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Erosion in peatlands: Recent research progress and future directions

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ABSTRACT

Peatlands cover approximately 2.84% of global land area while storing one third to one half of the world's soil carbon. While peat erosion is a natural process it has been enhanced by human mismanagement in many places worldwide. Enhanced peat erosion is a serious ecological and environmental problem that can have severe on-site and off-site impacts. A 2007 monograph by Evans and Warburton synthesized our understanding of peatland erosion at the time and here we provide an update covering: i) peat erosion processes across different scales; ii) techniques used to measure peat erosion; iii) factors affecting peat erosion; and iv) meta-analyses of reported peat erosion rates. We found that over the last decade there has been significant progress in studying the causes and effects of peat erosion and some progress in modelling peat erosion. However, there has been little progress in developing our understanding of the erosion processes. Despite the application of new peat surveying techniques there has been a lack of their use to specifically understand spatial and temporal peat erosion dynamics or processes in a range of peatland environments. Improved process understanding and more data on rates of erosion at different scales are urgently needed in order to improve model development and enable better predictions of future peat erosion under climate change and land management practices. We identify where further research is required on basic peat erosion processes, application of new and integrated measurement of different variables and the impact of drivers or mitigation techniques that may affect peat erosion.

1. Introduction

Peat is a slowly-accumulating organic-rich soil composed of poorly decomposed remains of plant materials (Charman, 2002). Peatlands are areas with a surface peat accumulation and they can be broadly subdivided into bogs, fens and some types of swamps (Joosten, 2016). Bogs, which can be subdivided into blanket peatlands and raised bog (Charman, 2002), are ombrotrophic and receive water and nutrients primarily from precipitation. Fens and swamps are minerotrophic and receive water and nutrients from groundwater. To initiate and develop, peatlands require water-saturated conditions. However, peatlands occur in a broad range of climatic conditions from the warm tropics through to the cold, high latitudes and in total they cover approximately 4.23 million km^2 (2.84%) of the world's land area (Xu et al., 2018). Peatlands serve as important terrestrial carbon sinks, storing carbon equivalent to more than two thirds of the atmospheric store (Yu et al., 2010). Quantification of the carbon flux from peatland systems is therefore vital to fully understand global carbon cycling (Evans and Warburton, 2007; Pawson et al., 2008). In addition, peatlands provide a wide range of important ecosystem services including water supply, recreation and biodiversity (Bonn et al., 2009; Osaki and Tsuji, 2015). The conditions required for peatland initiation and ongoing survival are relatively narrow and as a result they are fragile ecosystems that are sensitive to a wide range of external and internal pressures, including changes in topography due to peat growth, climate change, atmospheric pollution, grazing, burning, artificial drainage, afforestation and infrastructure (Fenner and Freeman, 2011; Holden et al., 2007c; Ise et al., 2008; Noble et al., 2017; Parry et al., 2014).

Peat erosion is a natural process driven primarily by actions of water and wind, but slight changes in conditions driven by human action can lead to accelerated erosion and degradation (Parry et al., 2014). Wind erosion can occur where the peat surface is largely bare and is common in windy uplands and peat mining areas (Foulds and Warburton, 2007a; Foulds and Warburton, 2007b). Erosion by water can occur through a number of different processes (both on and below the surface), with the scale of erosion varying by peatland type as well as how degraded they are. Rainsplash and runoff energy can cause erosion on bare peat surfaces. Where flow accumulates, both in artificial ditches and natural channels, further erosion can take place. In peatlands that have been drained ditch erosion often occurs while channel bank collapse may occur on all peatlands (Marttila and Kløve, 2010a). Erosion under the peat surface can also occur with piping being common in many peatlands globally (Jones, 2010).

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Rain-fed blanket peatlands cover 105,000 km^2 of the Earth's surface (Li et al., 2017a) and occur on sloping terrain, with slope angles as high as 15°. As a result, blanket peatlands are potentially more vulnerable to water erosion than other types of peatlands occurring in landscapes with very little surface gradient (Li et al., 2017a). It has been reported that many blanket peatlands have experienced severe erosion (Evans and Warburton, 2007; Grayson et al., 2012; Li et al., 2016b) and are under increasing erosion risk from future climate change (Li et al., 2016a; Li et al., 2017a). The erosion of peat with high carbon content will enhance losses of terrestrial carbon in many regions. The main erosion processes affecting blanket peat can be broadly divided into sediment supply processes (e.g., freeze–thaw and desiccation), sediment transfer from hillslopes (e.g., interrill erosion, rill erosion and gully erosion), bank failures and mass movement (Bower, 1961; Evans and Warburton, 2007; Francis, 1990; Labadz et al., 1991; Li et al., 2018a; Warburton and Evans, 2011). Fig. 1 shows some typical peat erosion features and processes in the uplands of northern England.

Extensive erosion of many blanket peatlands potentially compromises their ability to maintain ecosystem functions (Evans and Lindsay, 2010) and has been found to have adverse impacts on landscapes (Holden et al., 2007c), reservoir sedimentation (Labadz et al., 1991), water quality (Crowe et al., 2008; Daniels et al., 2008; Rothwell et al., 2008a; Rothwell et al., 2008b; Rothwell et al., 2010; Shuttleworth et al., 2015), carbon dynamics (Holden, 2005b; Worrall et al., 2011) and other ecosystem services (Osaki and Tsuji, 2015).

As a proportion of dry mass, blanket peat is typically around 50% carbon (e.g. Dawson et al. (2004)). Thus sediment loss from peatlands also represents a significant removal of carbon. However, most research

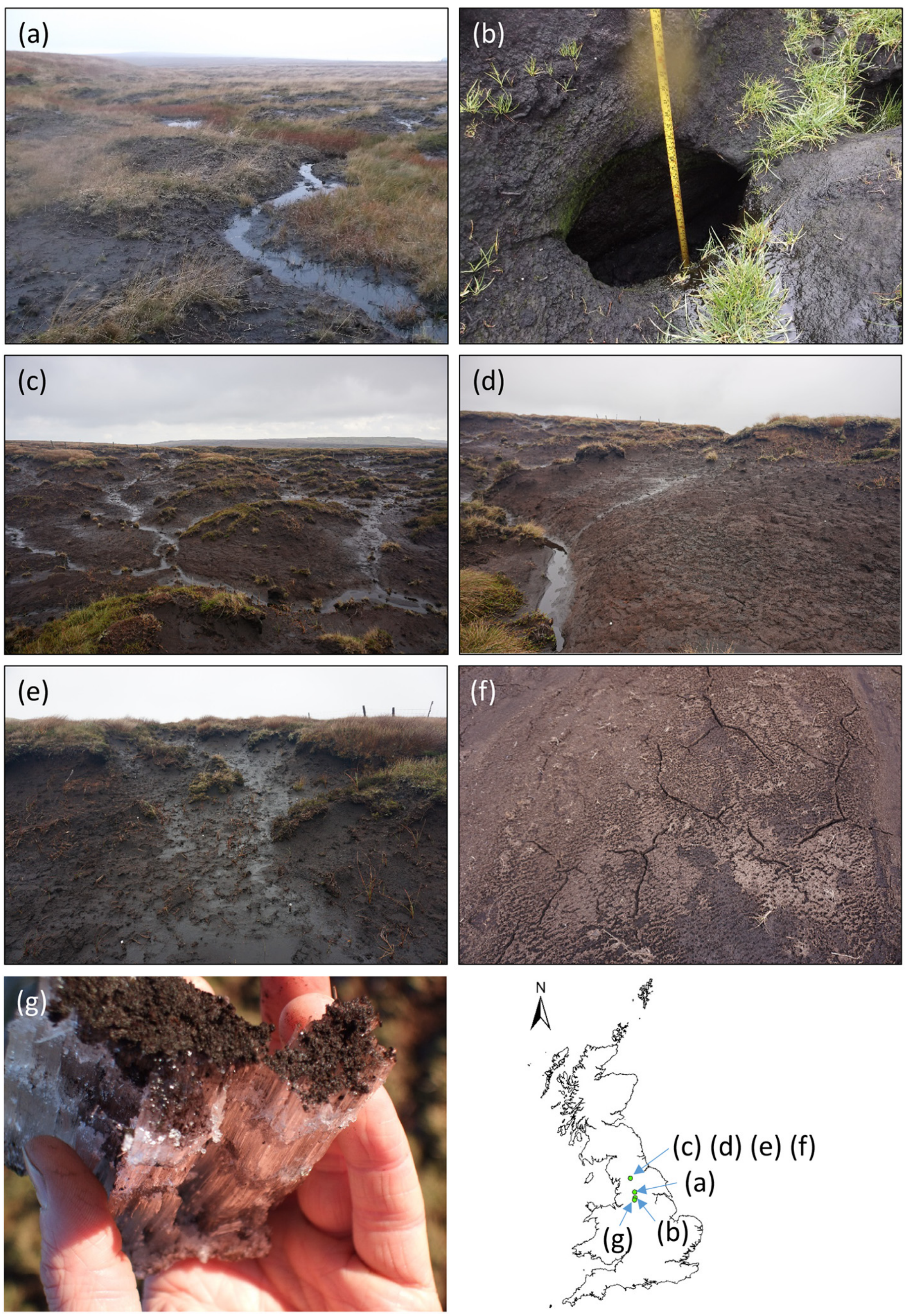

Fig. 1. Examples of erosion features and processes in blanket peatlands of northern England: (a) rill erosion; (b) pipe erosion; (c) eroded bare hillslopes; (d) gully wall; (e) gully head; (f) desiccation; (g) needle ice production.