G Model
ECOIND-2767; No. of Pages 7
ARTICLE IN PRESS
Ecological Indicators xxx (2015) xxx–xxx
Contents lists available at ScienceDirect
Ecological Indicators
journal homepage: www.elsevier.com/locate/ecolind

Can digital image classification be used as a standardised method for surveying peatland vegetation cover?

Catherine L. Baxendale[a,*], Nick J. Ostle[a,b], Claire M. Wood[b], Simon Oakley[b], Susan E. Ward[a,b]

[a] Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ, UK
[b] Centre for Ecology and Hydrology, Lancaster Environment Centre, Lancaster LA1 4AP, UK

ARTICLE INFO

Article history:
Received 15 May 2015
Received in revised form 9 November 2015
Accepted 12 November 2015
Available online xxx

Keywords:
Digital imaging
Peatlands
Vegetation survey
Plant functional type
Long-term monitoring
Moor House NNR

ABSTRACT

The ability to carry out systematic, accurate and repeatable vegetation surveys is an essential part of long-term scientific studies into ecosystem biodiversity and functioning. However, current widely used traditional survey techniques such as destructive harvests, pin frame quadrats and visual cover estimates can be very time consuming and are prone to subjective variations. We investigated the use of digital image techniques as an alternative way of recording vegetation cover to plant functional type level on a peatland ecosystem. Using an established plant manipulation experimental site at Moor House NNR (an Environmental Change Network site), we compared visual cover estimates of peatland vegetation with cover estimates using digital image classification methods, from 0.5 m × 0.5 m field plots. Our results show that digital image classification of photographs taken with a standard digital camera can be used successfully to estimate dwarf-shrub and graminoid vegetation cover at a comparable level to field visual cover estimates, although the methods were less effective for lower plants such as mosses and lichens. Our study illustrates the novel application of digital image techniques to provide a new way of measuring and monitoring peatland vegetation to the plant functional group level, which is less vulnerable to surveyor bias than are visual field surveys. Furthermore, as such digital techniques are highly repeatable, we suggest that they have potential for use in long-term monitoring studies, at both plot and landscape scales.

1. Introduction

The ability to carry out systematic, accurate and repeatable vegetation surveys is an essential part of scientific studies into ecosystem biodiversity and functioning. Such surveys, for example the Countryside Survey of Great Britain (Carey et al., 2008) and Environmental Change Network vegetation recording (Rose et al., this issue), can provide invaluable information about long-term vegetation change, biodiversity and indicators of environmental change. In addition, given the growing recognition that vegetation composition plays a vital role in driving important ecosystem functions, vegetation surveys can help to inform on the ecosystem service value of land. For example, vegetation composition is important in controlling ecosystem carbon cycling processes (De Deyn et al., 2008). This is particularly relevant to carbon-rich ecosystems such as peatlands (Gorham, 1991), where different plant functional types (PFTs) have been shown to influence both short- and long-term rates of carbon cycling (Dorrepaal et al., 2007; McNamara et al., 2008; Trinder et al., 2008). Indeed, the influence of vegetation composition on greenhouse gas fluxes and rates of decomposition has recently been shown to be stronger than the effects of moderate climate warming (Ward et al., 2013, 2015). These influences of vegetation on ecosystem function (Hooper and Vitousek, 1997; Tilman et al., 1997), may be the result of changes in different aspects of vegetation including: community species richness (Naeem et al., 1994; Tilman et al., 1996); effects of specific individual species (Chapin et al., 1995) or changes in the composition of plant functional traits (Lavorel and Garnier, 2002; Garnier et al., 2004; Diaz et al., 2007; Grigulis et al., 2013). Thus, the development of cost and time effective ways to repeatedly monitor vegetation composition accurately to PFT level, is of great relevance to ecosystem function studies, particularly for long-term monitoring sites such as those operated by the Environmental Change Network (ECN) and other networks in the International Long Term Ecological Research Network (ILTER).

* Corresponding author. Tel.: +44 01524594780.
E-mail addresses: c.baxendale@lancaster.ac.uk (C.L. Baxendale), n.ostle@lancaster.ac.uk (N.J. Ostle), clamw@ceh.ac.uk (C.M. Wood), soak@ceh.ac.uk (S. Oakley), s.e.ward@lancaster.ac.uk (S.E. Ward).

http://dx.doi.org/10.1016/j.ecolind.2015.11.035
1470-160X/

Please cite this article in press as: Baxendale, C.L., et al., Can digital image classification be used as a standardised method for surveying peatland vegetation cover? Ecol. Indicat. (2015), http://dx.doi.org/10.1016/j.ecolind.2015.11.035

To assess vegetation change over time, repeatable and reliable survey and monitoring techniques are needed to allow comparisons between data sets (Howard et al., 2003). However, current widespread traditional methods such as destructive harvests (Nordh and Verwijst, 2004), are damaging to the environment and therefore cannot be used in most long-term investigations where conservation is paramount and repeated sampling of other parameters is required (Gilbert and Butt, 2009). Although other survey methods such as visual cover estimates (Howard et al., 2003; Vittoz and Guisan, 2007) and recording presence/absence of species (Scott and Hallam, 2003) are non-destructive, they tend to be subjective and can be affected by errors and surveyor biases, and therefore can be difficult to repeat accurately. Techniques such as pin-frame point counts, although more accurate, can be time consuming.

Digital image analysis (DIA) offers a non-destructive method which is a potentially faster and less biased alternative to these commonly used techniques (Richardson et al., 2001; Rasmussen et al., 2007; Booth et al., 2008). Several DIA techniques show great potential for use in long-term monitoring projects to build up large scale temporal datasets (Laliberte et al., 2007), particularly for those that require survey data to PFT level rather than to detailed species level, which would require specialist botanical knowledge. Given the importance of PFTs as key drivers of ecosystem functions, the development of DIA techniques in monitoring to this scale could provide a standardised technique for monitoring vegetation change and hence the impact of change on ecosystem functions.

The aim of this study was to develop a practical, accurate and repeatable technique to distinguish between PFTs, using an established plant removal experiment on the peatland ECN site at Moor House National Nature Reserve (NNR). To do this, we used a standard compact digital camera (Nikon 5.1 Megapixel) and two methods of image classification. The first method was an unsupervised classification method, referred to as a histogram peak classification method, which classifies images on the basis of peaks in histograms of red, green and blue (RGB) values. The second method was a supervised classification method, which classifies images on the basis of training areas (manually defined pixels). These methods can be carried out using a variety of Geographical Information Systems software, including freeware such as QGIS and others, meaning that they are practical and affordable techniques for use in future studies by a range of projects and users. In our study, we used ArcGIS (version 9.3, ESRI UK. Ltd., Aylesbury, UK) for method 1, hereafter named as "histogram peak classification". For method 2, hereafter named as "supervised classification", we used ERDAS (version 9.1, ERDAS Inc., Norcross, GA, USA).

2. Materials and methods

2.1. Study site

Our study site was located on an area of blanket bog within Moor House NNR in the North Pennines of England (54°65′ N, 2°45′ W; altitude 590 m). Moor House NNR has been studied in ecological research since the 1930s (Crowle, 2008), and is currently the largest of the terrestrial ECN sites, making it an important long-term monitoring site with a wealth of historic and present day scientific information. The vegetation present on the blanket bog is typical of UK National Vegetation Classification M19b, *Calluna vulgaris-Eriophorum vaginatum* blanket mire, *Empetrum nigrum* ssp. *nigrum* sub-community (Rodwell, 1991). Species present can be divided into three broad functional types: ericoid dwarf-shrubs (dominated by *Calluna vulgaris* and *Empetrum nigrum*), graminoids (dominated by *Eriophorum vaginatum*) and lower plants (comprising a diverse community of mosses, liverworts and lichens, including *Sphagnum*, *Hypnum*, *Plagiothecium*, *Rhytidiadelphus*, *Aulacomnium*, *Polytrichum*, *Pleurozium*, *Dicranum*, *Campylopus* and *Cladonia* spp.).

More specifically, our study was based on an established plant removal manipulation experiment (Ward et al., 2013). This consisted of 1.5 m × 1.5 m plots where above-ground vegetation had been selectively removed to create areas with one, two or all of the 3 PFTs (dwarf-shrubs, graminoids and lower plants) in all combinations, giving a total of seven manipulation treatments, each replicated four times ($n = 28$).

2.2. Field techniques

For each field treatment plot, visual field surveys of vegetation cover were carried out and a digital photograph taken at two dates during the growing season. A white plastic quadrat measuring 0.5 m × 0.5 m was placed in each treatment plot, and the corner positions of the quadrat marked with fixed wooden canes, to ensure accurate repeat measurements. Digital photographs were taken using a Nikon Coolpix L3 5.1 Megapixel digital compact camera, mounted on a tripod with a horizontal boom and spirit level to ensure that the images were taken 1–1.2 m directly above the plot. A light metre (Skye Pyranometer Sensor, Skye Instruments, UK) was used to record light conditions and, wherever possible, images were taken whilst there was cloud cover and the light metre readings were less than 400 W m^{-2} in order to avoid shadows.

For the visual surveys, the percentage cover for each of the three PFTs was estimated by eye to the nearest 5%, a technique widely used in surveys such as the Countryside Survey (Maskell et al., 2008). Cover estimates were made on a two dimensional 'birds eye' view to total 100% cover, so that direct comparison could be made with the photographs. To investigate the effects of surveyor bias on the accuracy of visual field surveys, we compared percentage cover estimates of 9 plots from 5 different surveyors.

2.3. Visual estimate technique using a Fishnet grid

A schematic overview of all digital image techniques is given in Fig. 1. To provide a baseline estimate of PFT percentage cover upon which the results from the visual field surveys and DIA analysis could be compared, we first analysed each digital photograph using a fishnet grid technique. This visual estimate technique involved dividing each photograph into a 'fishnet grid' of 100 squares, with each square representing 1% of the total area. This grid provided a framework within which vegetation in each 1% square could then be allocated visually to one of the 3 PFTs, with the standard rule that any square that was more than half occupied by a functional group was recorded as 1% cover for that group. As with the visual field surveys, we tested the effect of surveyor bias on the accuracy of this technique by comparing cover estimates of 9 plots from 5 different surveyors.

2.4. Digital image analysis techniques

All images were initially standardised using Corel Paint Shop Pro (version X1, Corel Corporation, Maidenhead, Berks, UK), a commonly available digital photograph editing software package. Firstly, images were straightened and cropped to the plot boundary to remove any vegetation from outside the quadrat (final average image resolution was 3.1 mm). Secondly, the brightness and contrast of the digital photographs were altered in order to examine whether they affected the accuracy of DIA techniques in estimating PFT cover. We then analysed the images using two techniques, both of which classified images based on values of the red, green and blue (RGB) spectrum. One method used the histogram of RGB