	*ENVIRONMENT Climate regulation*	**SOCIAL Road issues**	*ENVIRONMENT* Soil and water*	*ENVIRONMENT* Soil and water*

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details. *These values were zero and share equal rank in analysis of relative ranks of economic, environmental and social values.

6.55 However, the listing of all values together could be regarded as not strictly ‘fair’. When the community groups inserted their social values into the pre-ranked economic and environmental values they were, in effect, being asked to consider social values relative to economic impacts and, separately, social values relative to environmental values, as the relationship between the economic and environmental values was fixed in advance. The overall comparison of social against economic and environmental values has therefore been done in a pair-wise way. For each orchard, ranks of all possible pairs of economic, social and environmental values were calculated for the 6 values in each pair, rank 6 being the highest and rank 1 the lowest. Where negative values had been identified by local people attending the meetings, these were given appropriate negative rank values. For example, the lowest rank value for Half Hyde Orchard was a social one concerned with road issues. This was given a rank of -1, while the highest rank value was adjusted accordingly to 5 rather than 6. This arrangement was paralleled by the negative monetary values found for some economic and environmental values in Chapters 7, such as the lack of profit at Tidnor. Here, instead of a profit, a loss occurred in the income versus expenditure account (Table 7. 3). The participants were made aware of whether there were any negative or negligible economic and environmental values at the time that they ranked social values in comparison to these two types of value. The relative rank position of each pair in each orchard is shown in Table 6.14 (“>” means rank “greater than”). Sums of ranks were calculated to derive the overall comparison across orchards in Table 6.14.

Table 6.14 Pair-wise comparison of social, economic and environmental value rankings

	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)	Overall rank
Economic (E) v Social (S)	E > S	S > E	S > E	E > S	S > E	E > S	E > S
Social v Environment (En)	S > En	S = En	S > En	S > En	S > En	S > En	S > En
Economic v Environment	E > En	En > E	E > En	E > En	E > En	E > En	E > En

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. See Chapter 3 for management details.

6.56 The revision of some monetary values after the community evenings would have affected rank order of two environmental values at Henhope and Tidnor, which might have influenced any 'post-revision' comparison with social values by local people. Two economic values at Half Hyde (orchard profit and cash flows in the local economy), switched position on a monetary basis but both were given greater ranks than any social value by local people so this change would not have affected the results. Revision of monetary values resulted in two swops among economic and environmental values, at Henhope and Salt Box, but overall economic value for each of these orchards always remained higher than combined environmental values.

6.57 Taking all the studied orchards together, and the original rankings for economic and environmental values, social values were rated below economic values, although individual sites has social values ranked higher than economic values, whether the orchard was intensive or traditional in type (Table 6.14). Overall, for almost all sites, environmental values were rated lower than social and economic values. The reason for these relative economic and social rankings seems to be that local people appreciate that generally orchards exist because of their commercial economic benefits, but that they themselves like simply to see, and be in, orchards, including experiencing nature in orchards. Given the pre-determined rankings of each environmental and economic value, it is difficult to arrive at a firm conclusion as to why social values as a set were always ranked above environmental values (except in one case, Tidnor), but in the community discussions, it appeared that the social values were more visible and direct. Despite the availability of explanations of the environmental values at the meeting (Appendix 8), it may be that, from these explanations at least, people did not readily appreciate whether environmental attributes of orchards had fundamental value. The wording of such explanations is obviously influential, and perhaps the environmental values should have been described in a way that showed more clearly how climate change, soil and water quality and biodiversity might relate to the interests of local people.

Comparison of views of local communities, general visitors, visitors to Lady Close Orchard and sponsors of trees at Tidnor Wood Orchards

Comparability of local community evaluations and surveys of visitors and sponsors

6.58 The results obtained from the community evenings and the completed questionnaires from general visitors, the visitors to Lady Close Orchard and the sponsors of Tidnor Wood Orchards Trust are not exactly comparable since the questionnaires used different terms to those used during the community evenings. Respondents to the questionnaires were asked to consider what sector orchards *contributed the most to* rather than what were the most important *impacts*, (values) of an orchard on people living near it. The *contribution* of orchards is considered here as a more implicit way of describing value and a broad comparison between the sectors and impacts seems possible. 'Nature' in the questionnaires reasonably equates to 'environment' in local community results, 'local economy' in the questionnaires to 'economy' in local community results and 'views', 'heritage' and 'leisure' to 'social' values in the local community results. Grouping of the last three sectors from the questionnaires into the 'social' category might be regarded as weighting the results too much in favour of social values. In fact, the numbers of times these features were chosen by interviewees were relatively low. (see Tables 6.2, 6.5 and 6.7). The one exception was the high ranking of heritage by Tidnor Wood Orchards tree sponsors. However, this was the only social value identified in this case.

Results and discussion of the comparison of economic, environmental and social sectors by different groups

6.59 The results suggest that the general visitor to Herefordshire sees the economic imperative of orchards as a type of agriculture, but has not even considered orchards as places to visit and appreciate. It is perhaps surprising that the ranking of the sets of values is very different between the local community's view of their local orchard (where environment was ranked last) and the visitors to, and sponsors of, specific orchards (where environment was ranked top). This may be because the visitors to Lady Close Orchard and sponsors of Tidnor Wood Orchards were influenced by their enjoyment of nature at the specific orchards – which in the community evenings was categorised as a social value. Alternatively, the difference could be due to other variable perceptions of the terms "nature" (in the questionnaires) and "environment" (in the community evenings). Among the social values recorded during the local community evenings, enjoying nature was consistently chosen as an important social impact by local communities living near specific orchards. Table 6.15 shows the ranking among the three sorts of value for each of the groups supplying views about orchards (highest in the list is the top rank).

Table 6.15 Comparison of the ranking of social, economic and environmental values by different groups

Local community	General visitors	Orchard visitors (Lady Close)	Orchard sponsors (Tidnor Wood)
Economic	Economic	Environment	Environment
Social	Environment	Social & Economic	Social
Environment	Social		Economic

6.60 For Tidnor Wood, heritage and the conservation of old varieties was an important draw for sponsors (see Table 6.7). People living locally did not however view this very strongly at all, valuing more the orchard just being there and the nice environment it created.

6.61 The small sample sizes in this pilot study and the methodological issues discussed earlier in this chapter mean that the results are only indicative, but suggest that the relationship between orchards and people can be powerful, though this relationship depends upon the degree of exposure to orchards.

6.62 While no other equivalent orchard study appears to exist, the University of Essex has published a report for the National Trust on visitor perceptions of the multifunctional benefits of five National Trust green spaces in the east of England (Hine and others 2007). The sites were compared using calculated multifunctional components representing social, environmental and economic impacts. The study found that sites scored highly on biodiversity, landscape character and leisure and recreation but that "many of the services that these sites provide are not even considered as part of the equation by the public". In particular, environmental values of climate change mitigation and water services did not score highly, as was the case for the orchard study. Farming services did not rate highly, in contrast to the high value placed on economic activity by local communities living around orchards and by the general visitor to Herefordshire. However, the National Trust green spaces were mainly not farmed. The conclusion of Hine and others (2007), that the multifunctional benefits of the sites need to be better understood and promoted, supports the findings of the orchard evaluation in respect of local communities and the general visitor, particularly with regard to environmental benefits.

Further exploration of community values

6.63 By involving local communities in evaluating orchards and by raising awareness of orchards more generally, the project was a catalyst for further community activity. Though not part of the formal valuations made by the project, these activities demonstrated a high degree of public interest in other community values of orchards, for example as inspiration for art and drama, which helped to take the message of the value of orchards to new audiences.

Orchard art competition

6.64 An orchard art competition, promoted by Tidnor Wood Orchards Community Interest Company (CIC), Hereford Cider Museum and the Herefordshire Orchards Community Evaluation Project attracted entries from artists of a wide range of ages and abilities. The main prizes for winners were donated by Tidnor Wood Orchards CIC. The entries, showing many different perspectives of orchards, were displayed at Hereford Cider Museum alongside the exhibition '*Orchard'* containing the sculptures of nationally acclaimed artist Edwina Bridgeman. The exhibition came to the Museum as part of a national tour. Three local organisations providing opportunities for people with disabilities (Herefordshire Headway, ECHO and Aspire) encouraged their clients to participate in the art competition and they also subsequently visited the exhibition. A group from ECHO prepared a collage of themselves in an orchard, which is shown on the project partnership cover of this report.

Spirit of the orchard drama

6.65 Further Education performing arts students from Hereford College of Arts wrote and performed a promenade drama called *Spirit of the Orchard* that took place throughout Hereford Cider Museum. The students demonstrated their understanding of the values of orchards described by the project and interpreted these for schoolchildren and family audiences. The play was performed for schools throughout the week leading up to the Orchard Art exhibition open day on 14 November 2008 and there were a series of performances for visitors throughout the open day.

Plate 6.7 A scene from *Spirit of the Orchard*

Orchard sense of place event

6.66 On 7 November 2008 a small group of Herefordshire people interested in spirituality and sense of place were invited to Breinton Springs orchard near Hereford, which is owned by the National Trust. The objective of the visit was to begin an exploration of the 'feel' of one orchard. Having spent a lot of time in each of the orchards throughout the Herefordshire orchard project, it had come apparent to David Marshall that each orchard had its own distinct atmosphere and mood. This is what the German thinker Goethe described as observation of the *location spirit* of a place. Whilst not distilled into numbers or data, this sense of place could form part of the account of an orchard. The group subsequently shared their observations of Breinton Springs orchard at a meeting at Hereford Cider Museum chaired by Reverend Nick Read OBE ARAgS, the Chaplain for Agriculture and Rural Life for the Diocese of Hereford. The group discussed the cultural significance of orchards and there was a shared desire to explore this area further.

Establishment of Tidnor Wood Community Interest Company

6.67 In 2008, a Community Interest Company (CIC) was established to secure Tidnor Wood Orchards into perpetuity and carry on activities which benefit the community, including providing a safe home for the National Collection of cider and cider-related apple varieties and to manage the Orchards organically and in an ecological manner. It is the owner's intention to transfer at least Museum Orchard into the CIC.

Using the evaluation methodology for other orchards

6.68 In March 2009, the community evaluation methodology was used at an evening meeting at the village of Colwall, in east Herefordshire, close by the Malvern Hills. David Marshall led the session, at the invitation of the Colwall Orchard Group. The Group is dedicated to revitalising the orchards of this parish. The evening looked at one old apple orchard called Snatford, for which environmental and economic value had also been calculated. The Snatford evening brought out the strong social value arising from having an orchard as a community focus. The Colwall Orchard Group subsequently described the evaluation as "an enlightening experience" and the experience shows that the methodology pioneered for the project is readily transferred to other orchards. There also seems to be no reason why the methodology could not be used for other land uses too.

Conclusions

6.69 The Herefordshire Orchards Community Evaluation Project provides the first detailed, published information about the importance of orchards for different groups of people:

- Local people had overwhelming positive responses to the presence of orchards in their area. Enjoying nature and visual attractiveness of orchards were the most important social values, followed by access for activities. Through the changing seasons, orchards provide a window on nature and a place for green exercise and, encouragingly, people recognise that these are valuable.
- Economic values were rated highly by people living locally, and general visitors to Herefordshire considered the contribution of orchards to the local economy was very important. Orchards are an integral part of the local agricultural economy, as they have been for centuries, and it is salutary that this is valued both by local people and visitors to Herefordshire. Furthermore, the active management of orchards also appears to provide reassurance for local people.
- The walkers in Lady Close orchard and the sponsors of trees at Tidnor Wood Orchards have developed a relationship with a specific orchard and these people considered that orchards contribute the most to nature. However, for local people, although enjoyment of nature and the natural beauty of orchards were predominant social values, they generally did not highly rate an orchard's environmental value *per se.* This could

indicate that more needs to be done to relate topics such as climate change and the importance of biodiversity, healthy soil and clean water to the lives of ordinary people.

- It is notable that people do not necessarily need to visit an orchard to appreciate its importance. This was the case at Henhope, which is valued by some of its neighbours just for being there, as it has been for most of their lives. It was also the case for more than a quarter of the sponsors of trees at Tidnor Wood Orchards who had never visited the Orchards.
- General visitors and visitors to Lady Close identified traditional orchards as deserving most financial support, rather than intensive orchards. However, people living near orchards valued orchards highly whether they were traditional or intensive orchards.
- General visitors did not pick out orchards as an important feature of the landscape and were mostly unaware that access to some orchards might be possible, although orchards were highly valued by people living close to a particular orchard. This suggests that more could be done to promote the opportunities that orchards offer. The findings of the project suggest that there is a wealth of opportunity for further developing the relationship that people have with orchards, and for promotion of the multifunctional benefits of orchards that may attract different people to experience these special places in different ways. The place that orchards have in people's lives is an important aspect that needs to be taken into account when considering future conservation.

Topics for further work

6.70 Future work possibilities include trying out different ways to draw people towards orchards in Herefordshire and beyond. The medium of art appears particularly attractive, as does exploring further the spiritual significance of orchards. There also appears to be scope to develop the tourist potential of orchards beyond what has been achieved to date in Herefordshire and a better understanding of the views of visitors at different times of year (particularly in the orchard 'seasons' of spring and autumn) could assist such a development. Partly in response to this, Herefordshire's Orchard Topic Group and Herefordshire Council have designated 2011 as Herefordshire *Year in the Orchard.* Providing access to more orchards and producing information about their wildlife and management will help spread the benefits of orchards identified by local communities to a wider public.

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7 Orchard triple bottom line accounts

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Introduction

7.1 Orchards in Herefordshire, and more widely in England, have been subjected to considerable change in recent decades. The area of traditional orchards has fallen sharply (Robertson and Wedge 2008), while the commercial market for fruit has fluctuated, with consequent changes in overall orchard areas and production (Defra 2010a). There is an urgent need to understand the wider environmental and social values of orchards, alongside their economic profitability, to assess the significance of such changes to policy makers, conservationists, tourists and local communities as well as to the orchard owners themselves.

7.2 The aim of the monetary valuation of the study orchards was to try to take account of values beyond the immediate economic profitability of the orchards, and in a way that would engage with local communities and businesses. The approach adopted provided a method of comparing and combining the disparate qualities and characteristics of the study orchards by using money as a common means of valuation. Although it could be argued that environmental and social values should not be reduced to numbers, a monetary evaluation at least gains recognition of these other values alongside conventional economic valuations.

7.3 The monetary valuation builds on the findings of preceding chapters, which explored economic, biodiversity, resource protection and social values of the study orchards in a largely qualitative way. The monetary representation of these values is examined in this chapter, and orchard accounts are presented for three types of value: economic, environmental and social values. The limitations of this monetisation approach are discussed and the relationship of the approach to ecosystem assessment is examined. Ecosystem assessment investigates the benefits that the natural environment provides to society and the consequences of ecosystem change for human well-being. Ecosystem assessment is becoming an important topic both in national and international policy spheres (Millennium Ecosystem Assessment 2005, Defra 2007, UK National Ecosystem Assessment 2010).

7.4 Preliminary estimates of the monetary social, economic and environmental values for the six study orchards studied were made available in 2008 (Taplin 2008). However, since that time, additional data collection and analyses have been undertaken and assumptions refined. The monetary valuations presented in this chapter have therefore been adjusted and replace the earlier figures.

Concepts and general methodology

The triple bottom line concept

7.5 The triple bottom line concept was first outlined by John Elkington three decades ago (Suggett and Goodsir 2002) to encompass environmental and social valuations undertaken by businesses, in addition to the usual economic valuations in their annual financial reports. The use of the term became widespread in the 1990s with the publication of the book entitled "Cannibals with forks: the triple bottom line of 21st century business" (Elkington 1997). The concept has been seen as having particular relevance to businesses, but also to be helpful in strengthening collaboration between businesses and local communities to promote sustainability (Suggett and Goodsir 2002). Various environmental and social indicators have been proposed for use in drawing up triple bottom line accounts for businesses. Example are energy consumption, emissions produced, and resources supplied to local community groups (Suggett and Goodsir 2002).

7.6 The orchard project takes the triple bottom line accounting approach and applies it to the orchard land use or habitat rather than to a business, although the findings are relevant to businesses and other organisations involved in management of the orchards. The employment of an accounting method follows the conceptual approach taken in Defra's environmental account for UK agriculture (Defra and others 2010). The framework for this account was developed by Atkinson and others (2004) and Spencer and others (2008). The account provides a snapshot of current conditions, and uses a baseline of zero activity. Other baselines or 'counterfactuals' are seen as immaterial to the accounting exercise, which is not an analysis of alternative scenarios of land uses (Atkinson and others 2004, Spencer and others 2008). In terms of public understanding, the development of an 'absolute' account for an orchard had the advantage over a policy-based analysis of alternative land uses of being related to the more familiar types of 'absolute' monetary accounts that are dealt with by local communities and businesses in their daily activities.

7.7 Within the orchard habitat boundary, appropriate environmental and social indicators of value have been chosen and an attempt made to attach monetary value to these indicators for the 6 main study orchards. These monetary values, along with monetary economic values, are then used to generate a monetary 'triple bottom line account' for each orchard. While not straying into the territory of assessing alternative land uses, the orchard study sites, viewed as 'businesses', should be capable of being analysed in terms of relative costs and profits resulting from differing levels of orchard management activity. The case study orchards were chosen to demonstrate values among a varied selection of orchards (see Chapter 2), although two broad categories were represented by several sites, namely, traditional and intensive orchards (see management descriptions in Chapter 3). Some comparisons in monetary accounts generated by these two categories of orchard were possible, and suggest how accounts might change with differing levels of management activity within the orchards. It should be emphasised that such comparisons are tentative. Many more orchards from each category would need to be studied to produce firm conclusions. Before these valuations and comparisons can be described in detail, the concepts lying behind the types of values considered by the project need to be explained.

Concepts of value

7.8 The value of a natural resource is often considered within a value framework known as Total Economic Value (TEV) (Defra 2007). This framework provides a useful way of identifying possible values that could be assigned to an orchard as a habitat or as a land use. The TEV framework usually divides TEV into use and non-use components. As the name suggests, use values (UV) are those that come from using the resource in some way, and are sub-divided into direct use values, indirect use values, and option values. On the other hand, non-use values (NUV) have no personal exploitation associated with them. Value is derived simply from the knowledge that the natural resource is maintained. Non-use values are often divided into bequest value, altruistic value and existence value (Ozdemiroglu and others 2006, Defra 2007). In classical environmental economics, the TEV of an environmental resource is the sum of all these different sorts of value.

Direct use value

7.9 Direct use value (DUV) flows from the consumption of products from the resource. The most obvious DUV of an orchard is the harvest of fruit it produces, but can also include value from other products such as the livestock grazing in an orchard (see Chapter 3). DUV can also come from non-consumptive use, for example, people visiting orchards for recreation. DUV of orchards can be traded on a market, eg the sale of cider apples to cider makers, or can be non-marketable, ie there is no formal market on which they are traded

(Defra 2007). An example of a non-marketable DUV might be the pleasure obtained by people from walking through an orchard on a public footpath.

Indirect use value

7.10 Indirect use value (IUV) typically comes from the value, often unrecognised, that is obtained indirectly by people from the natural processes occurring in the habitat. In this context, orchard habitat is treated as synonymous with the orchard 'ecosystem', which follows the UK National Ecosystem Assessment approach to habitat and ecosystem definition ((Watson and Albon 2010). Note that orchards would fall within the 'enclosed farmland' broad habitat categorisation employed by the UK National Ecosystem Assessment. The ecosystem functions of value are often key 'life-support' functions, such as climate regulation through carbon accumulation in orchard soils and fruit trees and nutrient supply to the fruit trees and orchard floor grassland from decomposition of organic matter in soils.

Option values

7.11 Option value (OV) can be thought of as an insurance value. The option value comes from having the resource on 'standby' and able to be used at some stage in the future. These future uses may be direct or indirect. An example of an option value would be the maintenance of genetic diversity within the populations of fruit trees so that new varieties can be developed in future to cope with changing climate or emergence of new diseases.

Bequest value

7.12 Bequest value (BV) is where an individual, or society, places a value on a resource being passed on to future generations. An example is conserving orchards so that future generations can also enjoy them.

Altruistic value

7.13 Altruistic value (AV) is where an individual attaches a value to the availability of the resource to others in the current generation, for example, the value that an orchard owner places on the enjoyment that others obtain from seeing his orchard.

Existence value

7.14 Existence value (EV) is the value an individual places on simply knowing that the resource exists, even though they themselves will never see or experience it. An example could be a person who donates money to maintain an orchard even though they have no plans to visit it.

Selection of orchard values for assessment

7.15 Although a resource may clearly have multiple values, very few studies have set out to capture them all. The orchard study was constrained by funding and time, so could only select some of the possible orchard values. However, the values considered by the project leader to be those of key importance were included, in consultation with the experts on the Herefordshire Orchard Topic Group (see Chapter 1). The values chosen were regarded as the most important three values in each category of economic, environmental and social values. Some of the values encompassed more than one type of TEV component. The selected values are shown in Table 7.1, along with the TEV types considered to be primarily represented. The background for each value is described in detail in preceding chapters, which provide the platform on which the monetary evaluation can be constructed.

Table 7.1 Orchard values selected for assessment and the value types that they represent

Orchard value	Type of value
Economic values	
Orchard profitability (excluding farm fixed costs)	Direct use (consumptive)
Gain from expenditure on orchard management by orchard owners to the local economy	Direct use (consumptive)
Gain to local economy from spending by tourists, apportioned to orchards	Direct use (consumptive)
Environmental values	
Biodiversity	Indirect use, option, bequest
Climate regulation through net carbon sequestration	Indirect use
Soil quality and protection from diffuse pollution	Indirect use
Social values	
Three social values per orchard identified by each local community	Direct use (non-consumptive), altruistic, existence

Overall methodology for valuation

7.16 The orchard project explicitly set out to engage with local people about different aspects of value of orchards. As such, the methodology for valuation had to be simple enough to be easily understood by non-experts, rather than following classic economic analysis. Valuations were made using readily available 'proxy' measures, including both costs and prices. It is accepted that the approach that we have adopted is simplistic and the choice of proxies may not be entirely theoretically sound as a measure of value, particularly the mixture of price and costs used, but the objective was to explore ways of valuing the orchards that could be practically adopted at a local level from available information, to provide at least a rough assessment of overall value. The detailed methods of monetary evaluation for each of the chosen economic, environmental and social values are given in later sections of this chapter. An essential overall aim of these methods was to avoid double-counting among the chosen values. The monetary evaluation was restricted to annual flows and did not cover capital values and depreciation. As far as possible, monetary values were calculated for the same time period, for most values this was 2006-2007. Monetary values were not adjusted to current values to take account of inflation. Orchard profitability was already in monetary form, as was expenditure in the local economy. Tourism value used tourism earnings information for Herefordshire. The environmental values relied on the prices that the UK Government was willing to pay for public goods, such as biodiversity, on behalf of the public. A monetary assessment of the social values identified by local communities around each orchard was based on a group consensus approach but the linking of the group view with a monetary value was problematic and the result should be regarded as experimental at best. As well as positive values, negative values or costs were also considered.

Costs and sustainability

7.17 Ideally, the orchard values needed to be related to the important concept of sustainability to enable a complete triple bottom line accounting assessment to be undertaken. The examination of environmental sustainability was a vital component of recent efforts to assess the health of the world's ecosystems, their value to humans and the likely future state of these ecosystems (Millennium Ecosystem Assessment 2003). A useful way of examining sustainability in monetary terms is to try to cost 'negative externalities', ie the damaging side-effects of economic activity which are not part of the market prices or production costs (Pretty and others 2000). Environmental accounts for agriculture in the UK, expressed in monetary terms, are now available on a yearly basis, expressed as annual flows (Defra and others 2010). Benefits and costs are both given monetary values in these accounts.

7.18 The accounts presented for annual flows of monetary values for the study orchards attempted to include costs of orchard management so that the sustainability of the supply of goods, be they economic, environmental or social, could be assessed. Expenditure on orchard management by the orchard owners was straightforward to quantify but for environmental costs only carbon emissions were given a cost. A positive value could be ascribed to biodiversity and soil quality and protection from diffuse pollution but it was not possible within the scope of the project to examine negative monetary consequences from loss of biodiversity or from diffuse pollution. The negative results that might arise from spending in the local economy or tourism, such as wear and tear of infrastructure, were also excluded. These results would be likely to be felt beyond the orchard boundary but should not be forgotten in wider studies of costs of land use and habitat management. Local communities were encouraged to identify both positive and negative social values in the discussion evenings held for each orchard (see Chapter 6).

Economic valuations

Orchard profitability and expenditure on orchard management in the local economy

7.19 Orchard profitability and expenditure in the local economy are explained in detail and calculations presented in Chapter 3. The resulting summary figures for each value are shown in Table 7.3 below, while the detailed breakdowns are given in Tables 3.5 and 3.7. The time period for the evaluation was 2006 or 2007 (Table 3.5). Orchard profitability represents the usual profit or loss account for a business. Various assumptions and estimates were necessary however, as explained in Chapter 3. Important among these was that notional amounts were used for services received or given which did not attract a monetary receipt or payment. Also, because each orchard comprised only one part of the land holdings of individual owners, some costs had to be estimated and apportioned to the orchard. No account was taken of overheads, taxation or the costs of centralised farm business functions. As a result, the final figures for overall profits are not 'actual' but are estimates and in specialist economic terminology represent contribution rather than 'net profit'.

7.20 Environmental Stewardship Scheme (Natural England 2010a, 2010b, 2010c) payments were excluded. Any such payments have been used in estimating environmental values so inclusion in orchard income would have caused double-counting. The income that the traditional orchards in the project received from Single Payment under the Common Agricultural Policy of the European Union was included in the economic value. These orchards met specific criteria for orchards of environmental value, and they were therefore eligible for the Single Payment, although not all orchard owners claimed the payments. It could be argued that as the orchard Single Payment recognized the environmental value of traditional orchards it should be included in a monetary value for biodiversity. However, the exclusion of intensive orchards from Single Payment was only temporary. Reform of the EU fruit and vegetable regime meant that all orchards were eligible to apply to be allocated new Single Payment from 2010 (Defra 2008). It was therefore decided to keep the Single Payment in the economic valuation of the orchards to avoid confusion if the figures from the project are compared to future studies of orchard profitability and environmental value.

7.21 The value of the expenditure on orchard management to the local economy was directly related to the orchard income and expenditure assessment. Spending by businesses with local suppliers has a positive impact upon a local economy which is worth more than the face value of the expenditure because cash put into the local economy can be spent again on further local goods and services (Sacks 2002). This re-spending is termed the local multiplier effect. Purchases made for the purposes of orchard management by the orchard owner from local suppliers, or employment of people who may have spent their wages locally, were identified. 'Local' was defined as the unitary authority area of Herefordshire. Some items were excluded, such as the notional costs of owner and family time spent managing the orchard. Tax taken on various items was not excluded from the total amount available for local spending although it would have reduced the actual amounts spent in the local economy. However, direct employment costs were estimated as notional take-home pay after deduction of 20% tax. This is because, unlike payments to other suppliers, which are inclusive of tax, employees only receive the net amount upon which to choose whether to spend locally.

7.22 It was beyond the scope of this study to track expenditure on the orchards through the subsequent payment cycles in the local economy to complete a full analysis. An estimated multiplier of 1.0 was therefore applied to the total of local purchases for labour, goods and services for each orchard (see Chapter 3). This was a conservative estimate compared to other studies of locally-focused businesses (Sacks 2002) because the choice was made to risk under-estimating value rather than over-estimating value.

Value of tourism for the local economy

7.23 The evaluation of the monetary worth of tourism connected to orchards was based upon estimates of the value of tourism to the Herefordshire economy in different categories of visits (Visit Heart of England Research Services 2001). No assessments were made of the direct use of the study orchards by visitors, except at Lady Close Orchard (see Chapter 6) where visitors are specifically attracted to the Bodenham Lake Nature Reserve of which the orchard forms a part. The assessment at Lady Close Orchard was used as a comparison with the more general estimate of tourism value obtained from the Herefordshire tourism spend figures.

7.24 Herefordshire data were only available at the time of the project for 2001, there were no equivalent data for more recent years. Overall value of tourism in 2001 was £271.5 million. There were some 8.4 million visitor trips to Herefordshire in 2001 of which the majority were day trips, with just 7% being trips involving an overnight stay in the county. The trip types that were considered to be related to the landscape attraction of Herefordshire were identified and their value summed. These types were countryside day trips (£71.6 million), holiday stays (£56.3 million) and other stays by visitors (£1.7 million). These earnings totalled £129.6 million. Trip types thought to be unrelated to Herefordshire's landscape attraction were town day trips (£103.3 million), staying for business trips (£29 million) and visits to friends and relatives (£9.6 million), in total £141.9 million. This total was excluded from the contribution of Herefordshire's landscape to tourism earnings.

7.25 Orchards are part of Herefordshire's rich and varied landscape. Herefordshire's Tourism Strategy describes this landscape as follows: "Herefordshire is arguably the most rural County in England. The landscape of rolling hills, small woodlands, hedgerows, orchards, hop yards, meadows and cultivated fields still provides a rich resource for rural tourism" (Herefordshire Council 2002). The relative importance of orchards in the landscape in encouraging tourism, and thus spend by tourists in the local economy, is not easy to quantify. Value may in part be related to social factors, including the perceptions of visitors as to the attractiveness of orchards as a whole and of different types of orchard. The landscape setting of individual orchards might also have an impact, as it affects the visibility of each orchard.

7.26 The results of a small survey of visitors in Hereford in 2007, described in Chapter 6, showed that orchards did not stand out among the different landscape elements such as hills, rivers and woodlands. Consequently, it was decided that the share of landscape-related tourism value contributed by orchards should be calculated based on the simple area of orchards in the county, with no application of weighting towards orchards. First, an estimate of the non-urban area of Herefordshire was made. Stevens and Associates (2010) reported that over 95% of Herefordshire was green space. Therefore, for the orchard study, the urban area was estimated to be 4% of the county area and the countryside landscape to be 96% of the county area, ie 209,254 ha. The landscape-related tourism value for Herefordshire was £129.6 million, as explained above. Tourism value per hectare of countryside, including orchards, is thus £619. Of course this is a very crude estimate, and value is likely to be unevenly distributed across the landscape because visitor attractions, sometimes called ‘honey-pots’, are embedded in the landscape and are likely to draw more visitor spending than the general countryside.

7.27 Lady Close Orchard provided the opportunity to approach the valuation of Herefordshire’s landscape, including orchards, through a different basis. The orchard is within Bodenham Lake Nature Reserve, which has a total area of 44.5 ha. The Nature Reserve is owned by Herefordshire Council. Use of the small car park close to the orchard is monitored by the Council. The Council’s records show that 12,979 cars entered the car park in the year May 2006 to April 2007. The survey can be used as indicative only, since it involved only 10 visitor groups arriving at the car park on one day. The survey is described in detail in Chapter 6. It should be noted that people who did not leave their cars were not interviewed, although the general environment, particularly the adjacent orchard, might have influenced their choice to park in the car park.

7.28 The car park use data and the visitor survey enabled a valuation to be calculated for the Nature Reserve based upon the cost of travel to and from the Reserve by visitors. An estimate of the amount that visitors spent in getting to and from the site was taken to be an element of their willingness to pay (WTP) for the facility. The visitor survey indicated that, among people who left their cars, an average round trip of 4.58 miles was made in order to visit the Reserve. Valuing the journeys at 40p per mile, the partial WTP to visit the Reserve could be considered to be £23,778 for a year. This is likely to be a conservative estimate since a more sophisticated WTP analysis could include, for example, the opportunity cost of the time spent in travelling to the site. From the area of the Reserve and the total WTP figure, the resultant tourism value per hectare for the Reserve was calculated to be £534. This figure is somewhat less than the average value per hectare estimated from the overall landscape-related tourism value for Herefordshire of £619 per hectare given above, but is of a similar order of magnitude. It should be remembered that this orchard is unusual, with the car park at the Reserve probably acting somewhat like a ‘honey-pot’, therefore increasing the value for the Reserve above that of a general piece of countryside with no parking facilities. Nevertheless, this simple and limited analysis provides some cross-check of the possible valuation of this orchard for visitors.

7.29 Using the tourism value / ha of Herefordshire’s landscape calculated above, an estimate of the total tourism value of orchards is the total area of orchards, 5,564 ha, (see Chapter 2) multiplied by £619, giving a total of £3.44 million for the county. However, it was decided that the estimate of tourism value for each of the study orchards would not be related to their individual areas. At the single orchard scale, visibility and type of orchard, traditional or intensive, was regarded as more important and were used to weight the value of individual orchards. Using area as well as these two factors was considered to inflate the value of larger orchards too much.

7.30 The estimated overall tourism value of orchards in Herefordshire based upon tourism spend (£3.44 million) was allocated among orchards based on the total number of orchards in the county. This number was derived from Herefordshire’s Phase 1 habitat survey, shown spatially on the Millennium Map (Herefordshire Biological Records Centre 2006). There were 3,006 orchard polygon shapes on the Map, so this number was taken to be the number of orchards in the county. When the total tourism value of orchards in Herefordshire was divided by 3,006, a value of £1,146 per orchard was obtained. The 6 study orchards together thus had a total value of £6,878.

7.31 The total tourism value for the 6 orchards was allocated amongst them using weightings for visibility and orchard type. This group of 6 orchards was regarded as independent of the other orchards in the county in that any weighting had to concern only these orchards and not be dependent on lower or higher values of other, unknown, orchards. This assumption was not considered to be unreasonable, since the study orchards were selected to represent the spectrum of orchards in the county (see Chapter 2).

7.32 The first factor used to weight the value of the orchards was the type of orchard, either traditional or intensive (see Chapters 2 and 3). The visitor survey in Hereford referred to above, and described in Chapter 6, included a question about the value of traditional and intensive orchards. Visitors were asked to look at photographs of a traditional orchard, a bush orchard and a remnant orchard and asked the following question: “In Herefordshire, there are broadly three types of orchard. If there was £100,000 available to support orchards in Herefordshire, please decide how you would like this to be shared between the types: Bush orchards, traditional orchards, remnant orchards.” This question was intended to elicit a proxy of relative value of each type of orchard. “Bush orchard” was used by the survey as a simple descriptor for orchards that are managed intensively.

7.33 People wanted most money to be spent on traditional orchards (60%), next, on bush orchards (25%) and the least on remnant orchards (15%). This division is used to indicate the relative value that people placed on the different types of orchard. The relative value of remnant orchards is ignored in the following calculation as they are unlikely to be part of the total orchard area estimated for Herefordshire (5,564 ha). In the traditional orchard inventory source for this figure (see Chapter 2), remnant orchards are not mapped. In the inventory, remnant orchards are defined as orchards that have too few trees or the trees are too widely spaced to qualify as orchards for mapping. The relative proportions of spend assigned to traditional and intensive orchards, if the proportion of spend on remnant orchards is removed, are 71% for traditional orchards and 29% for intensive orchards, ie traditional orchards were regarded as 2.4 times as valuable as intensive orchards (71/29). This weighting was applied to the value of each orchard in the study and the resultant values are shown in Table 7.2.

7.34 The landscape setting and visibility of each orchard is described in detail in Chapter 2. In summary form, the relative visibility of each orchard can be expressed by a subjective ‘visibility factor’ or ‘weighting’ depending upon its proximity to settlements, or to roads and footpaths. The visibility factor given to each orchard was within an arbitrary range set for orchards in Herefordshire of 0.1 (for very low visibility) to 2.0 times (for high very visibility). For example, Henhope Orchard is hidden in a valley, away from settlement or access routes, so was assigned the lowest visibility weighting of 0.1. In contrast, Half Hyde Orchard was adjacent to a busy main road and so was highly visible and was given the highest visibility weighting in the group of 6 orchards of 1.4. To ensure that weighting did not lead to total value exceeding £6,878 for all the orchards in the study, average visibility weighting across the study orchards must equal 1.0. As the orchards had already been weighted by type (traditional or intensive), the visibility weightings had to be treated separately in these two groups, both having an average value of 1.0. The visibility weighting, value for orchard type and resultant tourism value of each orchard is shown in Table 7.2. Three of the traditional orchards had higher tourism value than the intensive orchards but Henhope Orchard had lower visibility and lower tourism value than the intensive orchards.

Table 7.2 Tourism value of each orchard in pounds sterling (£)

	Henhope (T)	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**	**Total**
Value by orchard type £	1,423	1,423	1,423	1,423	593	593	6,878
Subjective visibility weighting	0.1	1.2	1.3	1.4	1.0	1.0	6.0
Tourism value £	142	1,708	1,850	1,992	593	593	6,878

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound.

Aggregate economic values

7.35 The three chosen economic values for each orchard are shown in Table 7.3 below, along with the aggregate monetary economic value and value per hectare. Note that Tidnor Wood Orchards was a special case as far as income and expenditure were concerned (see Chapter 3). Labour costs were high because of significant work being undertaken by the owner to develop the orchard in several ways. These included the establishment of the site as a registered National Collection of cider apples. If the cost of the owner's time is excluded from the overall cost, this gives a positive net overall value of £5,276 for orchard profitability. As a result, aggregate economic value would be £17,515 and economic value / ha would be £1,700.

Table 7.3 Aggregate economic values for each orchard in pounds sterling (£)

Orchard economic value	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Orchard profitability £	5,666	-7,172	34	1,372	15,197	6,365
Local economy value £	2,091	10,532	163	608	1,885	9,585
Tourism value £	142	1,708	1,850	1,992	593	593
Aggregate economic value £	7,900	5,067	2,047	3,973	17,675	16,543
Site area (ha)	4.5	10.3	1.8	2.5	5.4	6.2
Aggregate economic value £ / ha	1,756	492	1,137	1,589	3,273	2,668

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound.

7.36 Comparison of the relative amounts of the three economic monetary values presents a mixed picture. Orchard profitability was the highest monetary value for only two orchards, Henhope and Salt Box orchards. The value of support for the local economy was most important for Tidnor and Village Plum orchards, while tourism spending was the most significant for Lady Close and Half Hyde orchards. The two intensive orchards had the greatest overall economic value, including value / ha. Henhope and Half Hyde had somewhat similar per hectare values and Tidnor's per hectare value would have been comparable if the owner's labour input was excluded. Perhaps surprisingly, the economic value / ha of Lady Close Orchard was not very different to other traditional orchards despite no income being derived from its fruit crop.

Environmental valuations

Biodiversity

7.37 The biodiversity of the study orchards is described in Chapter 4. The orchard habitat and a selection of species groups were included in the assessment of biodiversity, there being insufficient resources to produce a complete species inventory. In addition, the genetic diversity of the fruit trees, represented by the number of fruit varieties present, was used to indicate the agricultural biological diversity of the orchards. The Conference of Parties (COP) to the international Convention on Biological Diversity have identified agricultural biological diversity as a major theme for biodiversity, especially in Decision III/11 (COP 1996). Orchard biodiversity is represented in summary form by the orchard habitat, which provides many different micro-habitats for flora and fauna. The 4 traditional orchards were identified in Chapter 4 as belonging to the 'Traditional orchards' priority habitat for conservation in the UK Biodiversity Action Plan (BAP) (UK BAP 2010). The UK BAP is the UK Government's response to the international Convention on Biological Diversity signed at the Rio Summit in 1992.

7.38 The Government recognized traditional orchards as a priority habitat after a comprehensive analysis of which habitats and species in the UK were most threatened. The review was carried out by 9 expert groups, which involved in excess of 500 experts (Biodiversity Reporting and Information Group 2007). Species and habitats in the UK that met agreed scientific criteria were placed on the UK list of priority species and habitats. Two key criteria of relevance to traditional orchards were threats to the habitat and the richness and rarity of the wildlife they support.

7.39 For the purposes of the Herefordshire orchard study, the expert biodiversity evaluation of traditional orchards is assumed to indicate the strictly 'ecological' value of traditional orchards to the functioning of the UK's ecosystems, in terms of the species populations supported by the habitat that are essential to ecosystem function and the services that the habitat provides. However, in common with the other habitats in the UK, it is currently not possible to quantify the relationships between the biodiversity of traditional orchards and the ecosystem services supported by them (UK National Ecosystem Assessment 2011). This environmental value ascribed to orchards is taken to exclude any cultural value of biodiversity recognized in social valuations of the study orchards.

7.40 The UK BAP covers some species regarded as priorities, separate to the assemblages of species supported by the priority habitats. The orchard project was unable to do a full species inventory so the number of priority BAP species present was unknown. Therefore the habitat value of the traditional orchards was assumed to include individual values of priority species.

7.41 Valuing biodiversity is notoriously difficult, including costing the impact of biodiversity change. There is more than one type of value associated with biodiversity (See Table 7.1), and these values are difficult to assess. Nunes and van den Bergh (2001) reviewed valuation methods and concluded that it was hard to identify an unambiguous monetary indicator. However, some kind of simple indicator was required for the project and a value for the orchard habitat was chosen based on payments under the Government's Environmental Stewardship Scheme (ESS) in England. Payments under this agri-environment scheme were taken to represent the value (per hectare) that the Government is willing to pay for the public goods which flow from the continued existence of the habitat, in this case the public good of biodiversity. Agri-environment schemes form the major source of expenditure related to implementation of the BAP in England, accounting for 48% of the total in 2005/2006, and the proportion was estimated to rise to 73% by 2010/2011 (White 2007).

7.42 The ESS in England includes payments for traditional orchards in the Higher Level (HLS) part of the scheme (Natural England 2010b). The options relevant to the BAP priority orchard habitat are HC18, 'Maintenance of high-value traditional orchards' and HC20 'Restoration of traditional orchards'. Orchards in Stewardship agreements under these options attracted annual payments of £250 / ha in 2006-2007. The resultant values for each of the traditional orchards can be seen in Table 7.5, and are used to represent the biodiversity values for all 4 traditional orchards, although only one orchard was actually in the Scheme. The level of payment / ha is related to factors such as positive incentives, the opportunity cost represented by income foregone in comparison to other crops, and management costs such as the expensive pruning required for large trees. It should be noted that payments under the ESS may be for other public goods such as high quality landscape features, but for the purposes of this study, the £250 / ha payment is taken to be for the value of biodiversity alone. Another ESS payment is used below to represent resource protection value, which includes soil quality. Soil biodiversity contributes to soil quality (see Chapter 5) and is therefore excluded from the biodiversity value represented by the £250 / ha payment. This payment is taken to cover only 'above-ground' biodiversity.

7.43 The ESS payments for orchards need to be interpreted with caution when used to represent biodiversity value. The payment does not represent the biodiversity value in any relative sense when compared with other habitats. For example, option HL9, 'Maintenance of moorland' attracts a payment of £40 / ha (Natural England 2010b). However, this is not because it is less valuable for wildlife than traditional orchards, merely that the payment reflects different incentives and costs deemed appropriate for different farming systems. The orchard biodiversity value therefore needs to be seen in the context of other orchard values, not values of other habitats.

7.44 It should also be noted that, in practice, entry into ESS is not unconditional for any piece of land. Some ESS agreements are awarded through competition among applicants, and all have various conditions that have to be met to qualify for the particular options and particular management requirements that must be implemented through the life of the agreement for agreement holders to remain in the scheme.

7.45 The biodiversity valuation made in Table 7.5 is only concerned with a positive value, no attempt has been made to quantify costs arising from a loss of biodiversity. Such costs might occur, for example, through reduction of pollinator populations in the intensive orchards. To some extent this will be reflected in the fruit yield and consequent income from sale of fruit, but this figure would not take account of pollinator losses that affect wild plants, which might suffer reduced seed set, and lowered ability to produce a new generation of plants, both in and around the orchards.

7.46 The Food and Environment Research Agency and Centre for Research in Environmental Appraisal and Management (2010) suggests that the benefits of ESS through enhanced wildlife and landscape values (based upon society's willingness to pay), and carbon savings could be three times the cost of such Schemes. In this study, these values are considered separately - carbon in climate regulation value as described in paragraph 7.48 and human use value within the social valuation as described in paragraph 7.54. Therefore, it was considered inappropriate to use a multiple of the stewardship scheme payment, due to the risk of duplication. The use of ESS payments, which could be considered to be the Government's willingness to pay for favourable habitat management, is used as a very crude proxy for the intrinsic value of better biodiversity. In fact, the future value from enhanced biodiversity cannot be known and therefore is immeasurable. The assumption is that the benefits delivered by ESS payments will be at least equal to the current cost to the public purse.

Climate regulation

7.47 As described in Chapter 5, the study orchards have been assessed for the carbon accumulation in soils and fruit trees and the carbon emissions due to management. These assessments have been used to work out the net carbon sequestration for each orchard on an annual basis. The value of this net sequestration is an indirect use value obtained indirectly by people in climate mitigation from the sinks for carbon, namely the fruit trees and the soil, in the orchards. Valuation of this sequestration is based on UK Government valuations of carbon. In July 2009, the Government carried out a major review of the approach to carbon valuation (DECC 2009). The new approach uses as its basis the cost of mitigation, taking into account the UK Government's emission targets, rather than the previous valuation based on damages associated with impacts.

7.48 The 2009 method treats emissions in 'traded' and 'non-traded' carbon sectors as different commodities because it is unlikely that costs of meeting targets in these two sectors will be the same (DECC 2009). Agricultural emissions are in the non-traded sector, so the orchard valuation is based on carbon prices in this sector. The DECC (2009) has published values of £ per ton of carbon dioxide equivalent (tCO_2e) for different years and ranges of prices. The value assumed for the purposes of the orchard study is the estimated cost of non-traded emission reductions in 2008, the closest year available to the main study valuation period of 2006-2007. The central range figure of £50 / tCO_2e is used to calculate the orchard carbon sequestration values, as shown in Table 7.4. The carbon sequestration figures have been derived from Table 5.14, and converted to carbon dioxide equivalent for valuation using a factor of 44/12, which reflects the relative molecular weights of carbon and carbon dioxide. Note that some orchards, such as Henhope, have a negative value because emissions exceed accumulation in these orchards. These figures are influenced by the assumption that 3 orchards, Henhope, Lady Close and Half Hyde, were not accumulating soil carbon at that time but instead had reached an equilibrium where soil carbon stored was balanced by soil carbon lost. In contrast, the other orchards were assumed to be accumulating soil carbon because levels had been lowered by soil disturbance in the recent past and that, to date, carbon accumulation exceeded soil carbon lost (see Chapter 5).

Table 7.4 Value of net carbon sequestration in each orchard in pounds sterling (£)

Carbon sequestration and value	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Net carbon sequestered, tons / year*	-0.35	11.32	-1.06	-0.84	7.51	7.12
Net carbon dioxide equivalent sequestered, tons / year	-1.27	41.51	-3.88	-3.08	27.55	26.11
Net carbon dioxide equivalent sequestered, tons / ha / year	-0.28	4.03	-2.16	-1.23	5.10	4.21
Net carbon dioxide equivalent sequestration value £ (£50 / tCO_2e)	-64	2,075	-194	-154	1,377	1,305
Net carbon dioxide equivalent sequestration value £ / ha (£50 / tCO_2e)	-14	202	-108	-62	255	211

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound. *Carbon sequestered based on carbon accumulated to date by fruit trees, plus soil accumulation, minus carbon emitted (but not including emissions from burning of prunings). See Chapter 5 for more details.

Soil quality and protection from diffuse pollution

7.49 In Chapter 5 a qualitative risk assessment was made for possible impacts of orchard management on soil quality and potential diffuse pollution problems arising from orchard management. Diffuse pollution could potentially affect aquatic and terrestrial habitats in the landscape around the orchards. Agricultural management, including horticulture, is the main source of diffuse pollution in the UK (see Chapter 5). The relative value of the traditional and intensive orchards in terms of protecting against such problems was based on the assessment in Chapter 5 that traditional orchards were more likely to maintain soil quality and generally have lower potential for causing diffuse pollution than the intensive orchards. This difference is regarded as an indirect use value of the traditional orchards for the purposes of the monetary evaluation.

7.50 The ESS includes protection of natural resources as one of its objectives (Natural England 2010b). This protection may take the form of improving water quality and reducing soil erosion and surface run-off. To represent the value of resource protection in traditional orchards, the payment for option OU1 ‘Organic management’ under the Organic Entry Level Scheme (OELS) is used in the current study. The payment is £30 per hectare per year and requires that synthetic nitrogen fertilisers, pesticides and herbicides are not applied to the land, and applications of nitrogen from animal manures is limited to an average of 170 kg / ha / year (Natural England 2010c). This type of management obtains in all the traditional orchards (see Chapters 3 and 5) and is considered to merit the £30 value / ha / year for resource protection. It should be noted that although management is ‘organic’ in this sense in all these orchards, only two of the orchards are formally certified as organic, which is another requirement in the actual OELS, but which is disregarded here. The results of applying this £30 / ha / year value to the traditional orchards can be found in Table 7.5.

7.51 The OELS payment is regarded as a positive representation of value in the current study, and the intensive orchards are not given negative costs for potential risks posed from diffuse pollution or degradation of soil. Other evidence suggests that the negative costs from agricultural use of land in terms of impacts on water quality, soils and other environmental resources may be greater than £30 / ha / year, if this is seen as a 'mitigation' cost. Environmental accounts are published each year for UK agriculture (Defra and others 2010). From the figures provided in these accounts, damages and costs were estimated to be £174 / ha in England in 2007, based on total area of agricultural land. If greenhouse gas emissions are excluded (as they are dealt with separately in the current study), the cost was £80 / ha / year for 2007. Arable and intensive grassland are likely to be the source of much of the costs, in contrast to rough grazing land and semi-natural habitats like heathland. A calculation using the area of arable, horticulture and improved grassland of 7,849,292 ha for England from the Land Cover Map 2000 (Natural England 2008) gives an estimate of £204 / ha / year or £95 / ha / year excluding greenhouse gas emissions for 2007. This estimate assumes that there had been no change in arable, horticulture and improved grassland area since the year 2000. Pretty and others (2000) came up with a similar estimate of £204 / ha / year for total 'external' costs attached to use of arable and permanent pasture land for 1996. The scale of these negative costs is noted here in the current orchard valuation but measurement of actual damages and costs was beyond the scope of the project so no other values were given to the orchards apart from the £30 / ha / year positive value assigned to the traditional orchards.

Aggregate environmental values

7.52 The three chosen environmental values for each orchard are shown in Table 7.5 below, along with the aggregate monetary environmental value and value per hectare. Tidnor had the greatest monetary environmental value both in total and per hectare. Climate regulation value played a large relative role in the overall monetary values, though the assumption referred to above about soil carbon being at equilibrium at the three sites with a negative climate regulation value should be kept in mind. Climate regulation value was the only monetary environmental value attached to the intensive orchards, while biodiversity value was the main contributor to environmental value of traditional orchards.

Table 7.5 Aggregate environmental values for each orchard in pounds sterling (£)

Orchard environmental value	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Biodiversity value £	1,125	2,575	450	625	0	0
Climate regulation value £	-64	2,075	-194	-154	1,377	1,305
Soil quality and protection from diffuse pollution value £	135	309	54	75	0	0
Aggregate environmental value £	1,196	4,959	310	546	1,377	1,305
Site area (ha)	4.5	10.3	1.8	2.5	5.4	6.2
Aggregate environmental value £ / ha	266	482	172	218	255	211

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound.

Social valuation

7.53 The social valuation was based on the views of local communities living around each orchard. These views were gathered at community meetings. The full methodology and detailed community views are described in Chapter 6 and Appendix 7. During these meetings, the people who lived around each orchard took part in structured discussions to consider the social values of the orchard for local people. People then voted on the values described by them, to identify the most popular 3 values. The values expressed by local communities were individual to each community, there was no attempt to standardise terms and apply definitions, rather, the values names were consensus categories for groups of views. These summary labels are shown in Table 6.13. However, their 'social' character (as opposed to economic or environmental character) is more fully shown in Appendix 9. Working in facilitated groups, participants then ranked these three social values in relation to the three economic and three environmental values described above. These had already been ordered by monetary value through previous project work but these values were not shown to the participants before they carried out the ranking. The results of the group rankings were then averaged across all groups. The type of approach was 'deliberative' or 'participatory' in that it involved groups of people who listened to the opinions of others and formed a collective view of values (Defra 2007). The discussions showed that the local communities attached several value types to the orchards. These were direct use (non-consumptive) value, for example access for walking, and altruistic and existence values (Table 7.1). Altruistic value is where an individual attaches a value to the availability of the resource to others in the current time, for instance the local people noted the educational value of orchards. They also liked the fact of an orchard being there even where access to it or views of it were restricted (existence value).

7.54 The comparisons made by the local people have been regarded as two separate comparisons: social versus economic value and social versus environmental value, as explained in Chapter 6 (paragraph 6.55). For each orchard, ranks (1 to 6) of all possible pairs of economic, social and environmental values were calculated for the 6 values in each pair. Sums of ranks were calculated to derive the overall comparison across orchards shown in Table 6.14. The ranks were based on the order of values given in Table 6.13. Given the pair-wise character of the comparisons, it was not easy to monetarily link social values to economic and environmental monetary values at the same time. As overall social value always out-ranked overall environmental value in every orchard except Tidnor, where they were equal, (Table 6.14) a monetary link was ignored and social value only linked to economic value.

7.55 The monetary link between economic and social value was made by using the proportional relationship between the sum of the ranks of the two types of value to estimate the social value as a proportion of aggregate economic value (Table 7.6). The identity of the individual values, such as orchard profitability, was ignored, only the overall values were of interest. It should be noted though that the preliminary economic valuation figures differed from the revised figures presented in Table 7.3. However, rankings of these values are the same as the original rankings with the exception of one case, where the orchard profitability value was swapped with tourism value for Half Hyde Orchard. Both economic values were rated higher than any social value at Half Hyde by local people so this swop of rank has been ignored.

7.56 Local communities were asked to identify both positive and negative values for each orchard. Both types of value were ranked as one set by the local people, and negative values were among the top 3 values at two sites, Tidnor and Half Hyde orchards. These negative values were treated as 'costs' in the same way as carbon emissions were in the climate regulation section and as expenditure on orchard management was in the orchard profitability section. The rankings incorporated these negative values, with the result that the overall sum of ranks for the social value of an orchard with a negative value was reduced compared to other orchards where all rankings were of positive values. These reduced social values also appropriately affect the proportional relationship between social and economic sums of ranks (Table 7.6).

7.57 The combined monetary value for the 3 social values identified for each orchard are shown in Table 7.6. These monetary figures are based on an assumption of an even distribution of value within the ranked list of economic and social values. Also, where social value exceeds the economic value, the estimate is just a minimum estimate. However, only at

Lady Close does any single social value rate higher than the top economic value. This means that the social monetary value must be of a similar order of magnitude as economic value for all sites except Lady Close, where this assumption would not hold.

7.58 From Table 7.6 it is obvious that a high economic value has a major influence on creating a high social value. On this basis, the intensive orchards have greater social value as well as economic value, and this would be likely to be the case elsewhere given the highly productive character of intensive orchards compared to most traditional orchards. However, the local people were only considering their orchard and were not aware of the other orchards and the differences in economic value between them. The lack of this wider frame of reference meant that the social value was heavily influenced by the economic value of the particular orchard that local people were discussing. Results might have been different if they had had an opportunity to see the full range of economic values across all the orchards. An alternative estimate of social value based on average economic value per hectare for each orchard was made to illustrate how such an average would affect social value (Table 7.6). Of course, the average value favours the less economically valuable orchards, the opposite to the individual approach to each orchard described above. Either of these estimates are merely experimental and no firm conclusions can be drawn from them. Both are shown in the triple bottom line accounts (Table 7.7 and Table 7.8) but any totals incorporating them should be treated with extreme caution.

Table 7.6 Estimated overall social value based on economic values of each orchard in pounds sterling (£)

Estimate of social value	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Sum of ranks of economic values	11	3	7	10	10	12
Sum of ranks of social values	10	4	14	4	11	9
Proportion of social rank sum to economic rank sum %	91	133	200	40	110	75
Aggregate economic value of each orchard, £	7,900	5,067	2,047	3,973	17,675	16,543
Overall social value as a proportion of aggregate economic value of each orchard, £	7,182	6,757	4,094	1,589	19,443	12,407
***Overall social value as a proportion of aggregate economic value based on average economic value, £**	7,090	23,801	6,239	1,733	10,295	8,059

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Ranks: highest rank scores 6, lowest rank scores 1 if all ranks positive. Where negative values occur ranks ranking as follows; Tidnor 4 to -2 (one negative economic value and one negative social value), Half Hyde 5 to -1 (one negative social value). *Average economic value is sum of economic values of all orchard divided by the total area of the orchards: £53,206 / 30.7 ha = £1,733 / ha. Figures for pounds are rounded to the nearest whole pound.

Triple bottom line accounts

7.59 The triple bottom line accounts for each orchard are shown in Tables 7.7 and 7.8. Table 7.7 uses the aggregate monetary economic value of each individual orchard and Table 7.8 uses the average monetary economic value / ha to estimate social monetary value. As explained above, the social values in the two alternative tables must be treated with great caution. They produce widely different aggregate values for Tidnor especially (a difference of £17,044), followed by Salt Box Orchard (£9,149). Lady Close (£2,145) and Village Plum (£4,348) show moderate differences while differences for Henhope (£92) and Half Hyde (£144) are minor.

7.60 The tables show that when only economic and environmental values are considered, the economic value always is greater than the environmental value, although the two values are similar at Tidnor, because of the unusually high labour costs affecting orchard profitability at this orchard, as explained above. Linking payments under the Environmental Stewardship Scheme to environmental values clearly has a major effect on the comparison to economic values. As a consequence, the relatively low monetary values assigned to environmental values such as biodiversity compare poorly to social values, which were estimated by comparison to economic values. As explained above, the environmental value of biodiversity is taken to be its ecosystem functional value, excluding cultural value of biodiversity. The local communities around the orchards ranked enjoying wildlife highly (see Chapter 6, Table 6.13). This enjoyment of wildlife is taken here to be the cultural value of biodiversity. Aggregate monetary environmental value, including functional biodiversity value, was always lower than aggregate monetary social value whichever way the calculations were done (Tables 7.7, 7.8). Environmental values are difficult to quantify in monetary terms and some of the issues affecting environmental values, beyond the annual valuations attempted here, are discussed further in the next section. The inter-related character of values is also discussed below, in the section on ecosystem assessment.

Table 7.7 Triple bottom line accounts for each orchard in pounds sterling (£), using social value based on aggregate economic value of each orchard

Orchard value £	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Aggregate economic value £	7,900	5,067	2,047	3,973	17,675	16,543
Aggregate environmental value £	1,196	4,959	310	546	1,377	1,305
Overall social value as a proportion of aggregate economic value of each orchard, £	7,182	6,757	4,094	1,589	19,443	12,407
Aggregate value economic + environment + social £	16,278	16,783	6,451	6,108	38,496	30,256
Orchard value £ / ha						
Site area (ha)	4.5	10.3	1.8	2.5	5.4	6.2
Aggregate economic value £ / ha	1,756	492	1,137	1,589	3,273	2,668
Aggregate environmental value £ / ha	266	482	172	218	255	211
Overall social value based on economic value of each individual orchard £ / ha	1,596	656	2,274	636	3,601	2,001
Aggregate value economic + environment + social £ / ha	3,617	1,629	3,584	2,443	7,129	4,880

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound.

Table 7.8 Triple bottom line accounts for each orchard in pounds sterling (£), using social value based on average economic value of the orchards

Orchard value £	**Henhope (T)**	**Tidnor (T)**	**Lady Close (T)**	**Half Hyde (T)**	**Salt Box (I)**	**Village Plum (I)**
Aggregate economic value £	7,900	5,067	2,047	3,973	17,675	16,543
Aggregate environmental value £	1,196	4,959	310	546	1,377	1,305
Overall social value as a proportion of aggregate economic value based on average economic value, £	7,090	23,801	6,239	1,733	10,295	8,059
Aggregate value economic + environment + social £	16,186	33,828	8,596	6,252	29,347	25,907
Orchard value £ / ha						
Site area (ha)	4.5	10.3	1.8	2.5	5.4	6.2
Aggregate economic value £ / ha	1,756	492	1,137	1,589	3,273	2,668
Aggregate environmental value £ / ha	266	482	172	218	255	211
Aggregate social value based on average economic value of the orchards, £ / ha	1,576	2,311	3,466	693	1,906	1,300
Aggregate value economic + environment + social £ / ha	3,597	3,284	4,776	2,501	5,435	4,179

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. Figures are rounded to the nearest whole pound.

Orchard evaluation limitations and alternative approaches

Price versus value

7.61 It may be impossible to fully represent some orchard values like biodiversity in a monetary way. Such values are sometimes referred to as 'intrinsic' values (Millennium Ecosystem Assessment 2003), although Bateman and others (2010) argue that usually they are non-use existence values conferred from the human point of view, rather than being 'intrinsic', for example, to the actual wild plants and animals. The orchard evaluation has had to rely on monetary estimates that are strongly linked to the market place. This approach is satisfactory when the orchard goods are produced for a competitive market, where the prices obtained are a reasonable reflection of value of the goods, for example to the orchard owner. However, this approach has also had to be taken for environmental goods such as biodiversity. Here, the value used is really a fixed price for maintaining biodiversity decided upon by Government. Note that actual costs of appropriate management and income obtained by farmers may vary widely, between traditional orchards and in comparison to intensive orchards, as shown by the income and expenditure accounts of the study orchards (Chapter 3). The 'real' value of traditional orchards in maintaining ecosystem function and services is not known. Similarly, the carbon value is the price of mitigation measures and the soil quality and diffuse pollution protection is the price set for using less intensive management in traditional orchards compared to conventional orchard management using pesticides.

Tax and subsidy

7.62 The orchard evaluation has largely ignored the effect of tax-take on the market values of orchard produce in the economic accounts presented above. The economic benefits to the orchard owner, for example, have not been reduced through subtraction of tax for Government purchase of other public goods such as education and health. However, this tax-take would have been partially offset by inclusion of subsidy for agricultural production through the European Union's Common Agricultural Policy, if, at the same time, subsidy had been included for all orchards. At the time of the study, only the traditional orchards were eligible for the Single Payment (see Chapter 3). Reform of the EU fruit and vegetable regime meant that all orchards were eligible to apply to be allocated new Single Payment from 2010 (Defra 2008). An indication of the level of the subsidy may be gained from estimates for 2010 of area payments for arable production of around £228 / hectare (ha) and dairy production of about £262 / ha (Horne 2010). The current orchard figures are lop-sided, as a partial inclusion of subsidy has been made, but no tax deducted from most items.

Capital assets

7.63 The orchard accounts have only considered annual monetary values including, where possible, costs as well as income and other positive values. The accounts do not consider the stocks of particular features, or 'capital', such as carbon in soils. The impact of use of an orchard to provide a sustained yearly harvest, or a range of other goods, depends critically on stock or 'capital' as well as yearly balance of 'profit' and 'loss' in each value category. In addition to capital value within the orchard, the capital value of farm assets required to manage the orchard are not included, such as machinery, nor its depreciation in value over time.

7.64 Two illustrations of the potential monetary value of 'capital' assets within the orchards are given below. First a valuation of carbon stocks in the orchard is made. As described in Chapter 5, the study orchards have been assessed for the carbon stored in soils and fruit trees. Using the same valuation as net carbon sequestration of £50 per ton of carbon dioxide equivalent, explained above in the climate regulation valuation, the resultant monetary values for carbon storage are shown in Table 7.9 below.

Table 7.9 Value of carbon stored in soil and fruit trees in each orchard in pounds sterling (£)

Orchard stored carbon and value	Henhope (T)	Tidnor (T)	Lady Close (T)	Half Hyde (T)	Salt Box (I)	Village Plum (I)
Site area ha	4.5	10.3	1.8	2.5	5.4	6.2
Total soil carbon, tonnes (0-30cm)	335.46	483.57	111.23	277.73	255.59	190.32
Total fruit tree carbon, tonnes	79.24	341.76	15.47	65.47	74.86	114.22
Total stored carbon tonnes	414.70	825.34	126.70	343.20	330.45	304.54
Total CO_2e, tonnes	1520.57	3026.23	464.55	1258.39	1211.65	1116.64
Total value CO_2e £	76,028	151,312	23,227	62,920	60,583	55,832
Total value CO_2e £ / ha	16,895	14,690	12,904	25,168	11,219	9,005

Notes: T = traditional orchard with low intensity management, I = intensive orchard with high intensity management. CO_2e = carbon dioxide equivalent (see Chapter 5). CO_2e is carbon x 44/12. Pounds (£) are rounded to the nearest whole pound.

7.65 The orchards are currently 'protecting' this stock of carbon, although in 3 orchards, estimates of emissions just exceed accumulation (see Table 7.4) so stocks in these orchards may be declining slowly. This estimate of 'capital' value needs to be seen in the context of long-term maintenance or loss of carbon. Future soil disturbance and removal of fruit trees would diminish the stock.

7.66 Genetic diversity of fruit trees is included in the value of biodiversity, as explained in the biodiversity evaluation section above. The value of this genetic diversity provides another illustration of capital assets. The traditional orchards have greater numbers of fruit varieties than the intensive orchards (Table 4.7), in particular Tidnor Wood Orchards which incorporates over 400 cider apple varieties in its National Collection®. This collection is recognised by the National Council for the Conservation of Plants and Gardens (NCCPG). Changing climatic conditions and pest and disease populations in the future may mean that new fruit varieties have to be developed. Thus the genetic diversity within the Tidnor Wood collection has an 'option value' as well as other biodiversity values (Table 7.1). If varieties grown currently have to be totally replaced because they are no longer economically competitive to grow, and suitable varieties are bred from existing varieties in the Tidnor collection, the cider collection might have a capital value equated to the total value of cider apple production at farm gate prices. In 2007 this value was about £12 million for the UK (Defra 2010a). England and Wales provided the major share of commercial orchard area in 2007, Scotland only had 0.2% of the total UK orchard area in that year (Scottish Government, Rural And Environment Research And Analysis Directorate 2009, Defra 2010a). The cider and perry production value therefore derives almost totally from England and Wales. Although this overall value includes perry pear value as well as cider apple value, perry pears only occupied 0.6% of the total area of cider apples plus perry pears in 2007 in England and Wales (Defra 2010b). Perry pears are therefore unlikely to make a major contribution to the overall value of production of cider apples and perry pears.

Additional orchard values related to the Environmental Stewardship Scheme

7.67 The orchard valuation included single values (ie prices) for biodiversity and resource protection derived from payments under the Government's Environmental Stewardship Scheme (ESS). The Scheme provides other options of relevance to orchards, that would increase values if used in the same way as the chosen values are employed in the valuations above. As well as biodiversity and resource protection, ESS has objectives for maintenance of landscape quality, public access and education. To illustrate possible additional values, a selection of options is listed in Table 7.10, for the two types of orchard, traditional and intensive. The options are non-overlapping, so that there is no double-counting. For instance, payment for buffer strips in grassland under the Entry Level Scheme (ELS) is not available for traditional orchards which are already in the HLS as this aspect is already covered by the HLS orchard options. For Entry Level or Organic Entry Level ES payments, a range of options can be chosen but the combined value must be a maximum of £30 / ha averaged across the farm. The OELS organic management payment (OU1) of £30 / ha used in the soil quality and protection from diffuse pollution valuation above (Table 7.5), is in addition to the basic ELS and OELS £30 / ha payment. The OU1 payment is shown in Table 7.10 under the heading of ESS options used already in the orchard valuations, while the basic payment is represented by the selection of ELS and OELS options shown under the heading of additional possible ESS option values.

Table 7.10 Examples of additional orchard values based on Environmental Stewardship Scheme options

Scheme type and option code	Option description	Traditional orchard payment	Intensive orchard payment
ESS option values used already			
HLS: HC18 / HC20 (biodiversity)	Maintenance of high value traditional orchards / Restoration of traditional orchards.	£250 / ha	0
OELS: OU1 (soil quality and protection from diffuse pollution)	Organic management	£30 / ha	0
Additional possible ESS option values			
HLS: Capital payments	Orchard capital works for restoration for orchards in options HC20 and HC18: management plan, restorative pruning of trees, tree planting, measures to facilitate grazing (such as tree guards, fencing, water supply)	*£250 / ha	0
ELS & OELS: EB1 or OB1 / EF4 or OF4 (biodiversity) / EE6 (protection against diffuse pollution)	Hedgerow option (a popular one of several hedgerow options). Management by trimming each hedge no more than once in every 2 calendar years, both sides of the hedgerow / Nectar and flower mix in 6 m wide strips or in blocks of 1 ha or less / 6 m wide buffer strips in grassland (one of several options)	£30 / ha	£30 / ha
HLS: HN9 (social value)	Educational access comprising a base payment and a payment per visit by groups to a maximum of 20 visits per year, using an educational pack developed for the orchard (on top of HC18/HC20)	Base payment £500 per year Per visit £100	0
Total payment		£530 / ha + £2,500 per orchard	£30 / ha

Notes: HLS = Higher Level scheme, ELS = Entry Level scheme, OELS = Organic Entry Level Scheme. * Estimated average / year over 10 year agreement across traditional orchards in HLS produced by Chris Wedge and Geoff Newman (Natural England). Details of options and payments can be found in Natural England (2010a, 2010b, 2010c).

7.68 The capital payment under HLS for traditional orchard management illustrate the issue of irregularly occurring benefits or costs beyond a one-year account. These capital payments can be seen as an additional value of the public goods provided by traditional orchards, because the public, in the form of Government, is willing to pay these sums to ensure the continued supply of public goods from the orchards. In contrast, owners of intensive orchards have to bear the cost of orchard replacement once the orchard has reached the end of its productive life and this cost should be factored in for any accounting of profits over longer periods than the current annual accounts shown in Table 7.3. Such costs could be about £7,500 / ha (Chris Fairs, Bulmer Orcharding, pers. comm.). Over a period of, say, 30 years, this cost would average £250 / ha.

Triple bottom line accounting compared to ecosystem assessment

7.69 Ecosystem assessment has become a significant way of evaluating the impact of human activity on the planet and the benefits to humans that the natural environment provides at international and national level (Millennium Ecosystem Assessment 2003, UK National Ecosystem Assessment 2010). An ecosystem is defined as a natural unit of living things (animals, including humans, plants, fungi and microorganisms) and their physical environment (Millennium Ecosystem Assessment 2003, Defra 2007). In the UK, ecosystems have been broadly equated to habitat groups such as woodlands and enclosed farmland (Watson and Albon 2010). Underpinning the attempt to value the contribution that ecosystems make to human well-being, a range of ‘ecosystem services’ have been identified that produce benefits and sustain human life (Millennium Ecosystem Assessment 2003). Ecosystem assessment also examines how sustainable these services are and what factors are responsible for changes in the ability of ecosystems to provide benefits (Millennium Ecosystem Assessment 2003, Watson and Albon 2010).

7.70 Ecosystem assessment has similarities to triple bottom line accounting as both approaches try to identify and quantify multiple values and costs. Triple bottom line accounting has focused to date mainly on individual businesses, but the definition of items to value as part of the approach in the current project for orchard habitats suggests some conceptual similarities with ecosystem assessment. The Millennium Ecosystem Assessment recognised several types of service: provisioning services, ie products obtained from ecosystems; regulating services, ie benefits from regulation of ecosystem processes; cultural services, ie non-material benefits that people obtain, for instance, through spiritual enrichment, inspiration and recreation; supporting services, ie those necessary for the production of all other ecosystem services (Millennium Ecosystem Assessment 2003, Defra 2007). Ecosystem services can be taken to mean goods obtained from ecosystems, such as food, as well as functions such as nutrient cycling (Defra 2007, UK National Ecosystem Assessment 2010). Traditional orchards have been recognised as supplying a wide range of ecosystem services across all 4 ecosystem service categories (Cole and others 2009).

7.71 To illustrate the links, and potential mis-matches between the two approaches, the values assessed in the orchard project are compared to ecosystem services in Table 7.11. Note that the economic valuation processes undertaken in the two approaches are not being compared here, only the definitions of items to value. The table tries to make links between triple bottom line values and ecosystem services by assignment of components of triple bottom line values to the various ecosystem service categories. This linkage is not always easy to make and text in italics in Table 7.11 indicates mis-matches of the two approaches.

Table 7.11 Comparison of triple bottom line accounting values and ecosystem services

Triple bottom line accounting values	Ecosystem services
Economic: Orchard profitability	**Provisioning:** fruit, firewood, wild products (mistletoe)
Economic: Gain from orchard expenditure to the local economy	***Secondary (?) provisioning:*** *secondary, multiplier, value from production of fruit, firewood and wild products (mistletoe)*
Economic: Gain to local economy from spending by tourists	**Cultural:** visitors enjoyment of landscape with orchards (eg aesthetic, spiritual) ***Secondary (?) provisioning:*** *'money crop' harvested from visitors spending in Herefordshire benefits local people*
Environmental: Biodiversity	***Provisioning:*** *genetic resource of fruit varieties,* ***Supporting:*** *photosynthesis by plants, nutrient cycling involving above-ground organisms*
Environmental: Climate regulation through net carbon sequestration	**Regulating:** mitigation of climate change through net carbon sequestration in orchard soils and fruit trees
Environmental: Soil quality and protection from diffuse pollution	**Regulating:** soil quality and reduction of soil erosion, reduction of diffuse pollution, pest regulation by natural enemies, safeguarding fruit crop pollinators **Supporting:** soil formation including role of soil biodiversity, nutrient cycling by below-ground biodiversity
Social: Three values per orchard identified by the local community	**Cultural:** local communities values including enjoyment of nature, enjoyment of orchard management in action, access for activity, visual attractiveness, tranquillity, existence value, sense of place

7.72 Two triple bottom line values, local economy spend and tourism spend, do not fit easily into the ecosystem services categories. Tourism value could be seen as what the visitor gains from visiting Herefordshire, such as aesthetic or spiritual benefits, and / or as monetary gains that local people make from tourism. The mis-match of 'provisioning' services and local spend is due to the local focus of the triple bottom line approach in the orchard study.

Spending in the local area, Herefordshire, means that money is not spent elsewhere and so these two local benefits would disappear at a national level of assessment.

7.73 Biodiversity categorization presents a particular problem and the matches suggested are only one possible linkage. The statement by the Board of the Millennium Ecosystem Assessment (2005) includes a conceptual diagram which shows biodiversity as surrounding all the ecosystem services, implying it is essential to all of them. Defra (2007) excludes biodiversity from a list of ecosystem services though says that biodiversity underpins all ecosystem services and can also be a service in itself. Cole and others (2009) note that biodiversity is sometimes treated as a service but also describe biodiversity as 'capital' from which services are generated. These authors included biodiversity in their evaluation of the contribution of ESS to ecosystem services, although not as a specific service. As discussed in the valuation sections above, in the orchard study, biodiversity has been seen as a component of environmental value and contributing to the social value of orchards through of enjoyment of wildlife by local people. For the purposes of the study biodiversity was not seen as an 'absolute', in the sense of biodiversity underpinning all services. Instead, the difference between traditional and intensive orchards was assessed. The UK National Ecosystem Assessment (2011) emphasized the difficulty of relating change in biodiversity to change in output of services as the values and benefits associated with biodiversity are not well understood. In the orchard study, high biodiversity, as represented by priority BAP status of traditional orchards, is assumed to confer benefits in services, in contrast to the lower biodiversity of intensive orchards, but empirical research is required to test this assumption.

7.74 Aside from the biodiversity issue, the identification of items to value by triple bottom line accounting appears to be simpler and more straightforward compared to the conceptual complexities of ecosystem assessment. Ecosystem services are treated as a hierarchy in the literature, in that supporting services are distinguished as a separate layer on which all the others depend (Millennium Ecosystem Assessment 2003, Harlow and others 2010). Watson and Albon (2010) have 4 layers within a larger conceptual diagram. These 4 layers, redrawn as rows rather than columns, are shown below:

Economic £

↑

Goods / benefits for people

Eg food, recreation, aesthetic / inspiration, disease / pest control

↑

Final ecosystem services

Eg pollination, crops, livestock, meaningful places

↑

Primary and intermediate processes

Eg soil formation, nutrient cycling, decomposition

7.75 Any framework of this nature can pose difficulties. So, for example, the distinction between pollination services and pest control may not be clear-cut. An invertebrate predator which prevents damage to a flower bud by a pest would seem to be in the same intermediate category as another invertebrate which pollinates the subsequent flower. Indeed, O'Gorman and Bann (2008) class disease and pest control as 'intermediate' rather than 'final' benefits of ecosystem services. The use of triple bottom line accounting in the orchard study suffers from similar problems of categorisation and interrelationship between values. For instance, 'enjoying wildlife' in orchards was identified as a social value in 5 out of the 6 orchards. However, this value was always ranked by local people more highly than the environmental value of biodiversity, on which it could depend. Similarly, biodiversity value, represented by ESS payments, can have consequences for economic values such as employment of labour, and thus spend in the local economy. Mills and others (2010) calculated that for every one Full-Time Employment (FTE) job created as a direct result of

ESS scheme expenditure in England, 0.25 FTE job was created in the local economy. Economic, environmental and social values defined by approaches based on triple bottom line accounting or ecosystem services are inter-connected and any divisions between them are likely to be somewhat arbitrary.

7.76 Although investigation of sustainability is an essential feature of ecosystem assessment, identification of items incurring annual costs and costs affecting capital assets may not be so easily related to identification of benefits of ecosystems services, compared to the costs recognised in triple bottom line accounting. Agbenyega and others (2009) had to introduce the terms 'negative services' and 'dis-services' in their woodland study, because they were needed to reflect some of the views of local people about the importance of various services or functions of community woodlands. This approach is similar to the way that 'negative values' were recognised in the orchard community meetings (Chapter 6 and social valuation section, Chapter 7).

7.77 The focus of the orchard study was on engaging local people in exploring the values of orchards. The approach had to attempt to define readily identifiable values. Even given this effort, environmental values may not have been as well-understood as other types of value, such as the profits from orchard production (see Chapter 6). Overall, triple bottom line accounting, with a rather simpler structure of values, and linkage to the more common experience of other kinds of monetary accounts, may be more suitable than ecosystem assessment when undertaken at a local level by local people or businesses. These interest groups are dealing with small areas of habitat, which probably have fewer types of value, compared to national and international assessment of ecosystems, and the simpler structure of triple bottom line accounting may be easier to adapt to local circumstances.

Conclusions on triple bottom line accounting for orchards

7.78 The monetary evaluation that was carried out for the triple bottom line accounts highlighted values of orchards beyond their profitability to orchard owners. The values identified in the orchards could be broadly equated to a categorisation of ecosystem services provided by orchards. Values included environmental values as well as other economic values. Triple bottom line accounting proved to be a useful, structured, way of assessing monetary value and costs, although the project could only partially cover the estimation of costs. The advantage of using triple bottom line accounting was as much about the focus that it contributed to the process of investigation as the absolute numbers that the accounts contain. There is no doubt that the analysis is simplistic and imperfect, not only because of some of the assumptions that have been made in the calculations (such as the valuations used for soil quality and biodiversity) but also because the interrelationships between values are not taken into account. The study is seen as a starting point for engaging local people in recognising the varied values of orchards. More accurate ways of valuing orchards need to be developed, for example through empirical research into the role of differences in biodiversity between traditional and intensive orchards in differences in ecosystem services and benefits. While the limitations of the measures used to arrive at monetary valuations must be kept in mind, the valuations indicated that the traditional and intensive orchards each had overall monetary values at least double that of profit alone, based on aggregate figures for each type of value.

7.79 The two intensive orchards had the greatest monetary economic value including on a per unit area basis. Orchard profitability to the owner was not always the highest economic value, it was exceeded either by value to the local economy or by tourism value in 4 out of the 6 orchards. Climate regulation value played a large part in determining the aggregate monetary environmental values of the orchards. It was the sole monetary environmental value attached to the intensive orchards while biodiversity was the main contributor to the environmental value of traditional orchards. Even though the orchards were clearly important to local communities, monetary social valuation was problematic and the experimental monetary values that were calculated were very influenced by the aggregate economic values of the orchards.

7.80 Monetary economic values always out-weighed environmental values even in the traditional orchards based on the choice of monetary values made in the study. It was difficult to assign realistic figures to environmental values. The chosen values were really prices rather than intrinsic values and a different valuation method might have changed the relationship between economic and environmental values. Other values and costs can be assigned to the orchards apart from the annual flows examined in the triple bottom line accounts. Inclusion of capital assets and additional values of environmental features in monetary terms, as well as other sources of costs, would provide a more complete picture of relative triple bottom line values.

7.81 The triple bottom line approach that has been adopted to value the orchards in this study has very much been an experimental exercise. The authors consider the approach to have been worthwhile, particularly at this local level. The inclusion of a value for biodiversity is problematic, but the approach adopted in this study was that it was preferable to include biodiversity value based upon this fixed cost for favourable habitat management rather than leave it out of the calculation on the grounds of immeasurability.

Topics for further work

7.82 There is a need for better understanding of costs as well as positive monetary benefits attached to orchard values. More knowledge is required about how ecosystems function and the role of components like biodiversity in order to make improved valuations of such features and environmental values in general. A more satisfactory way of expressing monetary social value is required, including how to assess social value in a wider context than a single orchard. The interrelationships between values need further investigation and ways found to take account of these interrelationships.

7.83 Broader consensus about the values that should be included in similar valuations as that attempted here would be helpful. In particular, the inclusion of the intrinsic value of biodiversity, whether based upon Environmental Stewardship Scheme payments or other proxies, is a topic for further debate.

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8 Conclusions

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8.1 Detailed conclusions about the different types of orchard values studied, monetary valuation, local engagement and suggested topics for further work can be found in the individual chapters. Here, conclusions relating to the broad objectives of the project, given in Chapter 1, are described.

Project objective 1: investigate values of orchards

8.2 The project significantly increased the knowledge of particular orchard values which had received relatively little investigation in the past, such as orchard biodiversity, carbon sequestration by orchards and values of orchards to local communities. All the orchards had multiple values, although not all orchards had all the values assessed, in particular, intensive orchards were not judged to have positive values for the maintenance of soil quality and prevention of diffuse pollution, while three of the traditional orchards were carbon sources rather than sinks. Values differed in importance across orchards, for example the profitability of the intensive cider orchard was greater than that of the traditional cider orchards, while traditional orchards had higher biodiversity value, in terms of habitats, species and fruit varieties, than the intensive orchards. The values identified in the orchards could be broadly equated to a categorisation of ecosystem services provided by orchards.

8.3 Although the project was confined to 6 case study orchards, it provided pointers to likely values attached to other orchards in the UK, which could be investigated by further research.

Project objective 2: monetary valuation of orchards

8.4 The monetary valuation process was not without difficulties but monetary values were assigned to each of the selected types of values, either by using established metrics, such as profit, or where these were not available, in the cases of tourism value and social value, by using innovative approaches to derive a measure of value. However, the latter results were tentative at best. While the limitations of the measures used to arrive at monetary valuations must be kept in mind, the valuations indicated that each orchard had overall monetary values at least double that of profit alone based on aggregate figures for each type of value.

8.5 The triple bottom line accounting method was a simple, structured way of carrying out monetary valuation. The process of valuation was just as important as the end result because the search for an acceptable financial value or proxy focused attention on exactly how values should be delimited. Although the values may not have been as discrete as a triple bottom line analysis would suggest, the categorisation into social, environmental and economic values appeared to make sense to the general public.

Project objective 3: engagement with local communities

8.6 Investigation of the social value of orchards showed that local communities cared about the orchards in their locality, were interested in what happens in them, and welcomed engagement about their worth. The community evenings held during the project brought local people together and encouraged them to think about the commonality of interest in their local landscape.

8.7 Overall, the methodological approach adopted for local community engagement was judged to have had merit. It had the capacity to generate results in a timely and engaging way and was successfully used in another similar project, suggesting it has wider utility than just for the Herefordshire Orchards Community Evaluation Project.

Project objective 4: inspire further action on orchards

8.8 The project was a catalyst for further community activity. Though not part of the formal valuations made by the project, these activities demonstrated a high degree of public interest in other community values of orchards, for example as inspiration for art and drama, which helped to take the message of the value of orchards to new audiences.

8.9 In 2011, Herefordshire coordinated its orchard-focused events into a celebrative 'Herefordshire Year in the Orchard'. This culminated in the presentation of a new Pomona award by the Royal Horticultural Society designed to promote and celebrate the best, the most innovative, the most diverse and the most historic orchards in Herefordshire. This award specifically took into account their impact on the wider community and measures to enhance the environment.

8.10 Overall, the project demonstrated that orchards have a wide range of values and that they deserve further attention to deepen our understanding of their multiple values and the ecosystem services that they provide.

Appendix 1 (A1) Habitat data for individual orchards

Table A1.1 Fruit tree data for Henhope Orchard

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
1	144		1			1	1
2	135		1		1		
3	45				1		1
4	112		1		1		1
5	95						1
6	104				1		1
7	130		1			1	
8	52		1		1		1
9	88		1		1	1	
10	112						
11	61						
12	71		1		1		
13	51				1		
14	118		1				1
15	100		1		1		
16	89		1		1		
17	91						
18	99		1				
19	46				1		
20	50						

Table A1.2 Grassland composition and cover for Henhope Orchard

Composition / Quadrat	1	2	3	4	5	Average
Grassland height cm	25	14	18	15	16	17.6
Grasses % cover	20	65	85	85	95	70
Broad-leaved herbs % cover	0	15	2	10	5	6.4
Nettles % cover	80	0	10	0	0	18
Thistles % cover	0	15	0	5	0	4
Docks % cover	0	5	3	0	0	1.6
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	0	0	0	0	0	0

Table A1.3 Hedgerow basal flora composition and cover for Henhope Orchard

Composition / Quadrat	1	2	3	4	5	Average
Vegetation height cm	70	80	190	110	57	101.4
Grasses % cover	25	0	0	10	100	27
Broad-leaved herbs % cover	25	0	0	0	0	5
Nettles % cover	50	80	80	80	0	58
Thistles % cover	0	0	10	5	0	3
Docks % cover	0	0	10	5	0	3
Cleavers % cover	0	0	0	0	0	0
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	0	20	0	0	0	4

Table A1.4 Boundary type, hedgerow dimensions and condition for Henhope Orchard

Boundary type	ID no on map	Species -rich	Length m	Height m	Width m	Cross-sectional area sq m	Final condition & failing attributes
Fence	1		71				
BAP line of trees + shrubs (hedgerow)	2	Yes	456	10.00	6.00	60.00	Unfavourable 2b, 2c, 4
Fence	3		100				
Fence	4		524				

Notes: Condition attributes and pass thresholds: 1a = height of hedgerow (≥ 1m); 1b = width of hedgerow (≥ 1.5m); 1c = cross-sectional area of hedgerow (≥ 3m); 2a = gaps along hedgerow (< 10% of hedgerow length); 2b = individual gaps (≤ 5m width); 2c = base of woody canopy above ground (≤ 0.5m); 3a = undisturbed ground (≥ 2m width), 3b = perennial herbaceous vegetation (≥ 1m width); 4 = eutrophication / disturbance plant indicators (< 20% cover); 5 = non-native woody species (≤ 10% cover).

Table A1.5 Fruit tree data for Tidnor Wood Orchards: Museum Orchard

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
1	14		1		1		
2	19						
3	18						
4	11						
5	18						
6	12						
7	6						
8	8						
9	14						
10	6						
11	10						
12	12				1		
13	16						
14	15						
15	17						
16	13						
17	22						
18	15						
19	20						
20	12						

Table A1.6 Fruit tree data for Tidnor Wood Orchards: French Orchard, Bottom and Old Orchards

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
1	68				1		1
2	69		1		1		1
3	53		1				
4	101		1		1		1
5	70		1		1		
6	88		1				1
7	98						1
8	72		1		1		1
9	67						
10	63				1		
11	102		1				1
12	109		1		1		
13	96						
14	65		1				
15	79		1				
16	115		1				1
17	76		1				
18	106		1		1		
19	105						
20	90						1

Table A1.7 Grassland composition and cover for Tidnor Wood Orchards: Museum Orchard

Composition / Quadrat	1	2	3	4	5	Average
Grassland height cm	24	14	10	21	14	16.6
Grasses % cover	65	50	60	10	30	43
Broad-leaved herbs % cover	35	30	20	80	70	47
Nettles % cover	0	5	0	0	0	1
Thistles % cover	0	5	0	5	0	2
Docks % cover	0	0	20	5	0	5
Bramble % cover	0	10	0	0	0	2
Bare ground % cover	0	0	0	0	0	0

Table A1.8 Grassland composition and cover for Tidnor Wood Orchards: French and Bottom Orchards

Composition / Quadrat	1	2	3	4	5	Average
Grassland height cm	7	8	9	16	20	12
Grasses % cover	75	75	95	100	90	87
Broad-leaved herbs % cover	15	25	5	0	5	10
Nettles % cover	0	0	0	0	0	0
Thistles % cover	0	0	0	0	0	0
Docks % cover	0	0	0	0	2	0.4
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	10	0	0	0	3	2.6

Table A1.9 Hedgerow basal flora composition and cover for Tidnor Wood Orchards

Composition / Quadrat	1	2	3	4	5	Average
Vegetation height cm	23	51	90	55	47	53.2
Grasses % cover	20	5	5	5	20	11
Broad-leaved herbs % cover	40	10	10	5	5	14
Nettles % cover	0	0	75	70	70	43
Thistles % cover	5	0	5	5	0	3
Docks % cover	5	0	5	5	0	3
Cleavers % cover	5	5	0	10	0	4
Bramble % cover	5	80	0	0	0	17
Bare ground % cover	20	0	0	0	5	5

Table A1.10 Boundary type, hedgerow dimensions and condition for Tidnor Wood Orchards

Boundary type	ID no on map	Species -rich	Length m	Height m	Width m	Cross-sectional area sq m	Final condition & failing attributes
BAP hedgerow	1	No	418	3.50	1.75	6.13	Unfavourable 2c, 3a, 3b, 4
BAP hedgerow	2	No	94	3.00	1.25	3.75	Unfavourable 1b, 2c
Fence	3		426				
Fence	4		169				
Fence + recently planted sections of BAP hedgerow	5	No	252	1.50	1.00	1.50	Not assessed because recently planted

Notes: Condition attributes and pass thresholds: 1a = height of hedgerow (≥ 1m); 1b = width of hedgerow (≥ 1.5m); 1c = cross-sectional area of hedgerow (≥ 3m); 2a = gaps along hedgerow (< 10% of hedgerow length); 2b = individual gaps (≤ 5m width); 2c = base of woody canopy above ground (≤ 0.5m); 3a = undisturbed ground (≥ 2m width), 3b = perennial herbaceous vegetation (≥ 1m width); 4 = eutrophication / disturbance plant indicators (< 20% cover); 5 = non-native woody species (≤ 10% cover).

Table A1.11 Fruit tree data for Lady Close Orchard

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
Young trees							
1	31						
2	11						
3	11						
4	15						
5	29				1		
6	32						
7	23				1		
8	21				1		
9	33		1		1	1	
10	11						
Old trees							
11	65	1			1	1	
12	184	1	1		1	1	1
13	96		1		1	1	1
14	177		1		1	1	1
15	116		1	1	1		1
16	96		1				
17	99		1		1	1	1
18	147			1	1		1
19	154		1	1	1		1
20	117		1				1

Table A1.12 Grassland composition and cover for Lady Close Orchard

Composition / Quadrat	1	2	3	4	5	Average
Grassland height cm	15	25	13	16	14	16.6
Grasses % cover	75	80	75	70	60	72
Broad-leaved herbs % cover	10	0	5	10	10	7
Nettles % cover	5	20	10	15	20	14
Thistles % cover	10	0	5	0	5	4
Docks % cover	0	0	5	5	5	3
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	0	0	0	0	0	0

Table A1.13 Hedgerow basal flora composition and cover for Lady Close Orchard

Composition / Quadrat	1	2	3	4	5	Average
Vegetation height cm	20	57	40	45	23	37
Grasses % cover	35	10	40	5	20	22
Broad-leaved herbs % cover	35	10	15	5	15	16
Nettles % cover	10	25	10	30	15	18
Thistles % cover	5	5	20	5	5	8
Docks % cover	0	0	5	5	5	3
Cleavers % cover	0	10	0	5	5	4
Bramble % cover	15	0	0	0	10	5
Bare ground % cover	0	40	10	45	25	24

Table A1.14 Boundary type, hedgerow dimensions and condition for Lady Close Orchard

Boundary type	ID no on map	Species -rich	Length m	Height m	Width m	Cross-sectional area sq m	Final condition & failing attributes
Line of trees + shrubs + fence	1	No	194	10.00	4.00	40.00	Unfavourable 2c, 4, 5*
BAP hedgerow	2	Yes	155	3.00	2.00	6.00	Unfavourable 2c, 4
BAP hedgerow	3	Yes	217	3.50	3.00	10.50	Unfavourable 2c, 4
Fence	4		41				
BAP hedgerow	5**	No	44	7.00	5.00	35.00	Unfavourable 2c, 4

Notes: Condition attributes and pass thresholds: 1a = height of hedgerow (≥ 1m); 1b = width of hedgerow (≥ 1.5m); 1c = cross-sectional area of hedgerow (≥ 3m); 2a = gaps along hedgerow (< 10% of hedgerow length); 2b = individual gaps (≤ 5m width); 2c = base of woody canopy above ground (≤ 0.5m); 3a = undisturbed ground (≥ 2m width), 3b = perennial herbaceous vegetation (≥ 1m width); 4 = eutrophication / disturbance plant indicators (< 20% cover); 5 = non-native woody species (≤ 10% cover).

* Unfavourable judged on criterion for BAP hedgerows of ≤ 10% non-native woody species cover but does not meet overall BAP definition of 80% native cover of woody species in any case.

** Length approximated from aerial photograph.

Table A1.15 Fruit tree data for Half Hyde Orchard

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
1	112					1	1
2	107				1		1
3	103		1				1
4	118		1				1
5	126				1		1
6	109	1	1		1		1
7	155		1	1			1
8	130		1		1		1
9	41						1
10	138		1		1		1
11	128		1		1		1
12	89		1		1		1
13	142		1		1		1
14	43		1		1		1
15	138	1	1		1		1
16	144		1	1	1	1	1
17	134		1		1		1
18	126		1		1	1	1
19	46				1		
20	42				1	1	

Table A1.16 Grassland composition and cover for Half Hyde Orchard

Composition / Quadrat	1	2	3	4	5	Average
Grassland height cm	12	16	90	121	62	60.2
Grasses % cover	100	70	20	30	20	48
Broad-leaved herbs % cover	0	0	0	0	0	0
Nettles % cover	0	0	80	30	40	30
Thistles % cover	0	0	0	0	0	0
Docks % cover	0	30	0	40	30	20
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	0	0	0	0	10	2

Table A1.17 Hedgerow basal flora composition and cover for Half Hyde Orchard

Composition / Quadrat	1	2	3	4	5	Average
Vegetation height cm	112	78	72	90	43	79
Grasses % cover	5	45	10	0	0	12
Broad-leaved herbs % cover	0	5	0	0	25	6
Nettles % cover	90	0	70	80	50	58
Thistles % cover	0	0	0	5	0	1
Docks % cover	0	0	0	0	5	1
Cleavers % cover	0	0	0	5	0	1
Bramble % cover	0	50	0	0	0	10
Bare ground % cover	5	0	20	10	20	11

Table A1.18 Boundary type, hedgerow dimensions and condition for Half Hyde Orchard

Boundary type	ID no on map	Species -rich	Length m	Height m	Width m	Cross-sectional area sq m	Final condition & failing attributes
BAP line of trees + shrubs (hedgerow) + fence	1	Yes	212	7.00	2.00	14.00	Unfavourable 2c, 4
BAP line of trees + shrubs (hedgerow)	2	Yes	155	7.00	3.00	21.00	Unfavourable 2c, 4
Fence	3		117				
Fence + occasional trees	4		162				

Notes: Condition attributes and pass thresholds: 1a = height of hedgerow (≥ 1m); 1b = width of hedgerow (≥ 1.5m); 1c = cross-sectional area of hedgerow (≥ 3m); 2a = gaps along hedgerow (< 10% of hedgerow length); 2b = individual gaps (≤ 5m width); 2c = base of woody canopy above ground (≤ 0.5m); 3a = undisturbed ground (≥ 2m width), 3b = perennial herbaceous vegetation (≥ 1m width); 4 = eutrophication / disturbance plant indicators (< 20% cover); 5 = non-native woody species (≤ 10% cover).

Table A1.19 Fruit tree data for Romulus Orchard

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
1	57					1	
2	51						
3	45				1		
4	53						
5	47					1	
6	42						
7	38						
8	36				1		
9	46						
10	32					1	
11	53					1	
12	58						
13	40						
14	20					1	
15	24						
16	19				1		
17	42				1		
18	41						
19	42		1				
20	18						

Table A1.20 Grassland composition and cover for Romulus Orchard

Composition / Quadrat	1	2	3	4	5	Average
Grassland height cm	20	18	15	20	23	19.2
Grasses % cover	60	90	55	75	90	74
Broad-leaved herbs % cover	30	10	40	5	0	17
Nettles % cover	0	0	0	0	10	2
Thistles % cover	5	0	5	0	0	2
Docks % cover	5	0	0	20	0	5
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	0	0	0	0	0	0

Table A1.21 Hedgerow basal flora composition and cover for Romulus Orchard

Composition / Quadrat	1	2	3	4	5	Average
Vegetation height cm	60	30	14	20	25	29.8
Grasses % cover	0	0	5	45	75	25
Broad-leaved herbs % cover	10	5	55	25	15	22
Nettles % cover	85	40	25	5	0	31
Thistles % cover	0	0	0	0	0	0
Docks % cover	0	0	5	15	0	4
Cleavers % cover	5	15	0	10	0	6
Bramble % cover	0	0	5	0	0	1
Bare ground % cover	0	40	5	0	10	11

Table A1.22 Boundary type, hedgerow dimensions and condition for Romulus Orchard

Boundary type	ID no on map	Species -rich	Length m	Height m	Width m	Cross-sectional area sq m	Final condition & failing attributes
BAP hedgerow	1	No	281	3.50	1.50	5.25	Unfavourable 2c, 4
*Short BAP hedgerow, part not shared with Half Hyde (1)	2	No	118	1.50	1.50	2.25	Unfavourable 4
Shared with Half Hyde (1), BAP line of trees + shrubs (hedgerow) + fence	2	Yes	139	7.00	2.00	14.00	Unfavourable 2c, 4
BAP hedgerow	3	No	178	10.00	3.00	30.00	Unfavourable 4
BAP hedgerow	4	No	263	6.00	2.00	12.00	Unfavourable 2c, 4
Fence	5		75				

Notes: Condition attributes and pass thresholds: 1a = height of hedgerow (≥ 1m); 1b = width of hedgerow (≥ 1.5m); 1c = cross-sectional area of hedgerow (≥ 3m); 2a = gaps along hedgerow (< 10% of hedgerow length); 2b = individual gaps (≤ 5m width); 2c = base of woody canopy above ground (≤ 0.5m); 3a = undisturbed ground (≥ 2m width), 3b = perennial herbaceous vegetation (≥ 1m width); 4 = eutrophication / disturbance plant indicators (< 20% cover); 5 = non-native woody species (≤ 10% cover).

Table A1.23 Fruit tree data for Salt Box Orchard

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
1	43						
2	36				1		
3	41				1	1	
4	39				1		
5	43						
6	42						
7	38						
8	38						
9	42						
10	36				1		
11	39						
12	37						
13	41						
14	39				1		
15	45						
16	45						
17	34				1		
18	43						
19	45				1		
20	40		1		1	1	

Table A1.24 Grassland composition and cover for Salt Box Orchard

Composition / Quadrat	**1**	**2**	**3**	**4**	**5**	**Average**
Grassland height cm	25	35	40	30	20	30
Grasses % cover	85	95	50	90	100	84
Broad-leaved herbs % cover	15	5	50	10	0	16
Nettles % cover	0	0	0	0	0	0
Thistles % cover	0	0	0	0	0	0
Docks % cover	0	0	0	0	0	0
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	0	0	0	0	0	0

Table A1.25 Hedgerow basal flora composition and cover for Salt Box Orchard

Composition / Quadrat	**1**	**2**	**3**	**4**	**5**	**Average**
Vegetation height cm	90	68	20	50	68	59.2
Grasses % cover	55	50	65	5	10	37
Broad-leaved herbs % cover	30	25	20	15	35	25
Nettles % cover	10	10	5	15	50	18
Thistles % cover	0	0	0	0	0	0
Docks % cover	0	0	0	40	0	8
Cleavers % cover	5	0	0	5	0	2
Bramble % cover	0	15	10	20	5	10
Bare ground % cover	0	0	0	0	0	0

Table A1.26 Boundary type, hedgerow dimensions and condition for Salt Box Orchard

Boundary type	ID no on map	Species -rich	Length m	Height m	Width m	Cross-sectional area sq m	Final condition & failing attributes
BAP hedgerow	1	No	244	1.75	1.50	2.63	Favourable
Fence	2		206				
Tall herbs on river bank	3		188				
BAP hedgerow	4	No	431	2.50	2.00	5.00	Favourable

Notes: Condition attributes and pass thresholds: 1a = height of hedgerow (≥ 1m); 1b = width of hedgerow (≥ 1.5m); 1c = cross-sectional area of hedgerow (≥ 3m); 2a = gaps along hedgerow (< 10% of hedgerow length); 2b = individual gaps (≤ 5m width); 2c = base of woody canopy above ground (≤ 0.5m); 3a = undisturbed ground (≥ 2m width), 3b = perennial herbaceous vegetation (≥ 1m width); 4 = eutrophication / disturbance plant indicators (< 20% cover); 5 = non-native woody species (≤ 10% cover).

Table A1.27 Fruit tree data for Village Plum Orchard

Observation no	Girth cm	Veteran tree features				Other data	
		Hollow trunk / major branches	Rot sites and holes	Sap runs	Split bark	Fallen dead wood below trees	Mistletoe
1	51				1	1	
2	43				1		
3	51				1	1	
4	20					1	
5	47					1	
6	12				1	1	
7	48				1	1	
8	37				1	1	
9	42				1	1	
10	25						
11	30						
12	60		1		1	1	
13	56					1	
14	26						
15	44				1	1	
16	40				1	1	
17	48						
18	44				1		
19	35				1		
20	35				1		

Table A1.28 Grassland composition and cover for Village Plum Orchard

Composition / Quadrat	1	2	3	4	5	Average
Grassland height cm	35	18	25	15	20	22.6
Grasses % cover	70	80	40	75	85	70
Broad-leaved herbs % cover	30	20	55	25	15	29
Nettles % cover	0	0	0	0	0	0
Thistles % cover	0	0	0	0	0	0
Docks % cover	0	0	5	0	0	1
Bramble % cover	0	0	0	0	0	0
Bare ground % cover	0	0	0	0	0	0

Table A1.29 Hedgerow basal flora composition and cover for Village Plum Orchard

Composition / Quadrat	1	2	3	4	5	Average
Vegetation height cm	110	20	80	130	64	80.8
Grasses % cover	55	65	30	70	50	54
Broad-leaved herbs % cover	15	30	25	5	15	18
Nettles % cover	10	0	10	15	10	9
Thistles % cover	0	0	0	0	10	2
Docks % cover	0	0	0	0	0	0
Cleavers % cover	5	0	10	0	5	4
Bramble % cover	15	0	20	10	10	11
Bare ground % cover	0	5	5	0	0	2

Table A1.30 Boundary type, hedgerow dimensions and condition for Village Plum Orchard

Boundary type	ID no on map	Species -rich	Length m	Height m	Width m	Cross-sectional area sq m	Final condition & failing attributes
BAP hedgerow	1	Yes	196	2.50	1.25	3.13	Unfavourable 1b
Mix of fence, hedgerow and BAP hedgerow	2	No	336	2.00	1.50	3.00	Unfavourable 2b, 4
BAP line of trees (hedgerow)	3	No	84	10.00	2.00	20.00	Favourable
Mix of fence, hedgerow	4	No	229	5.00	2.50	12.50	Unfavourable 4, 5*
BAP hedgerow	5	No	168	2.00	1.50	3.00	Unfavourable 4
BAP hedgerow	6	No	276	2.00	1.50	3.00	Unfavourable 4

Notes: Condition attributes and pass thresholds: 1a = height of hedgerow (≥ 1m); 1b = width of hedgerow (≥ 1.5m); 1c = cross-sectional area of hedgerow (≥ 3m); 2a = gaps along hedgerow (< 10% of hedgerow length); 2b = individual gaps (≤ 5m width); 2c = base of woody canopy above ground (≤ 0.5m); 3a = undisturbed ground (≥ 2m width), 3b = perennial herbaceous vegetation (≥ 1m width); 4 = eutrophication / disturbance plant indicators (< 20% cover); 5 = non-native woody species (≤ 10% cover).

*Unfavourable judged on criterion for BAP hedgerows of ≤ 10% non-native woody species cover but does not meet overall BAP definition of 80% native cover of woody species in any case.

Appendix 2 (A2) Grassland species composition in Tidnor Wood Orchards (Museum Orchard), Salt Box Orchard and Village Plum Orchard

Table A2.1 Grassland species in Tidnor Wood Orchards: Museum Orchard

Latin name	Common name	Abundance
Grasses		
Agrostis capillaris	Common bent	A
Agrostis stolonifera	Creeping bent	O
Alopercurus pratensis	Meadow foxtail	R
Anthoxanthum odoratum	Sweet vernal-grass	O
Dactylis glomerata	Cock's-foot	R
Festuca rubra agg.	Red fescue	F
Holcus lanatus	Yorkshire-fog	O
Lolium perenne	Perennial rye-grass	O
Phleum pratense	Timothy	O
Poa pratensis	Smooth meadow-grass	F
Herbs		
Ajuga reptans	Bugle	R
Cardamine pratensis	Cuckooflower	R
Carex sylvatica	Wood-sedge	R
Cerastium fontanum	Common mouse-ear	R
Cirsium arvense	Creeping thistle	R
Cirsium vulgare	Spear thistle	R
Ficaria verna	Lesser celandine	R
Geranium dissectum	Cut-leaved crane's-bill	O
Hyacinthoides non-scripta	Bluebell	O
Hypericum hirsutum	Hairy St John's-wort	R
Lotus pedunculatus	Greater bird's-foot-trefoil	R
Myosotis arvensis	Field forget-me-not	O
Plantago media	Hoary plantain	R
Primula vulgaris	Primrose	R
Prunella vulgaris	Selfheal	O
Pteridium aquilinum	Bracken	R
Ranunculus acris	Meadow buttercup	O
Ranunculus repens	Creeping buttercup	A
Rubus fruticosus agg.	Bramble	R
Rumex obtusifolius	Broad-leaved dock	O
Silene dioica	Red campion	R
Sonchus asper	Prickly sowthistle	R
Taraxacum sp.	Dandelion	O
Trifolium pratense	Red clover	O
Trifolium repens	White clover	A
Urtica dioica	Common nettle	R
Veronica chamaedrys	Germander speedwell	O
Veronica officinalis	Heath speedwell	O
Veronica serpyllifolia	Thyme-leaved speedwell	O
Vicia hirsuta	Hairy tare	O
Vicia sativa	Common vetch	R
Vicia sepium	Bush vetch	R

Note: Abundance categories are D = dominant, A = abundant, F = frequent, O = occasional and R = rare.

Table A2.2 Grassland species in grass alleys between tree-rows in Salt Box Orchard

Latin name	Common name	Abundance
Grasses		
Agrostis stoloifera	Creeping bent	R
Bromus hordeaceus	Soft-brome	R
Dactylis glomerata	Cock's-foot	O
Festuca rubra agg.	Red fescue	F
Holcus lanatus	Yorkshire-fog	O
Lolium perenne	Perennial rye-grass	O
Phleum pratense	Timothy	R
Poa annua	Annual Meadow-grass	O
Poa pratensis	Smooth meadow-grass	A
Herbs		
Galium aparine	Cleavers	R
Heracleum sphondylium	Hogweed	R
Potentilla reptans	Creeping Cinquefoil	R
Ranunculus repens	Creeping buttercup	R
Rumex crispus	Curled dock	O
Rumex obtusifolius	Broad-leaved dock	F
Taraxacum sp.	Dandelion	A
Trifolium repens	White clover	R
Urtica dioica	Common nettle	O

Note: Abundance categories are D = dominant, A = abundant, F = frequent, O = occasional and R = rare.

Table A2.3 Grassland species in grass alleys between tree-rows in Village Plum Orchard

Latin name	Common name	Widespread abundance	Local abundance	Ellenberg nitrogen value
Grasses				
Agrostis capillaris	Common bent	-	O	4
Dactylis glomerata	Cock's-foot	O	-	6
Holcus lanatus	Yorkshire-fog	F	-	5
Lolium perenne	Perennial rye-grass	F	A	6
Phleum pratense	Timothy	F	-	6
Poa pratensis	Smooth meadow-grass	-	O	5
Poa trivialis	Rough meadow-grass	O	-	6
Herbs				
Achillea millefolium	Yarrow	O	R	4
Anthriscus sylvestris	Cow parsley	-	R	7
Crepis capillaris	Smooth hawk's-beard	-	R	4
Glechoma hederacea	Ground-ivy	-	O	7
Heracleum sphondylium	Hogweed	-	R	7
Plantago lanceolata	Ribwort plantain	F	F	4
Plantago major	Greater plantain	-	R	7
Ranunculus repens	Creeping buttercup	F	-	7
Rumex crispus	Curled dock	O	-	6
Rumex obtusifolius	Broad-leaved dock	O	-	9
Senecio vulgaris	Groundsel	-	O	7
Taraxacum sp.	Dandelion	R	O	6
Trifolium repens	White clover	-	A	6
Urtica dioica	Common nettle	R	-	8

Note: Ellenberg Values from Hill and others (2004), see reference in Chapter 4. Definitions: 4 = Between 3 (more or less infertile conditions) and 5; 5 = Indicator of sites of intermediate fertility; 6 = Between 5 and 7; 7 = Plant often found in richly fertile places; 8 = Between 7 and 9; 9 = Indicator of extremely rich situations, such as cattle resting places or near polluted rivers.

Note: Abundance categories are D = dominant, A = abundant, F = frequent, O = occasional and R = rare.

Appendix 3 (A3) Named fruit varieties present in the orchards

Table A3.1 Named fruit varieties in Henhope Orchard

Fruit type	Fruit variety	Place and date of origin or first record	Identifier
Cider apple	Bedan	France (Bore and Fleckinger 1997). Date unknown.	Chris Fairs
Cider apple	Binet Rouge	France (Bore and Fleckinger 1997). Date unknown.	Chris Fairs
Cooking apple	Bramley's Seedling	Nottinghamshire, UK. Raised 1809-1813.	Chris Fairs
Cider apple	Brown Snout	Herefordshire, UK. Probably arose about 1850.	Chris Fairs
Cider apple	Brown's Apple	Devon, UK. Raised early 1900s.	Chris Fairs
Cider apple	Bulmer's Norman	Normandy, France. Introduced to UK early 1900s.	Chris Fairs
Cider apple	Chisel Jersey	Somerset, UK. Arose C19th.	Owner
Cider apple	Dabinett	Somerset, UK. Found probably early 1900s.	Chris Fairs
Dessert apple	Egremont Russet	Probably arose in England, UK. Recorded in 1872 in Somerset.	Chris Fairs
Cider apple	Michelin	Normandy, France. First fruited 1872.	Chris Fairs
Cider apple	Red French	No published reference found.	Owner
Cider apple	Tremlett's Bitter	Devon, UK. Probably arose late C19th.	Chris Fairs
Cider apple	Vilberie	Brittainy, France. Date of origin unknown, introduced into Herefordshire late C19th.	Owner
Cider apple	Yarlington Mill	Somerset, UK. Probably arose early 1900s.	Chris Fairs

Notes: C = century. Information on places and origins of other varieties of apples is from Morgan and Richards (2002) unless otherwise specified.

Table A3.2 Named fruit varieties in Lady Close Orchard: young trees

Fruit type	Fruit variety	Place and date of origin or first record
Dessert apple	Ashmead's Kernal	Gloucestershire, UK. Raised 1731.
Dessert apple	Brookes's	Shropshire, UK. First recorded 1820.
Cooking apple	Byford Wonder	Herefordshire, UK. First recorded 1893.
Dessert apple	Colwall Quoining	Probably Worcestershire (though Colwall is in Herefordshire), UK. Date unknown, sent to National Fruit Collection in 1949.
Cooking and cider apple	Gennet Moyle	UK. Known since C17th, variety in National Fruit Collection probably from C19th (when grown widely in Herefordshire).
Dessert and cider apple	Golden Harvey	Probably Herefordshire, UK. Probably dates from early 1600s.
Cooking and cider apple	Golden Spire	Lancashire, UK. Found about 1850.
Cooking apple	Herefordshire Beefing	Herefordshire, UK. Known from late 1700s.
Dessert apple	Herefordshire Pomeroy	Herefordshire, UK. Existed in C19th (see under Pomeroy of Somerset in Morgan and Richards 2002).
Dessert apple	Herefordshire Russet	Kent, UK. Raised in 1975 (National Fruit Collection Database).
Dessert apple	Irish Peach	Ireland. First recorded 1819.
Cooking and dessert apple	King of the Pippins (synonym Reine des Reinettes)	France or UK. Possibly arose in France in 1770s and introduced in early C19th in London, UK.
Cooking apple	King's Acre Bountiful	Herefordshire, UK. First introduced 1904.
Dessert apple	King's Acre Pippin	Herefordshire, UK. First introduced 1899.
Dessert apple	Lord Hindlip	Worcestershire, UK. First recorded 1896.
Dessert apple	May Queen	Worcestershire, UK. First recorded 1888.
Dessert apple	Pig's Nose Pippin	Probably Herefordshire, UK. First described 1884.
Dessert apple	Pitmaston Pine Apple	Herefordshire, UK. Raised about 1785.
Cooking apple	Queen	Essex, UK. Raised 1858.
Cooking apple	Royal Jubilee	Middlesex, UK. First recorded 1888.
Dessert apple	Rushock Pearmain	Worcestershire, UK. Raised about 1821 (National Fruit Collection Database).
Dessert apple	Sam's Crab synonym Longville's Kernal	Probably Herefordshire, UK. Information from Hogg (1851).
Dessert apple	Saint Cecelia	Gwent, UK. Raised 1900.
Dessert apple	Stoke Edith Pippin	Probably Herefordshire, UK. First recorded 1872.
Dessert apple	Ten Commandments	Herefordshire, UK. First described 1884.
Cooking and dessert apple	Tillington Court	Probably Herefordshire, UK. Probably first record is from 1934.
Cooking apple	Tyler's Kernal	Herefordshire, UK. First recorded 1883.
Dessert apple	Yellow Ingrestrie	Probably Shropshire, UK. Raised about 1800.

Notes: C = century. Varieties identified by the orchard owner. Information on places and origins of varieties of apples is from Morgan and Richards (2002) unless otherwise specified.

Table A3.3 Named fruit varieties in Lady Close Orchard: old trees

Fruit type	Fruit variety	Place and date of origin or first record
Cooking apple	Annie Elizabeth	Leicestershire, UK. Raised about 1857.
Cooking apple	Bismarck	Australia. Raised about 1861.
Cooking apple	Bramley's Seedling	Nottinghamshire, UK. Raised 1809-1813.
Cooking and cider apple	Golden Spire	Lancashire, UK. Found about 1850.
Cooking and dessert apple	King of the Pippins (synonym Reine des Reinettes)	France or UK. Possibly arose in France in 1770s and introduced in early C19th in London, UK.
Dessert apple	Lady Sudeley	Probably Kent, UK. Probably arose about 1849.
Cooking apple	Lord Derby	Cheshire, UK. First recorded 1862.
Cooking apple	Monarch (probably)	Essex, UK. Raised 1888.
Cooking apple	Tower of Glamis or Warner's King	Tower of Glamis: Possibly Scotland, UK. If Scottish variety, known before 1800.
Cooking apple	Warner's King	UK. Known in late 1700s.
Dessert apple	Worcester Pearmain	Worcestershire, UK. First recorded 1873.

Notes: C = century. Varieties identified by the orchard owner. Information on places and origins of varieties of apples is from Morgan and Richards (2002).

Table A3.4 Named fruit varieties in Half Hyde Orchard

Fruit type	Fruit variety	Place and date of origin or first record
Cider apple	Brown Snout	Herefordshire, UK. Probably arose about 1850.
Cider apple	Bulmer's Norman	Normandy, France. Introduced to UK early 1900s.
Cider apple	Court Royal	Probably Devon, UK. Date unknown but for sale in early 1900s.
Cider apple	Dabinett	Somerset, UK. Found probably early 1900s.
Cider apple	Michelin	Normandy, France. First fruited 1872.
Cider apple	Tremlett's Bitter	Devon, UK. Probably arose late C19th.
Cider apple	Yarlington Mill	Somerset, UK. Probably arose early 1900s.

Notes: C = century. Varieties identified by the orchard owner. Information on places and origins of varieties of apples is from Morgan and Richards (2002).

Table A3.5 Named fruit varieties in Romulus Orchard, Salt Box Orchard and Village Plum Orchard

Orchard	Fruit type	Fruit variety	Place and date of origin or first record
Romulus	Cider apple	Dabinett	Somerset, UK. Found probably early 1900s.
Romulus	Cider apple	Michelin	Normandy, France. First fruited 1872.
Salt Box	Cider apple	Dabinett	Somerset, UK. Found probably early 1900s.
Salt Box	Cider apple	Michelin	Normandy, France. First fruited 1872.
Village Plum	Plum	Victoria	Sussex, UK. Found in 1840 (Taylor 1949).

Notes: Varieties identified by the orchard owners. Information on places and origins of varieties of apples is from Morgan and Richards (2002).

Source for information on named fruit varieties in Tidnor Wood Orchards

Tidnor Wood Orchards contains the National Collection of Cider Varieties. The collection comprises over 400 cider apple varieties, which are not listed in the tables in this report. For details of varieties at Tidnor Wood Orchards see the list at http://www.tidnorwood.org.uk/trees.htm (last accessed September 2011). Note that some of the varieties named are synonyms of other varieties on the list.

Appendix 4 Questionnaire for survey of views about orchards among general visitors to Herefordshire

The intention of this survey is to help us to understand the importance of orchards in Herefordshire.

1. **Date of visit:**

2. **Where do you live? (✓ one)**
   - ☐ Within Herefordshire
   - ☐ Elsewhere in UK
   - ☐ Overseas

3. **What are the main reasons for your visit? (✓ as many as apply)**
   - ☐ Culture
   - ☐ Enjoy natural beauty
   - ☐ Activities
   - ☐ Visiting friends or family
   - ☐ Business
   - ☐ Other(please specify):

4. **Which of the following landscape features are important to you as a visitor? (rank your top 3)**
   - ☐ Woodland
   - ☐ Orchards
   - ☐ Parkland
   - ☐ Hedgerows
   - ☐ Fields
   - ☐ Hills
   - ☐ Rivers
   - ☐ Other (please specify):

5. **How important were orchards in your decision to visit Herefordshire? (✓ one)**
   - ☐ Very
   - ☐ Slightly
   - ☐ Not at all

6. **Have you seen any orchards during your visit? (✓ one)**
   - ☐ Yes
   - ☐ No

7. **Did you drive to Hereford on the main road from Brecon or Worcester? (✓ one)**
   - ☐ Yes
   - ☐ No

8. If yes, did you notice these orchards? (✓ one)

- ☐ Salt Box at Byford on the A438 Brecon Road
- ☐ Half Hide at Fromes Hill on the A4103 Worcester Road

9. Have you walked in an orchard during your visit? (✓ one)

- ☐ Yes
- ☐ No

If no, are there any reasons that have prevented you from doing so?:

10. To which of these do you think that orchards contribute the most?: (✓ one)

- ☐ Nature
- ☐ Local economy
- ☐ Views
- ☐ Heritage
- ☐ Leisure
- ☐ Other (please specify):

11. Are there any particular orchards that have had a positive impact on your visit? (✓ one)

- ☐ Yes
- ☐ No

If yes, please specify and explain why:

12. In Herefordshire, there are broadly three types of orchard. If there was £100,000 available to support orchards in Herefordshire, please decide how you would like this to be shared between the types:

Bush orchards	**£**
Traditional orchards	**£**
Remnant orchards	**£**
	£ 100,000

13. Any other comments that you think will be helpful to our study of the value of orchards including any ideas on how the value or use of orchards could be enhanced.

Appendix 5 Questionnaire for survey of views about orchards among visitors to Lady Close Orchard

1. **Where do you live? (✓ one)**
   - ☐ Within Bodenham
   - ☐ Elsewhere in Herefordshire
   - ☐ Elsewhere in UK
   - ☐ Overseas

2. **How did you get to Bodenham Lake Nature Reserve? (✓ one)**
   - ☐ On foot
   - ☐ By car
   - ☐ Other(please specify):

   If by car, how far have you driven to get here?

3. **On average, how regularly do you visit the Nature Reserve? (✓ one)**
   - ☐ Daily
   - ☐ Weekly
   - ☐ Monthly
   - ☐ Less frequently

4. **Why do you visit the Nature Reserve? (✓ as many as apply)**
   - ☐ For exercise
   - ☐ To exercise the dog
   - ☐ To allow children space to play
   - ☐ To observe nature
   - ☐ To observe the trees in the Orchard
   - ☐ Accessibility
   - ☐ Car parking
   - ☐ Information/education
   - ☐ Other(please specify):

5. **If the Nature Reserve was not here, where would you go instead?**

6. **When you visit the Nature Reserve, do you walk in the Old Orchard? (✓ one)**
   - ☐ Nearly always
   - ☐ Sometimes
   - ☐ Rarely

7. **How important is the Old Orchard to your visit? (✓ one)**
   - ☐ High
   - ☐ Moderate
   - ☐ Negligible

8. **Have you walked in any other orchards in Herefordshire? (✓ one)**
   - ☐ Yes
   - ☐ No

   If no, are there any reasons that have prevented you from doing so?:

9. **To which of these do you think that orchards contribute the most?: (✓ one)**
   - ☐ Nature
   - ☐ Local economy
   - ☐ Views
   - ☐ Heritage
   - ☐ Leisure
   - ☐ Other (please specify):

10. **In Herefordshire, there are broadly three types of orchard. If there was £100,000 available to support orchards in Herefordshire, please decide how you would like this to be shared between the types:**

Bush orchards	**£**
Traditional orchards	**£**
Remnant orchards (like Bodenham Lake)	**£**
	£ 100,000

11. **Please add any other comments that you think will be helpful to our study of the value of Bodenham Lake Orchard including any ideas on how the value or use of the Orchard could be enhanced.**

Appendix 6 Questionnaire for survey of views about orchards among sponsors of trees at Tidnor Wood Orchards

Herefordshire Orchards Community Evaluation project aims to increase understanding of the value of orchards. We are studying six very different local orchards, and are delighted that Tidnor Wood Orchards are participating in the study.

Our evaluation encompasses economic, environmental and social aspects of the orchard – the so-called *triple bottom line.* As part of this study, we would really appreciate the perspective of those, like you, who are supporting the work of Tidnor Wood Orchard Trust.

1. **Name:**

2. **Where do you live? (□ one)**
   - ☐ Within Herefordshire
   - ☐ Elsewhere in UK
   - ☐ Overseas

3. **What was the main reason for your sponsorship? (□ one)**
   - ☐ To protect a specific tree variety
   - ☐ To help to protect an orchard
   - ☐ To be able to visit the orchard on Open Days
   - ☐ To be part of an innovative enterprise
   - ☐ Henry's personality
   - ☐ A gift or in memory of a loved one
   - ☐ Other (please specify):

4. **The current price for sponsoring a tree, for the life of that tree, in the Tidnor Museum Orchard is £60. Do you think that this is:**
   - ☐ About right
   - ☐ Really good value

   (□ one)
   Please explain your answer:

5. **How did you first find out about Tidnor Wood Orchard Trust? (□ one)**
   - ☐ From Henry
   - ☐ From a friend or family member
   - ☐ From a Trust newsletter
   - ☐ From another publication
   - ☐ From the web site (www.tidnorwood.org.uk)
   - ☐ Other (please specify):

6. **Have you visited Tidnor Wood Orchards? (□ one)**
   - ☐ Yes
   - ☐ No

7. **If yes,**
   How many times have you visited?

   Was the visit to Tidnor Wood Orchards the main reason for your trips?
   - ☐ Yes
   - ☐ No

   Could you please explain the impact that your visit to the orchard had upon you:

8. **Have you walked in any other orchards in Herefordshire? (☐ one)**
   - ☐ Yes
   - ☐ No

   If no, are there any reasons that have prevented you from doing so?:

9. **To which of these do you think that orchards contribute the most?: (☐ one)**
   - ☐ Nature
   - ☐ Local economy
   - ☐ Views
   - ☐ Heritage
   - ☐ Leisure
   - ☐ Other (please specify):

10. **Please add any other comments that you think will be helpful to our study of the value of Tidnor Wood Orchards including any ideas on how the value or use of the Orchard could be enhanced.**

Appendix 7 Structure of the community evenings

Recording impacts

- In small facilitated groups, people were encouraged to think about good and bad things they associated with the orchard when they were in the orchard, and good and bad things when outside the orchard. These four categories, created following the pilot evening at Henhope, encouraged people to consider the negative as well as the positive impacts. The categorization also promoted the consideration of both the active interaction with the orchard (inside the orchard), if people had access to it, and passive observation of the orchard (outside the orchard). Categorization also helped to simplify subsequent collation of individual impacts by facilitators during the evening.

- It was stressed that the purpose of the evening was to understand the social impact of the orchard upon local people, rather than the economic or environmental impacts of the orchards. Facilitators were tasked with ensuring that the impacts were social ones. Where people identified economic or environmental impacts, they were asked to translate these into what such impacts meant to them. Potential or possible impacts were excluded, so that only current impacts were recorded. The sort of prompts that facilitators used were:

  - Do you think that this orchard has an impact on you? On the local area? In what ways?
  - Good or bad impacts? Positive or negative?
  - What things is the orchard used for locally?
  - Suggest that we are looking at how this particular orchard has impacted on you, your family, your community.

- Views of participants were recorded individually on post-it notes. Post-it notes were collated by the facilitators for all groups and views that overlapped were clustered into broad types, described in general terms, such as “Walking and exercise” and “Enjoying nature”. This classification was made anew at each evening and was not pre-determined by the organizers. It was somewhat subjective and completed under time pressure. Nevertheless, judging by the comments made by participants through the evening as a whole, it appeared to be a pretty robust summary of the feelings of each community.

Identifying the most important social impacts

- People were given three sticky paper dots to vote for the type or types of impact that were most important for them, whether these were good or bad. They could apply more than one of their dots to a single type if this reflected their strength of feeling. The three most voted-for types were agreed to be the three most important social impacts for that local community, and these three impact types were written on a separate cards.

Ranking impacts

- Working in facilitated groups, participants then ranked these three social impacts in relation to three economic and three environmental impacts that had already been ordered by monetary value through previous project work on these aspects.

  The three economic values were:

  - profitability of the orchard
  - cash flows in the local economy
  - draw for tourism

  The three environmental values were:

  - climate change
  - biodiversity
  - soil and water (together)

- These economic and environmental values were written on separate cards and laid out on the table in front of each group in the ranked order of their previously calculated values. The groups were not permitted to change the ranking of these economic and environmental impact cards, but each group was asked to insert the three new 'social' cards into the order in relation to what they thought their value was relative to the other six. The monetary values of the economic and environmental values were not disclosed at this stage. The nature of the economic and environmental values (and the basis on which their value had been calculated) were briefly explained. Facilitators were also provided with a short written explanation of each of them so that they could be clarified by the facilitators in a consistent manner across the groups, but only if people asked for this clarification (see Appendix 8). This guide was refined slightly through the course of the project.

- The relative ranking of the social values by local community participants did not have to be in the same order as the initial voting by dots and in practice sometimes the ordering was changed. Not constraining this discussion by the original popularity voting allowed each group to refine its thinking about the nature of the impacts. The results from each group were then brought together to derive an average ranking of social values across all the groups. In practice, there was quite broad consensus across groups about the relative importance for each type of social value.

Appendix 8 Explanation of the environmental, economic and social impacts used by facilitators at local community evenings

Table A8.1 Explanation of the environmental, economic and social impacts used by facilitators at local community evenings

Environmental impacts	
Biodiversity	Plants and animals supported by the orchard being there. This is a positive benefit. *Valued using the Government's Environment Stewardship Scheme.*
Climate change	The impact of the orchard on climate change The balance of greenhouse gases (carbon dioxide from fuel use) against the carbon dioxide that the orchard absorbs as it grows. This can be a positive benefit or may be negative. *Net flow valued using the external carbon dioxide costs in Stern..*
Soil and water	The soil in the orchard is held in this permanent state, so it doesn't erode and wash into streams and rivers. The soil also acts as a sponge for rainwater, helps prevent flooding, and has a water 'cleaning' function. This is a positive benefit. (This impact captures the qualities of the soil that aren't included in the other impacts, e.g. biodiversity of soil is included in biodiversity)*. *Benefit to water companies of cleaner water runoff.*
Economic impacts	
Cash flows in the local economy	This includes purchases in the local area for the orchard, including employment. This is a positive benefit. *Local cashflows identified and multiplier applied.*
Profitability of the orchard	This is the profit that the orchard produces every year, as a result of it being there. Benefits from this are to the orchard owner, but mean that it is a viable local business. This is a positive benefit or may be negative. *From farmer's orchard accounts.*
Draw for tourism	Spend in the area as a result of people visiting the area because the orchard is there. This is a positive benefit. *Considers the overall value of tourism to Herefordshire that can be attributed to the orchard.*

Note: * Soil biodiversity is included in soil quality in Chapter 5, and therefore in soil quality for monetary valuation purposes in Chapter 7.

Appendix 9 Discussion of the findings of each community evening

Henhope Orchard

This was the first community evening run by the project and some small changes to the process were subsequently made to address some minor difficulties experienced during the evening. For example, there was no attempt to categorize impacts as inside or outside Henhope Orchard. The role of the facilitator was strengthened following this evening, including agreeing when the lead facilitator should intervene to support a group. At subsequent evenings more time was also taken to explain the background to the project and why the local community's views were being sought. The results for Henhope Orchard were re-calculated according to these changes to make them comparable as far as possible to results from the other sites.

The most voted-for types of social impact were:

- **Enjoying nature:** 27% ("haven for wildlife, flora and fauna", "organic – no sprays, lots of plant species, lichens, mosses", "watch the wildlife")
- **Conservation:** 25% ("untouched", "good to think wild flowers are preserved")
- **Walking:** 12% ("good to walk by and see woodpeckers", "amenity")

The examples of somewhat overlapping views given above illustrate the difficulty of trying to produce a consensus about broad types of impacts from the individual views in a limited time. However, what was apparent about Henhope was that it had been a feature of the lives of local people, and that people valued the fact that it was there. This was despite there being no public access to the orchard and neither is it particularly visible in the landscape. The neighbours just valued it being there, as it had been throughout most of their lives. They did not generally want to gain access to the orchard, indeed they were happy that it was left there untouched, except for the respected owner's sympathetic management.

Tidnor Wood Orchards

The most voted-for types of social impact were:

- **Lack of knowledge - a bad thing:** 18% ("what is the business?", "lack of publicity about the orchard – never been")
- **Like it being there:** 17% ("knowing its there is reassuring", "miss the orchard if it wasn't there", "I like having an orchard as a neighbour")
- **Nice environment to be in:** 14% ("pleasing, excellent orchard, well managed", "enhances environment – improves healthy lifestyle")

Local people recognised the work that has been put in by the owner in revitalising the orchard over the last few years. "If you go to the top and look south, he has done a magnificent job. If you look across the floodplain and look back at it, it is beautiful. I take my hat off to him and wish him all success." Whilst some neighbours were concerned about what the plans were for the orchard, some saw this as the owner's business. Others welcomed a subsequent invitation to visit the orchard and discuss the plans with the owner. During this evening some confusion arose between good and bad things during the subsequent discussions. For some people lack of knowledge of the orchard (by outsiders) was a good thing, discouraging visitors. However most people were voting for lack of knowledge of the orchard as a bad thing, as locals want to know what changes are happening in their neighbourhood. Also it was clear that for some individuals living close to the orchard, the lack of knowledge was a much more important factor than for those living further away. Given the lack of public access to the orchard, the value attributed to 'nice environment to be in' is somewhat surprising – however, several neighbours did in fact walk around the orchard regularly (although permission of the owner is required to do this). One group also noted that having the orchard there contributed to general quality of life.

Lady Close Orchard

The most voted-for types of social impact were:

- **Enjoying wildlife and nature:** 34% ("look at the trees and be with nature", "blossom-time", "clean/natural place as unusual birds there. Must be safe")
- **Walking and exercise:** 21% ("dog walking", "good exercise and recreational value")
- **Education:** 9% ("an educational resource", "enjoy the comparison between the old and new orchards")

Lady Close Orchard was seen by the community as part of the benefit of having a nature reserve on their doorstep, less a destination in itself but part of a circular walk incorporating the shore of Bodenham Lakes. They appreciated the window on nature, and the seasons, that it provided. As described by one of the neighbours: "It's slightly sad because its an old orchard and a lot of old orchards are going round here, but its so well looked after and there's a new orchard coming on. I don't feel hugely strongly about that orchard, apart that it's our route through and we like it. I like it particularly in spring with the blossoms but I like it all year. I quite like it in the winter actually." The community rated the social impacts of Lady Close particularly highly.

Half Hyde Orchard

The most voted-for types of social impact were:

- **View:** 33% ("wonderful view as you see Herefordshire stretching away in front", "Blossom in spring, cattle under the trees")
- **Enjoying wildlife:** 18% ("the certain abundance of wildlife under and in the trees")
- **Road issues** – a bad thing: 16% (**"**Mud on road, idiot car drivers, leaves on road, slow farm traffic")

The evening showed a big difference between people who spent time in the orchard (the owner and contractors) and other neighbours – particularly in the number of impacts identified inside the orchard. One quarter of the people who attended this evening had worked at some time in the orchard. The interrelationship of the orchard and the adjacent main road was difficult to assess – with the community identifying a number of factors that appeared to be more the impact of the road on the orchard. The biggest positive factor – the view – was likely to have been chosen because the orchard was visible from the road. This insight was recorded by a neighbour: "I think it is a very thriving (wildlife) community there. It does make a nice touristy frame for people coming through the countryside and hopefully attracting them, and also it is farmed…So it is on the boundary, joining all three uses together."

Salt Box Orchard

The most voted-for types of social impact were:

- **Work/income:** 20% ("provides work", "product: apples=income")
- **Enjoying wildlife:** 20% ("plenty of birds", "the big ditch is full of primroses in spring")
- **Walking:** 14% ("great place to walk the dogs – except harvest time", "allows the freedom to explore")

The key finding at Salt Box was the high value attached by this community to having a working rural economy close by – they valued this being there as well as interacting with it. They liked seeing people and tractors tending the orchard. "A good thing about the orchard is it keeps people employed." This is considered to be a social impact, rather than economic, since it related to the community's appreciation of the work happening, rather than the work itself. The orchard is intensively managed and the impact of chemical spraying in the orchard was noted by some people.

Village Plum Orchard

The most voted-for types of social impact were:

- **Peace:** 23% ("green quiet open space", "sense of well-being")
- **Natural beauty:** 14% ("the fantastic views of the village from inside the orchard", "the orchard provides beauty – blossom, berries, leaves and wildflowers")
- **Enjoying wildlife:** 13% ("good for wildlife", "we like the bats and birds")

The orchard is in the centre of the village of Glewstone and local people use it as a regular walk – as one neighbour said it "feels like an extended garden" and a place of beauty throughout the seasons. Spraying was mentioned as a negative impact, mainly concerning the type and timing of spraying, but received very few votes considering that the orchard is in the centre of the village. This was a particularly well attended and vibrant evening, with one attendee suggesting that another positive impact of the orchard was that it encouraged a village meeting to be held!

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