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Research article

Combining remote sensing and on-site monitoring methods to investigate footpath erosion within a popular recreational heathland environment

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ABSTRACT

Footpaths are a prominent consequence of natural area tourism and reflect damage caused to valuable, sensitive habitats by people pressure. Degradation impacts on vegetation, wildlife, on and off-site soil movement and loss, creation of additional informal off-path footpaths (desire lines), and visual destruction of landscapes. Impacts need to be measured and monitored on a large temporal and spatial scale to aid in land management to maintain access and preserve natural environments. This study combined remote sensing (Light Detection and Ranging [LiDAR] and aerial photography) with on-site measurement of footpaths within a sensitive heathland habitat (Land's End, Cornwall, UK). Soil loss, slope angle change, vegetation damage and a hydrology model were combined to comprehensively study the site. Results showed 0.09 m mean soil loss over five years, footpath widening, increasing grass cover into heathland, and water channelling on the footpaths exacerbating erosion. The environments surrounding the footpaths were affected with visitors walking off path, requiring further management and monitoring. Multiple remote sensing techniques were highly successful in comprehensively assessing the area, particularly the hydrology model, demonstrating the potential of providing a valuable objective and quantitative monitoring and management tool.

1. Introduction

Although a key infrastructure element (Tomczyk and Ewertowski, 2013), footpaths are potentially the most visible and contentious feature of the natural environment tourism industry (Rodway-Dyer, 2004). Of the 1.235 billion international tourists in 2016 (UNWTO, 2017), the majority that explored the natural environment will have accessed footpaths, yet tourists are often unaware of the vital role they can play in protecting the environment (Rodway-Dyer, 2004). A footpath can broadly be described as a human trace in the physical environment which is a product of the interaction between use by walkers and the terrain on which they walk (Aitken, 1982; Rodway-Dyer, 2004). Therefore, footpaths embody tourism and environmental interaction, channelling visitors through their natural environment experience like corridors (Jensen and Guthrie, 2006), minimising wider disturbance (Olive and Marion, 2009). However, with natural area tourism growing exponentially worldwide, footpaths and surrounding environments are under increasing threat (Newsome et al., 2013).

The extent to which erosion (removal of soil) and degradation (breakdown of soil quality) occur are affected by environmental factors including soil type, land cover, vegetation density and height, terrain morphology, regolith geology, and macro and meso climate (Coleman, 1981; Leung and Marion, 1999; Rodway-Dyer and Walling, 2010). Despite these environmental factors, footpath erosion is mostly considered a product of footpath use, particularly the number of visitors to an area or recreational pressure (Coleman, 1981), often ignoring other factors such as wild or grazing animals.

This paper aims to explore the use of multiple remote sensing techniques in combination with on-site measurement to assess anthropological and hydrological impacts within a sensitive heathland environment. The focus is on the methods, supported by

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a small scale case study, demonstrating the potential for upscaling for natural-based tourism impact research globally.

Damaging effects upon the footpath (most commonly cited as the effects of footpath erosion) include the measured loss of soil, trail widening, changes in slope angle or the muddying of footpaths (Pröbstl-Haider and Haider, 2013; Sun and Walsh, 1998). Soil formation is slow as is natural recovery, therefore soil erosion and degradation rates are particularly important to study (Aitken, 1985; Commission of the European Communities (CEC), 2006; Leung and Marion, 2000) with Jewell and Hammitt (2000) believing soils are central in all footpath assessments. On-site measurements have often been constrained to immediate soil loss with no survey of the surrounding environment (Garland, 1990). For example, a traditional study by Morrocco and Ballantyne (2008) in the Mamore Mountains, Scotland, found that erosion on the footpath of up to 0.2 m had occurred over five years, with greater rates present in areas of higher footpath pressure. However, a detailed study by Rodway-Dyer (2004) evidenced that although erosion is often focused upon the footpaths themselves, erosion off path can also be damaging to the environment, with vegetation loss and habitat disturbance. Longer-term soil erosion rates (ca. 40 years) were calculated using fallout radionuclide measurements: a Profile Distribution Model compared ^{137}Cs inventories for on and off path erosion rates and established soil redistribution rates within sites, taking into account natural drainage and runoff processes. This research in SW England showed the combined mean soil loss for all sites 'on paths' as 1.41 kg m^{-2} yr^{-1} with the combined 'off path' soil loss as 0.79 kg m^{-2} yr^{-1} establishing that degradation and erosion had occurred across large areas (Rodway-Dyer, 2004; Rodway-Dyer and Walling, 2010). Harden (2001) found that footpaths act similarly to roads, channelling surface water and intensifying erosion, and where a footpath has been compacted by recreational pressure, reduced water infiltration further increases surface erosion (Snyder et al., 1976). While acknowledged as an impact upon footpaths, there are limited studies into the effect of surface runoff upon footpaths (Tomczyk and Ewertowski, 2013).

Surrounding vegetation species can indicate footpath stress and influence footpath degradation, for example increasing erosion through decreased coverage (Cole, 2004), whilst dense impenetrable vegetation will restrict access. The presence of wild or grazing animals can additionally impact on erosion rates (Evans, 1998; Harrod et al., 2000) as vegetation may change in extent or species dominance due to trampling (anthropogenic and fauna) or consumption. Numerous studies have shown greater grass extent to be associated with increased trampling, due to its resilience and quick growth when compared to other plant species (Arnesen, 1999; Bayfield, 1979).

Informal footpaths known as 'desire lines' result from visitors using the fastest route, often accessing a specific area (such as a viewpoint) or avoiding muddy paths in vulnerable environments (Myhill, 2004; Rodway-Dyer, 2004). Hampton and Cole (2003) proved that on average it only takes fifteen people walking the same route to create a desire line, which endangers the natural environment with visitor impacts spreading over a wider area. There is a need for greater scientific research on wider impacts of desire lines to support management of key footpaths.

The aim of management is to limit impacts on an environment to preserve natural resources and enhance visitor experience (Dartmoor National Park Authority, 2003; Gundersen et al., 2015; Pröbstl-Haider and Haider, 2013) whilst maintaining environmental services. Therefore, it is vital impacts are monitored and quantified to protect environments (Sun and Walsh, 1998), however inconsistencies between studies often makes comparison difficult (Rodway-Dyer, 2004; Tomczyk and Ewertowski, 2013). On-site monitoring is a common solution, such as problem based surveys and point sampling (Cole, 2004; Leung and Marion, 2000; Mende and Newsome, 2006). However, these approaches are often limited to the immediate path and the wider environment is not considered, despite research evidencing the impacts. One aspect of Rodway-Dyer's (2004) multi-disciplinary study of environmental degradation at sites in SW England showed longer-term changes in footpath and site histories via the use of aerial photographs and historical records, reflecting changes in management practices and access. The use of remote sensing has improved on this, with economically viable, high resolution data available over a longer time series than field monitoring (Kincey and Challis, 2010). This provides the spatial and temporal coverage needed for wider environmental analysis, as well as quantifiable data which is uniform across studies. Marion and Leung (2011) demonstrated standardised measurement of erosion rates across a set area by monitoring slope changes, erosion and the presence of informal trails across Zion National Park, Colorado. Such field techniques are still important in validating findings, for example by the collection of GPS coordinates through trail inventories (Ólafsdóttir and Runnström, 2013).

This study utilised remote sensing and on-site measurement validation to assess footpath characteristics and to ascertain the wider impact of recreational pressure upon a popular natural environment, comparable to other worldwide popular, easily accessible natural attractions (Table 1). Most studies are limited singularly to erosion or vegetation changes along footpaths (Table 2), and few have embraced the effect of surface water with these studies. Although only a small scale localised study, the research has implications for future management strategies worldwide.

2. Materials and methods

2.1. Study site

The South West Coast Path (SWCP), one of the UK's National Trails, stretches 630 miles (1014 km) around the southwest coast and attracts 8.7 million visitors annually (SWCP, 2015a; Visit Cornwall, 2012). This is particularly important in Cornwall, where 80% of yearly visitors use the coastal footpaths whilst on holiday (Visit Cornwall, 2016). Along the SWCP lies Land's End (Fig. 1), a popular tourist destination for on average 400,000 visitors per year (Land's End, 2016). Resultantly the 1.5 km route between Land's End and Sennen Cove is one of the most intensely used sections of the SWCP (National Trust, 2012), demonstrating year round pressure on the environmentally vulnerable and small (46ha) designated Priority Habitats of Lowland Heath and Maritime Cliffs and Slopes (Maddock, 2011). A perfect site for a methodological study combining on-site measurements with remote sensing methods to comprehensively establish recreational impacts and determine the influence of topography and natural hydrological processes on erosion.

Land's End is underlain by coarse-grained granite to the south of Land's End itself, and finer grain to the north, derived from a granite pluton (Powell et al., 1999). The soil layer is thin and exposed, with adapted hardy, lowland shrubbery the dominant vegetation in the area (Malloch, 1972). This heathland is a Designated Priority Habitat under the UK Biodiversity Action Plan (Maddock, 2011). The harsh Atlantic wind and rain factors combine to make Land's End a vulnerable landscape and an interesting study site for this research.

2.2. Remote sensing

Changes in elevation and slope angle were assessed using LiDAR data (Light Detection and Ranging), where laser scanners project a