Tor-grass mapping feasibility study

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CEH project number: NEC05545
NE project reference: RP02081

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Aims

- To assess the potential for using aerial photography as a tool for supporting field survey - for ultimately assessing tor-grass (*Brachypodium pinnatum/rupestre, currently BSBI recommend using Brachypodium* agg.) cover and consequently chalk grassland condition, and understanding the rate of change on Salisbury Plain SSSI.
- To identify the aerial photography datasets with the greatest potential for visual estimation of tor-grass cover on other areas, without any prior field survey

Methods

Potential 200 m x 200 m squares to survey were identified from local knowledge of *Brachypodium* agg. occurrence, data from a 1996-1997 survey by CEH which recorded relative abundance of plant species within distinct NVC communities on the DAFOR scale (Kershaw 1985) and quadrat data from more recent CEH surveys (2007-2014). Survey squares were chosen to be at least 500m apart in order to give good coverage of the plain and to lessen bias in ease of identification due to local lighting conditions the time of aerial photography. Squares were also chosen to represent the West, East and central areas of the plain. Field surveyors from CEH and Natural England visited each potential square and searched for *Brachypodium* agg. in January and February 2015. Where a square contained some cover of *Brachypodium* agg.*,* all patches over approximately one metre squared in area were digitally mapped onto Trimble Juno handheld computers. Mapping continued until at least twenty 200 m x 200 m squares had been surveyed, to give a sufficient sample size for analysis.

The resulting digital maps were combined and manually corrected (e.g. to remove overlapping or self-intersecting polygons) using ArcGIS (v10.2, ESRI). Total cover of *Brachypodium* agg. was calculated for each survey square, and survey squares and the polygons representing mapped *Brachypodium* agg. patches were then overlain on aerial photography datasets.

Nine aerial photography datasets were available for analysis. These consisted of summer imagery for July 1999, June 2002, August 2003, September 2006, August 2007, August 2010 and September 2014 and spring imagery for April 1996 and April 2008. Most of these datasets consisted of red, green and blue (RGB) bands, with the near infra-red (NIR) band available for 2008, 2010 and 2014. All photography was converted to TIFF format and mosaicked within year. Histogram matching was performed in order to normalise colour across the mosaic (i.e. to minimise the effect of local lighting conditions). Image handling and analysis was performed in ArcGIS and ENVI (v5.1, Exelis).

An initial visual inspection was performed in order to determine which years of photography showed some potential for detecting present *Brachypodium* agg.. Years of aerial photography which showed potential for identifying *Brachypodium* agg. were then analysed in detail. The values of the red, green, blue and infrared bands of all pixels falling within patches of mapped *Brachypodium* agg. were extracted, and used to compare distributions and mean values with pixels from non-*Brachypodium* agg. grassland, scrub and bare ground.

Results and Discussion

FIELD SURVEY AND SELECTING AERIAL PHOTOGRAPHY

Twenty survey squares were found which contained some cover of *Brachypodium* agg. (Figure 1). Several additional squares were found to contain large patches of either *B. sylvaticum* or *Festuca arundinacea,* both of which appeared similar to *Brachypodium* agg. to surveyors from a distance and which were thus mapped to give information on potential sources of misidentification in aerial photography. A further survey square was only partially surveyed due to military activity.

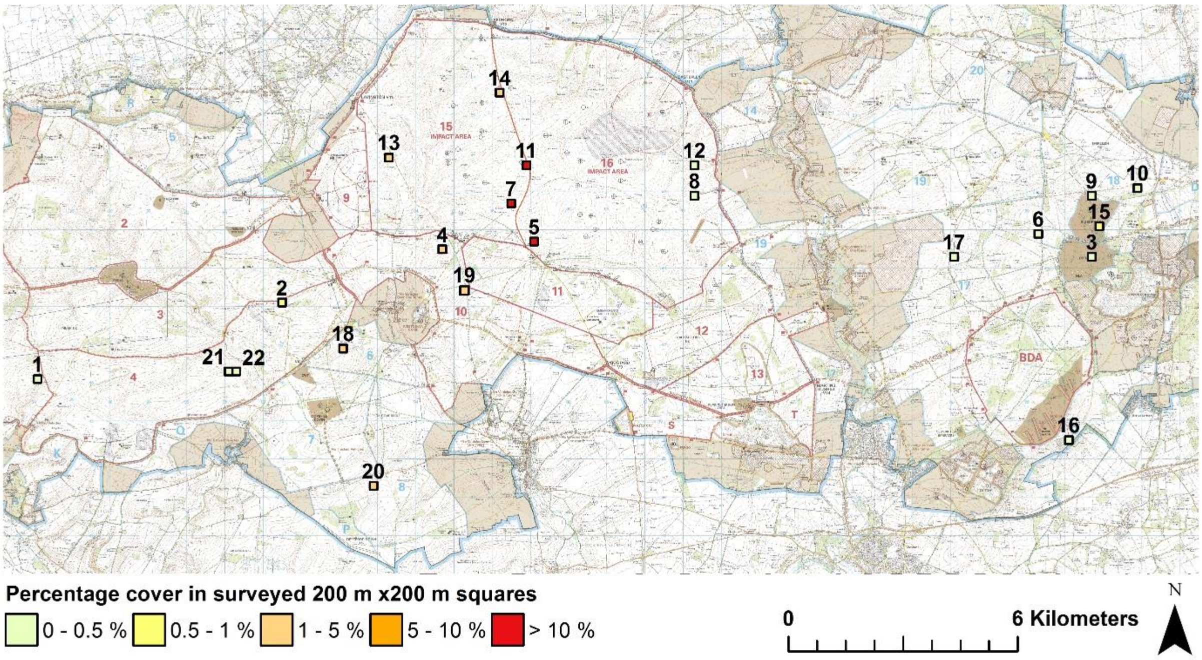

Figure 1. Location of surveyed 200 m x 200 m squares on Salisbury Plain SSSI. Squares are shaded by percentage cover of *Brachypodium* agg. patches. Red squares (> 10% cover) would fail the target threshold for CG2/CG3 grassland SSSI condition assessment (Robertson and Jefferson 2000).

Aerial photography prior to 2000 showed little *Brachypodium* agg. even within areas currently identified as contiguous patches (e.g. Figure 2, Appendix 1). This is unsurprising, as in the 1996-1997 NVC survey data *Brachypodium* agg. is not present in a large number of NVC communities, and is usually recorded as occasional or rare in the communities where it does occur. In many cases, areas which did have *Brachypodium* agg. in the NVC survey were searched by field surveyors and found to have no extant cover, potentially due to changes in scrub management and grazing. Aerial photographs of this age are thus unlikely to be of use in determining extant cover, although they do provide an important baseline from which to date the current expansion of *Brachypodium* agg..

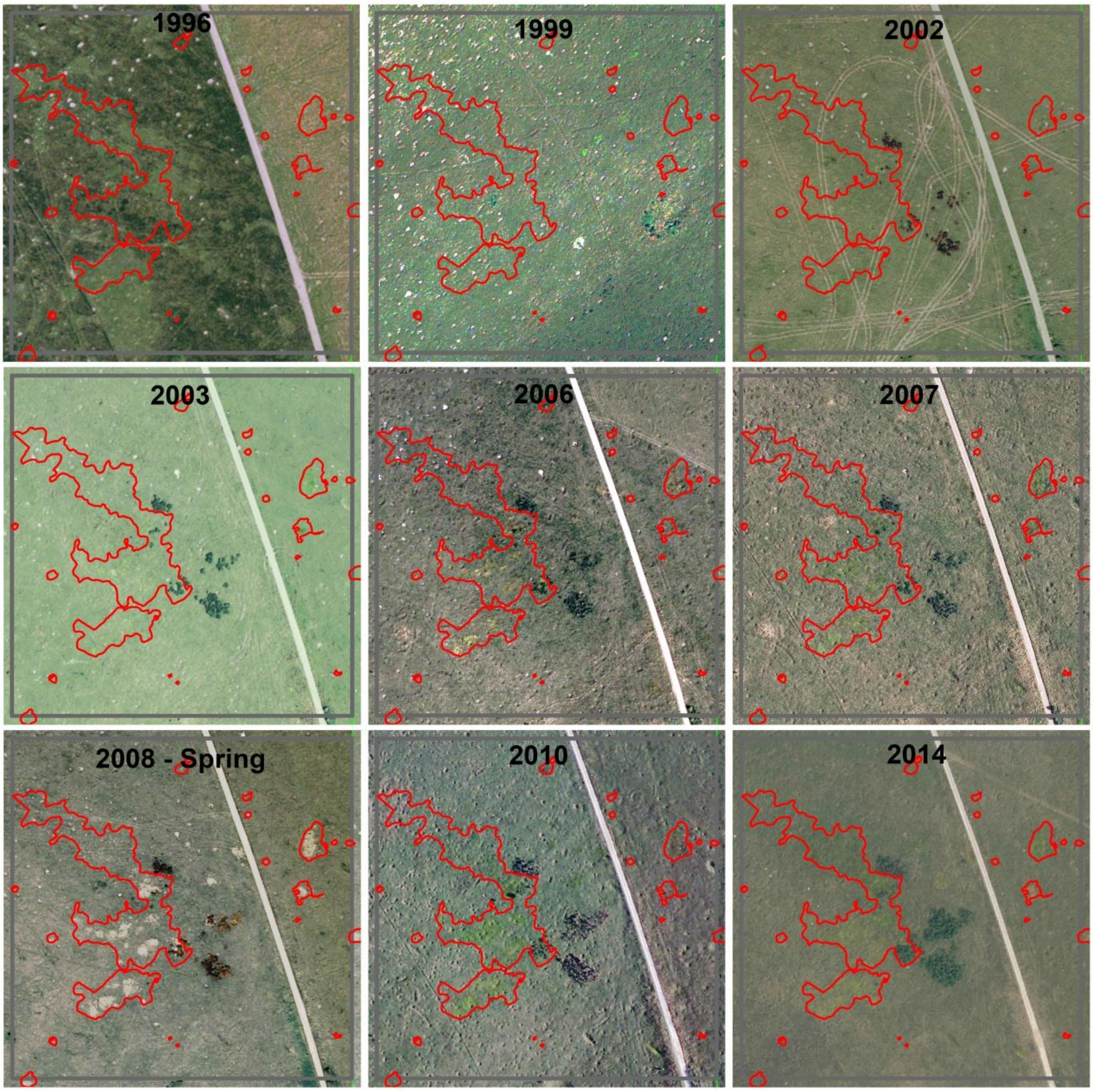

Figure 2. A single 200 m x 200 m survey square with current dense cover, as seen in nine different aerial photography datasets from different years (all June-August images, except 2008 which was taken in April). Red outlined areas are current (January 2015) *Brachypodium* agg. cover as detected in field survey. Whilst image quality and lighting conditions vary, it can be seen that no clear *Brachypodium* agg. presence is apparent until 2006, with cover gradually filling in the present day

cover over the following years. Equivalent images for all surveyed 200 m x 200 m squares are given in Appendix 1

Examination of aerial photography from around 2002 onwards clearly shows that, in areas with high overall cover or large, dense patches, *Brachypodium* agg. is detectable from aerial photography by the human eye (i.e. manual interpretation of aerial imagery), especially if the contrast of the imagery is slightly increased (i.e. increasing the difference between the darkest and lightest colors in the image). Bright green (summer) or pale (spring) patches fall within the boundaries of mapped polygons, and the comparison of the two seasons aids in distinguishing *Brachypodium* agg. from bare ground (which remains pale all year round). However, smaller or less dense patches are often difficult to distinguish, even in the most recent imagery.

It is clear that the extent of *Brachypodium* agg. has undergone significant expansion over the past ten years. Although areas are frequently visible between 2003 and 2007, they do not approach the current extent and correspond well to the boundaries of the mapped polygons until 2008 or later (e.g. Figure 2). Whilst this implies that combining images from different years (i.e. multi-temporal imagery) in order to detect current occurrence is limited to recent years it also suggests potential for a time series of images to be analysed in order to detect the rate of spread of *Brachypodium* agg. in areas of current high cover.

For the reasons above, it was decided to concentrate detailed analysis on the three most recent datasets; 2008, 2010 and 2014. Not only has there been sufficiently little change within this time period such that the three datasets can be combined, but these three datasets contain the near infrared band, giving additional spectral information.

Spectral characteristics of habitat classes

Analysing the pixel values from the three years of aerial imagery show that, at the per pixel level, there is a great deal of overlap between classes (Figure 3). Despite this, bare ground is readily identified in all three imagery datasets by uniformly high levels in the RGB colour bands, arising from the bright whites and greys of exposed chalk. Scrub has generally lower intensity across RGB bands, probably because of the influence of shadow as well as the generally darker green apparent to the observer. The near infrared band appears uninformative when all parcels are considered, with similar levels across classes in all three years.

Although larger patches of *Brachypodium* agg. are frequently distinguishable by manual interpretation of aerial photographs, there is considerable variation between them even in photographs from the same date, despite normalisation between imagery tiles. This is likely due to variations in microclimate, disturbance and grazing, such that in some early summer images the patches are showing the bright green of new growth, whereas others are still largely brown with dead leaves (Figure 4C). Other grasslands, too, show much variation across imagery, for the same variety of reasons. This likely accounts for the large overlap with other grasslands seen in Figure 3.

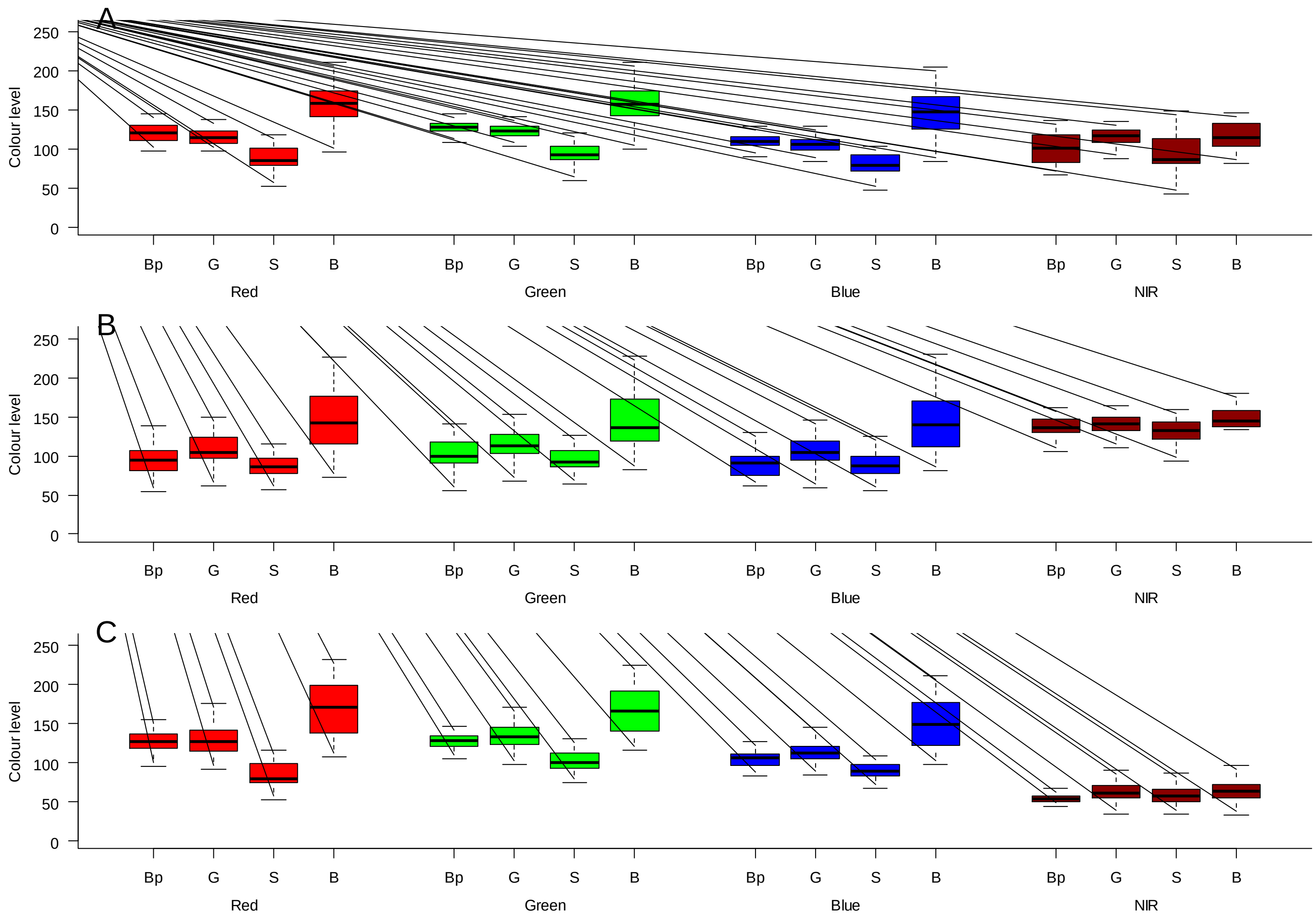

Figure 3 Boxplots of mean colour values for the red, green, blue and near infrared bands of all discrete areas of *Brachypodium* agg. (Bp), other grassland (G), bare ground (B) and scrub/plantation (S), in the surveyed 200 m x 200m squares from A) spring 2008, B) summer 2010 and C) summer 2014 aerial imagery

It thus appears that *Brachypodium* agg. and other grasslands are so variable in spectral characteristics that the relative ease of manual detection (which is achieved by looking for differences between a potential *Brachypodium* agg. patch and its local surroundings) is simply not reproducible when examining all pixels across the surveyed squares. Instead, it is based on other cues available to the human eye such as patch shape, texture, contrast with local surroundings and proximity to local landscape features, which are not taken into account in a per pixel analysis of the colour bands.

Testing manual interpretation

Given the detectability of many *Brachypodium* agg. patches to the human eye, a rapid manual digitizing of suspected tor grass patches was attempted on the 20 surveyed squares, based on the RGB bands of the three imagery layers analysed above. The resultant digitized patches were overlain with those digitized in the field (as exemplified in Figure 4), in order to estimate the ability of manual identification from aerial photography to detect and estimate cover of *Brachypodium* agg..

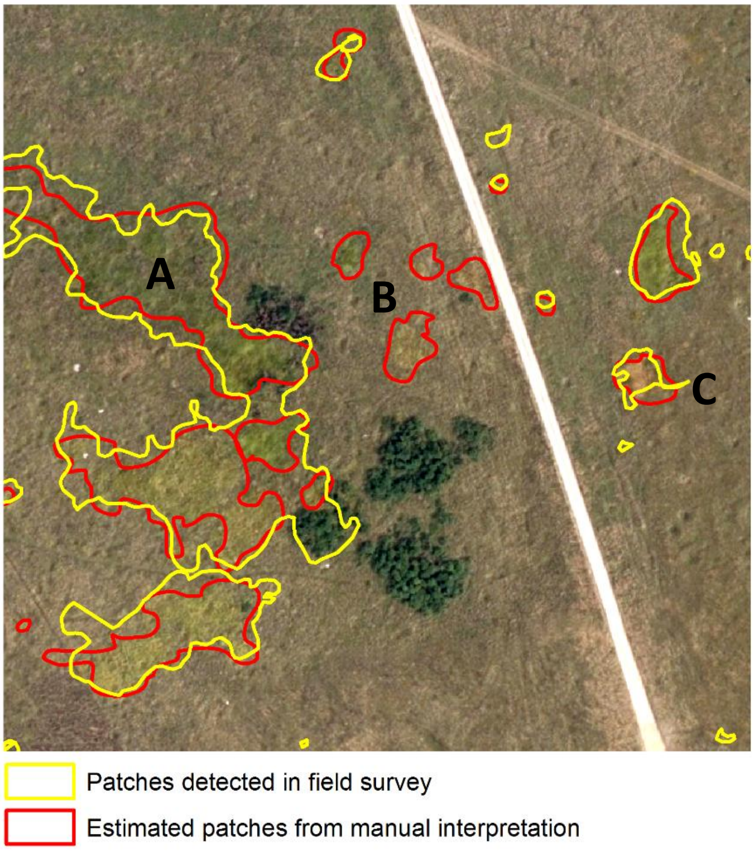

Figure 4. Example surveyed 200 m x 200 m square, showing field surveyed and manually estimated *Brachypodium* agg. cover. **A**) This large patch is well captured by manual

interpretation. **B**) These are false positives, possibly from another grass species. **C**) This *Brachypodium* agg. patch shows as pale, rather than the bright greens of the other patches in the same square

This approach successfully identified 63% of the area of field-surveyed *Brachypodium* agg., although much of this is due to successful detection of the largest patches in the high cover areas of the Central Impact Area. Overall, only 35% of the patches detected by field survey were detected by manual digitizing of aerial photographs, mostly due to the large numbers of small patches (between 0.01 m^2 and 5 m^2 in area) which were not detected (Figure 5). As the resolution of the aerial photos is 0.25 m x 0.25 m such small patches, will contain only a few pixels, so it is unsurprising that they are insufficiently distinct for manual detection from aerial imagery. Figure 5 suggests that patches over 20 m^2 begin to have a higher rate of detection, and that few patches over 100m^2 in area are not detected.

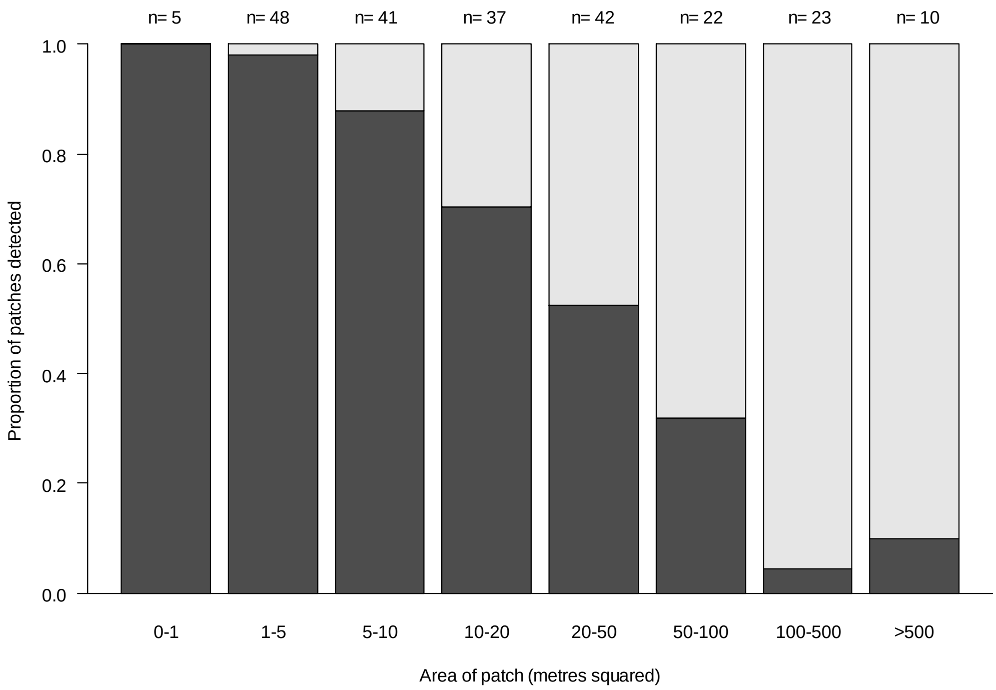

Figure 5. Bar plot of proportion of field surveyed tor grass patches detected by manual interpretation of aerial photographs (i.e. having the majority of the patch area from field survey covered by a manually placed polygon). Light sections of bars show proportion successfully detected. Numbers above the bars show the number of patches of each size range surveyed.

Although some false positives occurred (Figure 4B), with manual interpretation recording patches which did not occur in the field, these were not numerous (n = 17) and mostly (n= 14) involved patches under 100 m^2 in area, where detection of genuine patches is unreliable in any case. These may have been caused by other grasses, such as *B. sylvaticum* and *F. arundinacea.* Patches mapped in the field and noted as containing these two species were largely indistinguishable from those dominated by *Brachypodium* agg. *(*Appendix 1)*,* although many were too small to be visible.

Testing automated detection

The variation between patches of *Brachypodium* agg. seen within each imagery dataset (Figures 3 and 4) make it unlikely that an automated detection process would be successful, as consistent spectral targets within aerial photography datasets would be hard to find. Running a pixel-based supervised maximum likelihood classification, with training data derived from field surveyed patches for *Brachypodium* agg.*,* and manually digitized scrub and bare ground areas, confirmed this, with much confusion between pixels from patches of *Brachypodium* agg. and other grasslands, although scrub and bare ground were generally well separated from *Brachypodium* agg. (Figure 5), as might be expected from Figure 3. Although this pixel-based classification was largely unsuccessful, the growth habits of *Brachypodium* agg.*,* forming dense, distinctive patches, means that there may be scope for object oriented classification, where the image is segmented into spectrally similar parcels before attempting classification. Whilst this has the potential to mimic the same cues as a human observer (e.g. patch shape, texture, local context), such procedures are would be very time consuming to test and to run. Even a successful classification procedure would also need re-adjusting for every update of aerial photography which required analysing.

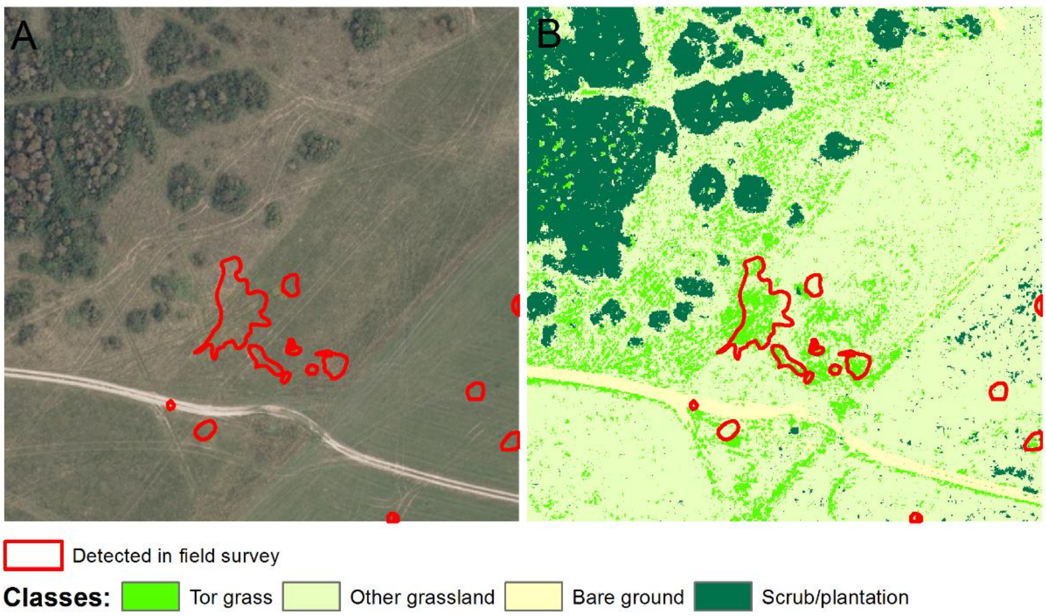

Figure 5. Example surveyed 200 m x 200 m square, showing **A**) summer 2014 aerial photography and **B**) maximum likelihood classification. Both images are overlain with current (January 2015) *Brachypodium* agg. cover as detected in field survey (red outlines). Whilst bare ground and scrub are well separated, *Brachypodium* agg. is frequently misclassified, with both false positives and false negatives.

Conclusions and Recommendations

- The occurrence and extent of *Brachypodium* agg. on Salisbury plain has changed considerably over the past twenty years, and even over the past decade, with the result that only comparatively recent imagery (2008, 2010 ad 2014) is likely to be of use in detecting current extent. However, older imagery may be used track rates of spread within target areas over the last two decades.

- Multi-seasonal imagery is of assistance in detecting patches, by providing information on seasonal change. However, there is much variation in the appearance of *Brachypodium* agg. in relation to the surrounding grassland even within seasons, due to grazing, microclimate, burning and other factors.

- Large patches (over 100 m^2) of *Brachypodium* agg. are readily identifiable from aerial photography, mostly using the red, green and blue bands alone. However, smaller patches are frequently missed. Despite this, 100m^2 of *Brachypodium* agg. per hectare is only 1% cover, so patches are very likely to be detected before they reach the threshold for condition assessment failure (10%). Thus manual interpretation of RGB aerial imagery to detect spread of existing *Brachypodium* agg. patches or to monitor areas at particular risk or vulnerability to invasion should be a useful tool, especially in the already high cover areas of the Central Impact Area.

- Automated detection is unlikely to be successful without considerable investment of time into bespoke classification procedures. While these may ultimately be successful in identifying *Brachypodium* agg., they may not be cost effective.

- Aerial imagery suitable for manual interpretation from 2008, 2010 and 2014 has been extracted for the Central Impact Area and is provided as Appendix 2

References

Kershaw, K.A. 1985. Quantitative and dynamic plant ecology. Edward Arnold, London, UK.

Robertson, H.J. & Jefferson, R.G. 2000. Monitoring the condition of lowland grassland SSSIs: English Nature's rapid assessment method. English Nature report R315, English Nature, Peterborough, UK. Available at http://publications.naturalengland.org.uk/publication/64033?category=45006

Appendix 1

TorGrass_Comparing_Aerial_photography_datasets.pdf: Images of all surveyed 200 m x 200 m squares from nine different aerial photography datasets from different years (all June-August images, except 2008 which was taken in April). Red outlined areas are current (January 2015) *Brachypodium* agg. cover as detected in field survey.

Appendix 2

TorGrass_CIA_Imagery.zip: Zipped folder containing 1km tiles of RGB aerial imagery for the Central Impact Area, for each of the three most recent years (2008, 2010 and 2014)

Further information

Natural England evidence can be downloaded from our **Access to Evidence Catalogue**. For more information about Natural England and our work see **Gov.UK**. For any queries contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk** .

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Report number RP02081
ISBN 978-1-78354-426-4