Evaluation of digital photography as a tool for field monitoring in potentially inhospitable environments

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SUMMARY

Efficient and accurate vegetation monitoring is essential for successful assessment of upland moorland restoration. Working conditions on open moorland may be difficult, and surveying and monitoring of vegetation problematic. Image capture by digital photography, with subsequent computer analysis, was used to monitor *Calluna vulgaris* post-wildfire. Problems, for example picture warp, associated with close range photography of quadrats, were overcome. Digital imagery measurements of vegetation cover showed no significant difference compared with a traditional point quadrat method.

KEY WORDS: peat moorland, point quadrat, sampling, vegetation cover, wildfire.

INTRODUCTION

Upland moorlands are often subjected to wildfires that destroy all vegetation and burn down into the underlying peat. Natural regeneration of vegetation is often slow and many badly burnt sites remain bare for decades after wildfires (Radley 1965, Maltby *et al.* 1990, Gilchrist *et al.* 2004). Post wildfire management may consist of liming, fertilising and sowing with seeds of selected grasses and *Calluna vulgaris* (ling heather). The success of restoration must be assessed by field measurements. One of the main issues associated with such field techniques is how to achieve adequate accuracy of vegetation cover estimation (Kent & Coker 1992). Although harvest of ground vegetation would provide an exact measurement of above-ground plant biomass, this method cannot be used when damage to the surveyed site is undesirable. A non-destructive method is, therefore, required. The accuracy of field measurements may be influenced by many factors; for example, different observers and methods used (Nilsson & Nilsson 1985, Fenner 1997). Consistent results may also be difficult to achieve (Hope-Simpson 1940) with few examples of quality control cited in the literature (Kercher *et al.* 2003). One of the most frequently used objective methods for estimating vegetation cover is the point quadrat or 'pin-frame' (Bonhamn 1989, Silvertown *et al.* 1992). As this method is objective, it is less susceptible to operator influence than other techniques; however, it is very time intensive (Fenner 1997). A visual estimate of cover, where a frame or grid quadrat is placed over the plants and cover estimated, may be accurate (Fenner 1997). However, such estimates are subjective and may therefore be influenced by the surveyor, grid size and type of vegetation surveyed (Goodall 1951, Shimwell 1971, Fenner 1997).

Aerial photography is an acceptable method for recording vegetation change (on a large scale) and has been used extensively (Zharikov *et al.* 2005, Tong *et al.* 2006, Booth *et al.* 2007). Photography of smaller quadrats has also been used to record changes in vegetation cover, but some authors (Cooper 1924, Owens *et al.* 1985) were not supportive of this method, although Law (1981) successfully followed development of individual plants. With advances in digital photography and computer technology, more trials and use of photography for vegetation surveying have been undertaken. Bennett *et al.* (2000) concluded that vertical photography and digital image analysis was sufficiently accurate to measure cover change in perennial grasslands. In addition Vanha-Majamaa *et al.* (2000) used computer software to distinguish between cover of different plant species from digital images, and although results were unreliable in estimating cover of multi-layered vegetation, they were useful for detecting changes in vegetation that had a simple vertical structure.

The major difficulty in evaluating methods for estimating vegetation cover is that the actual cover value is unknown. Fenner's (1997) study showed that shapes and sizes of vegetation influenced accuracy, with compact shapes and small areas being easier to estimate than dispersed shapes and larger areas. Lindquist (1931) had previously undertaken similar research and had used cut paper shapes to demonstrate over-estimation of percentage cover by large diameter pins in point-quadrat assessments.

Another problem that arises when using photography to estimate vegetation cover within a quadrat is the angle of the camera to the quadrat giving an 'un-square' image. This was overcome by Bennett *et al.* (2000) who used a large frame to hold the camera level and at the centre of the quadrat. Nevertheless, this method would be impractical on rough terrain or if all equipment had to be transported to high altitude.

The aim of this study was to evaluate the use of digital photography for monitoring *C. vulgaris* regeneration on upland moorland after burning. The method chosen had to be reliable, efficient and relatively rapid as adverse weather conditions often limited the number of hours that could be spent on the moor. Digital photography allows estimation of vegetation cover to be undertaken later, in a comfortable environment.

METHODS

Two trials were used to evaluate the method for use in large field surveys on moorland. The first trial was conducted with a known simulated vegetation cover and the second trial was undertaken on an upland moor.

Trial 1: Evaluation of sampling methods with known cover

An arena (3 m x 2 m) was populated with simulated vegetation using irregularly shaped pieces of paper of various sizes and four colours. The paper was scattered on a level survey area but individual pieces were not allowed to overlap. The four colours simulated four different vegetation types with the uncovered area representing 'bare soil' or an unvegetated area. Vegetation patch sizes ranged from 100 cm^2 to 625 cm^2 and were of random shapes with 65% of the total area uncovered. Actual percentage cover of simulated vegetation was not calculated until after the survey so as not to influence cover estimation. As the patches did not overlap, total cover (simulated vegetation and bare ground) was 100 %. This method was similar to that used by Lindquist (1931) and Fenner (1997). Within the arena, 50 cm x 50 cm square quadrats were placed using random number coordinates. Quadrat size was selected to fit the camera viewfinder at a height of approximately 1 m. All sampling was undertaken by one person with results unknown until all sampling was complete.

A photographic image of each quadrat (n=30) was taken with a digital camera and the images were transferred to a computer. The problem of picture warp, where the angle of the photographed terrain or the angle of the camera shows the square quadrat to have unequal sides, as in Figure 1a, was corrected prior to calculation of vegetation cover. Picture-warp was removed and the true shape of the image restored by geometric correction or rubbersheet transformation (Baxes 1994) using the 'crop' tool with the 'perspective' option selected in Adobe Photoshop. Figure 1b shows the corrected image of Figure 1a. This procedure rectifies the image, keeping the vegetation cover proportions in the image the same as in the quadrat. Figures 1c and 1d confirm this using a photographic image of a chessboard.

A 5 x 5 grid was superimposed on the transformed (squared) images within Adobe Photoshop and the cover estimated by eye. For comparison, and using the same arena and simulated vegetation as above, a 50 cm x 50 cm square quadrat was placed randomly and the vegetation sampled using 25 point quadrats in a frame.

(a) (b) (c) (d)

Figure 1. (a) Image of simulated vegetation within a 50 cm x 50 cm square quadrat. The sides of the quadrat are unequal due to camera angle. (b) Image of simulated vegetation, as in (a), but squared and cropped to remove extraneous area. (c) and (d) show the identical method of image correction and result for a chessboard.

Trial 2: Evaluation of methods in the field

The same 50 cm x 50 cm square quadrat was placed every 5 m along a transect on a fire-damaged section of moorland (*n*=25). Each quadrat was assessed using two methods (digital photography and point quadrat) as in Trial 1. Only the first vegetation or un-vegetated area to receive a 'hit' or touch from a pin was recorded. Figure 2 is an example of a photographic record taken in the field plus the squared image prepared for cover estimation.

RESULTS

Trial 1

ANOVA results showed no significant differences in simulated vegetation cover within the quadrats using point quadrat or digital photography ($P > 0.05$). Also no differences were recorded between the methods and the actual vegetation cover ($P > 0.05$) (Figure 3 and Table 1.).

Trial 2

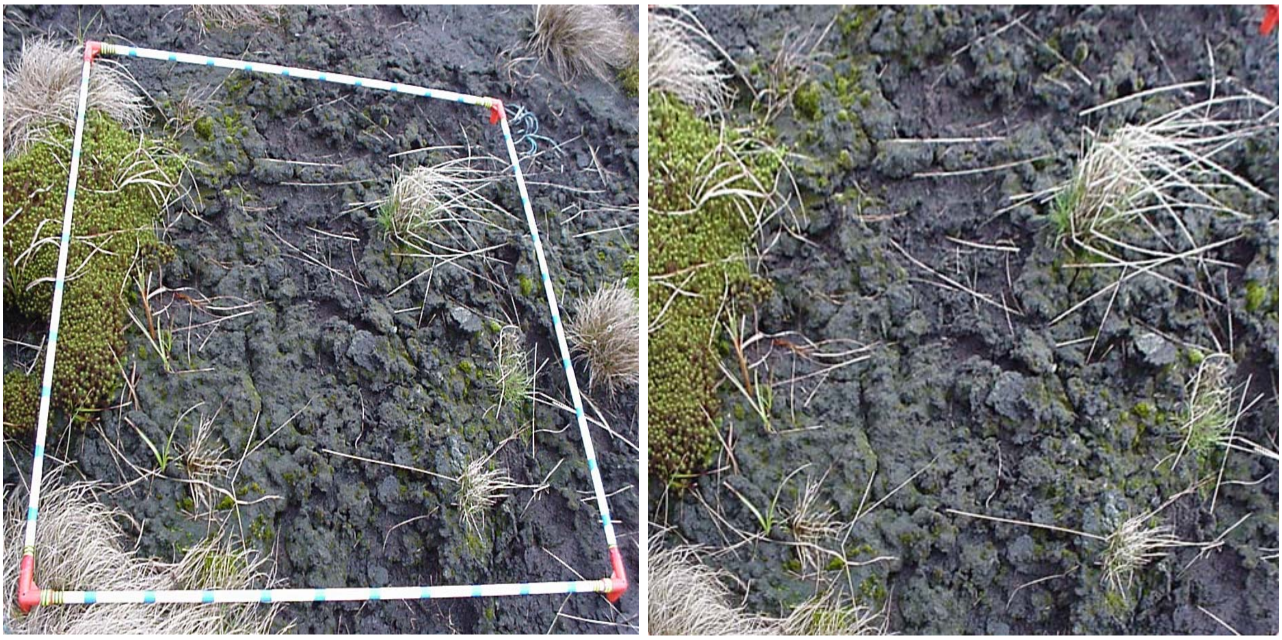
ANOVA results showed no significant difference in vegetation cover between the two methods tested (point quadrat and digital photography) (P >0.05). The largest difference in cover between the two survey methods was recorded in moss species (other than *Sphagnum* spp.) and bare peat; 4.5% and 6.2% respectively. However, these were not significantly different (P >0.05) (Figure 4 and Table 2).

Table 1. ANOVA results for sampling methods with known cover.

source	df	Mean Square	F	*P* value
sampling methods	2	19.148	0.256	0.775
plants within sampling methods	8	23.338	0.312	0.959
error	68	74.898		
total	83			

Table 2. ANOVA results for field sampling methods.

source	df	Mean Square	F	*P* value
sampling methods	1	11.734	0.015	0.902
plants within sampling methods	4	219.415	0.287	0.885
error	82	763.627		
total	92			



(a) (b)

Figure 2. Field sample site showing (a) uncorrected and (b) transformed (squared) image, prepared for estimation of vegetation cover.

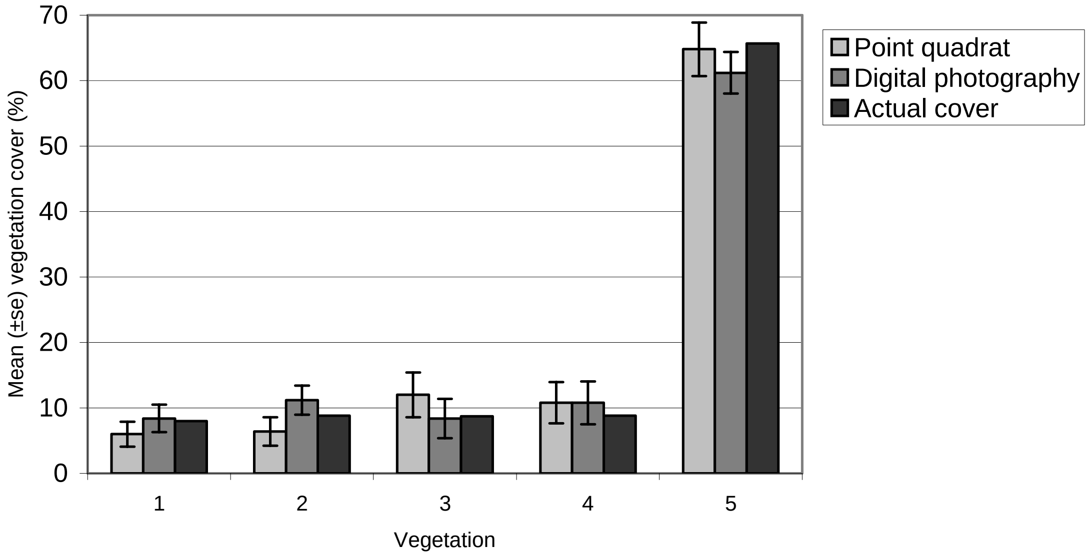


Figure 3. Estimated cover of simulated vegetation using point quadrats and digital photography, for comparison with the actual cover (*n*=30). Coloured paper represented 'vegetation' types 1–4 whilst 5 = 'bare' (no paper present). The sum of all five is 100 %.

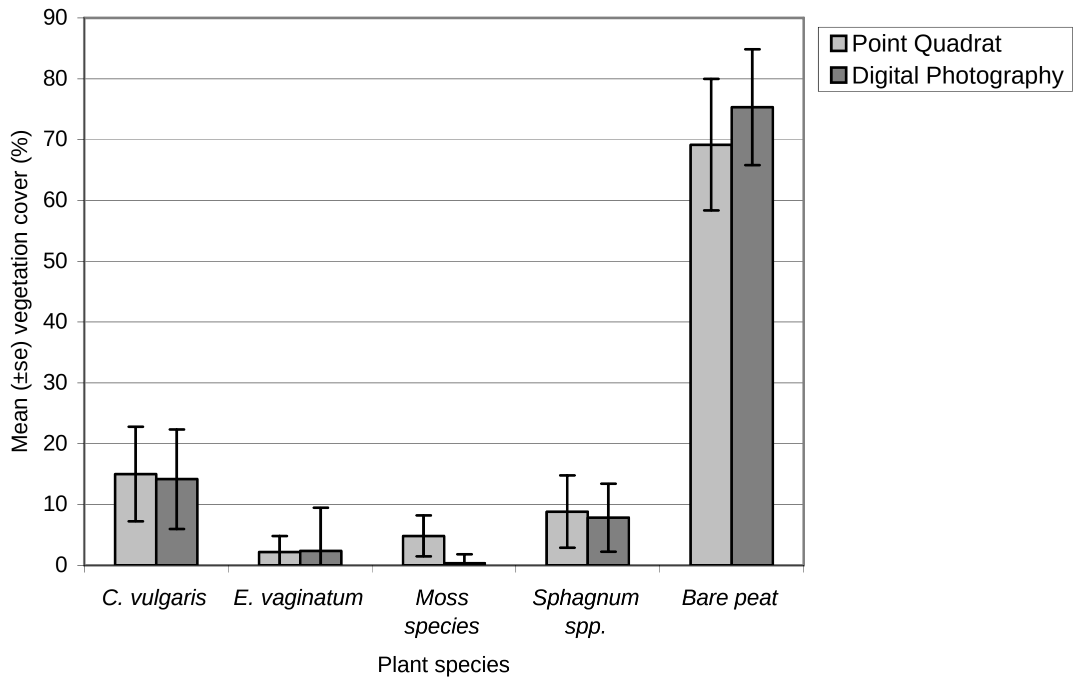


Figure 4. Comparison of techniques for field survey of a fire-damaged section of moorland (*n*=25).

DISCUSSION

Picture warp was successfully corrected. This is a major advantage because it avoids the time-consuming adjustment of a tripod on uneven ground that is necessary for vertical photography.

The two trials undertaken, artificial and field-based, demonstrated the value of using digital photography as a tool in measuring vegetation cover. Comparing results of the digital and point quadrat methods indicated that they were not significantly different ($P > 0.05$), permitting confident use of the digital technique.

Enhanced speed of data collection is most useful in areas of poor climatic conditions or poor accessibility, as on upland moors. With reduced time in the field, sampling fatigue does not influence results; time spent on computer analysis of images can be conveniently interrupted within a comfortable environment. Also images can be easily archived allowing re-examination of data, the sequence of individual quadrats can be viewed, and images can be used in retrospective studies that may examine new questions. This is in contrast to other methods, where the primary source is lost once the quadrat is removed, leaving only the collected data.

Accuracy was the main criterion by which the two survey methods were evaluated. Digital photography was shown to be as accurate as a traditional point quadrat, a method that is widely accepted for estimating vegetation cover. All this concurs with work by Dietz & Steinlein (1996), Bennett *et al.* (2000) and Smith *et al.* (2000).

An extension of this work could be to count different coloured pixels within a digital image (Adobe-Photoshop 2000, Schooler & McEvoy 2006, Riegl *et al.* 2005). Although this was not undertaken within the current study due to the complexity of the plant community of the upland site, it is simple to calculate percentage cover within a quadrat with only one or two species against a uniform background cover e.g. peat. Using Adobe Photoshop, pixels of one colour can be calculated as a percentage of total pixel count.

Two large surveys, each with 456 samples, have now been completed using the methods described in this article on a fire-damaged moor (Gilbert 2008), showing that the technique is practicable on a large scale.

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