Natural and anthropogenic causes of peat instability and landslides

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Summary

This paper provides results from a systematic programme of research into peatland instability that are intended to reinforce appropriate management of potential landslide risks from blanket bogs. It presents well-known and commonly cited contributory factors associated with peat failures but, for the first time, by reference to specific source information, i.e. as inferred by published accounts and interpreted from recent surveys of many of the known failure sites. Until research into peat geotechnics and failure mechanisms can provide a new basis for quantitative stability analyses, these factors should be regarded as 'primary risk factors' for natural hazard or environmental impact assessments relating to blanket bogs.

Key index words: blanket bog, landslides, peat slides, bogflows, environmental assessment

Introduction

Landslides involving peat have become prominent in the minds of engineers and local authorities in the British Isles since the events of late 2003 in western Ireland and northern Scotland. Not since the Knocknageeha bog burst in Co. Kerry, southwest Ireland, killed eight people in 1896 has so much public and scientific attention been paid to such events (Sollas *et al.*, 1897). Systematic research into peatland instability and failure began before the more recent events (Kirk, 2001; Mills, 2002). The storms of 19 September 2003 that caused severe localised landsliding of peat and soil at Dooncarton Mountain, Co. Mayo, Ireland and South Shetland, Scotland (Dykes and Warburton, 2007a, 2008) led to several reviews that established the state of knowledge of peat instability and identified key areas for future research (Warburton *et al.*, 2004; Dykes and Kirk, 2006; Dykes and Warburton, 2007b).

The current focus of this research on Ireland and northern Britain reflects the known distribution of peat failures. Around 60% of the recorded events are in Ireland (in this paper 'Ireland' refers to the geographical island that comprises the Republic of Ireland and Northern Ireland), and a further 20% occurred in England and Scotland (Dykes and Kirk, 2006). Although more widespread peatland instability elsewhere is a distinct possibility in the future in response to climate change and related effects, such as melting of permafrost in Siberia and Canada, recent work in Ireland has identified a number of factors that need further investigation if more potentially damaging peat landslides are to be avoided. The aim of this paper is to highlight these potentially critical factors and to outline the implications for the management or development of the remaining areas of Irish and British blanket bogs.

Materials and methods

The sites of known peat landslides in Ireland were visited during 2004–2006. Bog bursts involving raised bogs were not included in this programme of work as no examples of this type have occurred since the early 20th century. Where possible, the failures were surveyed and mapped using a hand-held GPS with an estimated relative horizontal accuracy of 1–2 m combined with field drawings of morphological details and measurements of source area gradients. Aerial photographs or other images (e.g. GoogleEarth™) have also been examined where available. Types of peat failures (i.e. 'bogflow', 'peat flow', etc.) are used in precise accordance with the definitions set out by Dykes and Warburton (2007b).

Results

Contributary causal factors have been identified for many of the blanket bog failures in Ireland. These are subdivided into 'natural' and 'anthropogenic' factors and shown with the type of landslide and season of occurrence in Table 1. These sites have all been visited for this research. Comparisons of new geomorphological maps with original published descriptions, and examinations of some recent peat landslides within a few days after they occurred, has allowed some older, previously undescribed failures to be mapped and interpreted for the first time. For example, the 1973 bog slide on Slieve Bloom, listed in Feehan and O'Donovan (1996), can now be interpreted as having failed from the head: an area of approximately 50 × 30 m on a 6° slope and crossed by three narrow drainage ditches initially slipped and developed into a 280 m long, 19,000 m^3 landslide. In other peat landslides such as the 1986 Conaghra bogflow and the 2003 peat flows at Slieve Bearnagh and Derrybrien in the Slieve Aughty range, the

Table 1. Selection of Irish blanket bog failures and inferred contributary factors (expanded from Dykes and Kirk, 2001). Parentheses indicate limited or uncertain influence. Notes: [1] BN, burnt or eroded peat; BD, boundary ditch; DD, (agricultural) drainage ditch; FD, forestry drainage ditch or plough furrow; PC, peat cutting (manual), including other peat banks resulting from excavation; PE, peat extraction (mechanical using Difco machines, leaving tines); PL, peat loading (by placement of fill or spoil). [2] CV, concave break of slope or shallow basin/depression/flush; CX, convex break of slope (*escarpment edge); HA, high antecedent rainfall; LA, very dry antecedent conditions; MS, mineral substrate characteristics; SP, soil (or peat) pipes; PB, peat 'bank', including e.g. river bank. [3] HR, high rainfall; UN, unknown trigger. [4] BF, bogflow; BS, bog slide; PS, peat slide; PDS, peaty-debris slide; PF, peat flow (Dykes and Warburton, 2007b). [5] No evidence remained when sites were visited.

Peat landslide	Type[4]	Season	Anthropogenic factors[1]							Natural factors[2]							Trigger[3]		References
			B/E	BD	DD	FD	PC	PE	PL	CV	CX	HA	LA	MS	SP	PB	HR	UN	
Lough Boleynagee, Co. Mayo	BF	Winter									Y	Y			(Y)	(Y)		Y	Delap *et al.* (1932)
Maghera (1934), Co. Clare	BF	Autumn									Y*						Y		Mitchell (1935)
Glendun, Co. Antrim	BF	Autumn								Y		Y					Y		Colhoun *et al.* (1965)
Barnesmore, Co. Donegal[5]	BF	Autumn			Y		Y			Y							Y		Colhoun *et al.* (1965)
Carrowmacculla, Co. Fermanagh	BF	Autumn	B	Y							Y	Y					Y		Tomlinson (1981)
Tullynascreen, Co. Sligo	BF	Spring						Y			Y	Y					Y		Alexander *et al.* (1985)
Straduff (1984), Co. Sligo	BF	Autumn	B								Y*		Y	Y			(Y)		Alexander *et al.* (1986)
Maghera (200?), Co. Clare	BF	?				Y					Y*							Y	
Slieve Bloom (1988), Co. Laois	BF	?			Y						Y							Y	
Conaghra, Co. Mayo	BF	Winter				Y					(Y)					(Y)		Y	
Meenacharvy, Co. Donegal	BS	Winter	E				Y				Y						Y		Bishopp and Mitchell (1946)
Slieve Rushen (1965), Co. Cavan[5]	BS	Winter					Y				Y	Y					Y		Colhoun (1966)
Bellacorrick Forest, Co. Mayo[5]	BS	Summer				Y				Y			Y						Hendrick (1990)
Skerry Hill (×2), Co. Antrim	BS	Autumn			Y					Y			(Y)				Y		Wilson and Hegarty (1993)
Carntogher, Co. Londonderry	BS	Autumn	E		Y					(Y)	Y	Y			(Y)		Y		Wilson *et al.* (1996)
East Cuilcagh (1986), Co. Cavan	BS	?								Y						Y		Y	Dykes *et al.* (in press)
East Cuilcagh (1992), Co. Cavan	BS	Summer								Y						Y	Y		Dykes *et al.* (in press)
East Cuilcagh (1998), Co. Cavan	BS	?								Y						Y		Y	Dykes *et al.* (in press)
Slieve Bloom ('73), Co. Offally	BS	?			Y													Y	
Cuilcagh (1986), Co. Fermanagh	PS	Summer										Y		(Y)			Y		Dykes *et al.* (in press)
Dooncarton Mtn. SE5, Co. Mayo	PS	Autumn						Y					Y	(Y)			Y		Dykes and Warburton (2007a)
Slieve-an-Orra (×7), Co. Antrim[5]	PDS	Summer			Y	Y				Y	Y	Y		Y			Y		Tomlinson and Gardiner (1982)
Slievenakilla (×2), Co. Leitrim	PDS	Summer					(Y)			Y	Y		Y	Y			Y		Coxon *et al.* (1989)
Cuilcagh (1998), Co. Fermanagh	PDS	Autumn			Y								(Y)	Y	Y		Y		Dykes and Kirk (2001)
Cuilcagh (2000), Co. Fermanagh	PDS	Spring			Y								Y	Y			Y		Dykes *et al.* (in press)
Dooncarton Mtn. S1 and SE8	PDS	Autumn		Y							Y		Y	Y	Y		Y		Dykes and Warburton (2007a)
Dooncarton Mtn. (×9), Co. Mayo	PDS	Autumn									Y		Y	Y	Y		Y		Dykes and Warburton (2007a)
Slieve Bearnach, Co. Clare	PF	Summer				Y			Y	Y									
Sonnagh Old, Co. Galway	PF	Autumn				(Y)			Y		Y*								
Derrybrien (×2), Co. Galway	PF	Autumn			Y	Y			Y	(Y)			Y						Bragg (2007)

influence of ploughing the peat for forestry is clearly revealed by smooth, straight sides to source area margins and displaced peat blocks.

Twenty-seven significant peat landslides in Ireland have been associated with human disturbance of the blanket bog since 1960, with one earlier example (1945) and one (partially) affected by burning but no 'structural' disturbance (Table 1). If the few natural peat landslides not included in Table 1 are also taken into account, this means that slightly more than 50% of the recorded blanket bog failures in Ireland may have occurred only because landowners or engineers (forestry or windfarm) had compromised the structural integrity of the respective bogs by cutting, ploughing, excavating or loading them.

Irrespective of any anthropogenic factors, Table 1 highlights some interesting patterns in the natural factors that may combine to give rise to failure of a blanket bog-covered hill slope. Whilst these factors are cited as relevant in most of the published accounts, they have not previously been correlated with the type of peat failure. Of particular note, therefore, are: (i) that bog slides tend to be associated with concave breaks of slope whereas bogflows are more common on convex slopes or escarpments; (ii) that bogflows seem to follow prolonged periods of much wetter weather than usual but peat slides and peaty-debris slides have often been linked to extremely dry periods; and (iii) that heavy rainfall is the most common trigger for all types of peat landslides – although there are various mechanisms by which failure can result from such rainfall (Warburton *et al.*, 2004).

Discussion

This paper has presented the most commonly identified factors that contribute to failures in upland blanket peat, but does not attempt to deterministically quantify any of these. This is because the most appropriate techniques for determining and mathematically representing the geotechnical behaviour of peat have yet to be reliably established (Long, 2005). However, the respective roles of the contributory factors are reasonably well understood in theory (Warburton *et al.*, 2004; Dykes and Kirk, 2006) and the nature and potential scale of direct damage and indirect impacts from peat failures are well known.

There is an increasing threat of future peat landslides from several influences. Firstly, climate change scenarios for western Britain and Ireland are consistently predicting warmer, drier summers and wetter winters. More frequent storms bringing high intensity rainfall can be expected to result in continuing occurrences of blanket bog failures of various types and sizes. More frequent and intense summer desiccation with associated cracking of the surface peat (Holden and Burt, 2002, 2003) will make the peatlands more susceptible to failure due to to the adverse hydrological effects of subsequent heavy rainfall (Warburton *et al.*, 2004; Dykes and Warburton, 2007a, 2008). Secondly, the many old and degraded land drains and boundary ditches can either act to focus runoff water onto a particular part of a slope (e.g. Wilson *et al.*, 1996) or to reduce lateral support for the peat layer upslope of the ditch, as demonstrated quantitatively by Dykes and Kirk (2001). Thirdly, forestry operations necessarily disrupt the natural mechanical and hydrological continuity of the peat deposits through the pre-plantation ploughing and, in one known case so far, the loading of sloping blanket peat from a forestry road. New windfarms are also increasing the risk of future peat failures (i) from excavations and associated drainage works for the turbines and (ii) from loading of the peat by 'floating' gravel access roads and placement of excavated peat spoil.

Conclusion

The factors identified in this paper as contributing to peat landslides should be regarded as 'primary risk factors' for any natural hazard or environmental impact assessments relating to largely intact blanket bogs, or indeed for any planned activities by landowners that might compromise the integrity of a peat bog such as excavating ditches or extracting peat for fuel. Research is continuing with the aim of developing reliable approaches to quantitative modelling and assessment of peat stability in order to improve the basis of such assessments.

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