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Prediction of blanket peat erosion across Great Britain under environmental change

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Abstract

A recently developed fluvial erosion model for blanket peatlands, PESERA-PEAT, was applied at ten sites across Great Britain to predict the response of blanket peat erosion to environmental change. Climate change to 2099 was derived from seven UKCP09 future projections and the UK Met Office's historical dataset. Land management scenarios were established based on outputs from earlier published investigations. Modelling results suggested that as climate changes, the response of blanket peat erosion will be spatially very variable across Great Britain. Both relative changes and absolute values of sediment yield were predicted to be higher in southern and eastern areas than in western and northern parts of Great Britain, peaking in the North York Moors of eastern England. Areas with high precipitation and low temperature were predicted to have low relative erosion changes and absolute sediment yield. The model suggested that summer desiccation may become more important for blanket peat erosion under future climate change, and that temperature was more dominant than precipitation in controlling long-term blanket peat erosion change. However, in the North York Moors, precipitation appeared to be more dominant in driving long-term erosion change. Land management measures were shown to provide a means to mitigate against the impacts of climate change on blanket peat erosion.

1. Introduction

Peatlands are globally important, storing one third to half of the world's soil carbon (Yu 2012). Blanket peatlands, an important subset of peatlands, mainly occur in temperate, hyperoceanic, coastal regions, where there is high precipitation in comparison to evapotranspiration (Lindsay et al., 1988; Gallego-Sala and Prentice 2012). Blanket peatlands often occur on sloping terrain which makes them highly susceptible to erosion if surface vegetation becomes damaged (Evans and Warburton, 2007). In some regions, blanket peatlands have become degraded and eroded due to human influences on the water balance (e.g. artificial drainage) and surface vegetation composition (e.g. overgrazing, pollution and fire).

The British Isles hosts around 10% of global blanket peatlands. These peatlands range from good, actively forming *Sphagnum*-rich peatlands (e.g. Flow Country, northern Scotland) to those which have undergone significant erosion with plentiful bare peat and incisions (e.g. Peak District, northern England) (Evans and Warburton, 2007). There are around 3500 km^2 of eroded blanket peat in the British Isles (Tallis, 1998). Peat erosion impacts water quality leading to high turbidity and heavy metal pollution (Pattinson et al., 1994; Rothwell et al., 2007; Rothwell et al., 2005), disturbed river ecology (Ramchunder et al., 2009), sedimentation of reservoirs (Labadz et al., 1991), and loss of carbon (Grayson et al., 2012; Pawson et al., 2012). There is therefore a large amount of investment aimed at reducing erosion losses from blanket peatlands (Parry et al., 2014).

Blanket peat erosion is often viewed as an artificial product of human action via disturbance. However, climate affects the stability of the peat and associated erosion. The water balance and temperature regime drives the balance between peatland growth and decay, mediated by the nature of the surface vegetation cover. Climate shifts impact blanket peat weathering, which appears to be dominated by freeze-thaw and desiccation, and transport of peat, contributing to peat erosion (Francis, 1990; Labadz et al., 1991; Holden and Burt, 2002). Bioclimatic modelling results have suggested that the areas suitable for British blanket peatlands may retreat towards the north and west with climate change to the end of the 21st Century (Clark et al., 2010; Gallego-Sala et al., 2010). The degradation of peatlands is therefore much more likely in these marginal areas. However, there has been no modelling to examine peat erosion processes and how both their functioning and rates of operation might be affected by climate change.

The first fluvial erosion model for blanket peatlands (PESERA-PEAT) has recently been developed (Li, 2014; Li et al., in review), offering an opportunity to undertake investigations of how climate change might drive changes in fluvial blanket peat erosion. PESERA-PEAT was modified from the original PESERA-GRID model established by Kirkby et al. (2008). PESERA-GRID is a physically-based, spatially distributed, long-term soil erosion model. The hydrological part of the model centres on a water balance, with precipitation divided into runoff, evapotranspiration and soil water storage. Blanket peatlands are dominated by saturation-excess overland flow (Holden and Burt, 2003) and PESERA-GRID is theoretically capable of modelling runoff production in blanket peatlands, since the core of the hydrological part is TOPMODEL, which is well suited to saturation-excess overland flow dominated environments (Beven et al., 1984). The emphasis of PESERA-GRID is prediction of hillslope erosion, and delivery of erosion products to the base of each hillslope. Channel delivery processes and channel routing are not involved. Total sediment yield is estimated as the sum of transporting capacity of overland flow, which is driven by erodibility, overland flow and local relief, weighted for fractional vegetation cover, assuming erodible materials are always ample for runoff wash. Vegetation growth in the model involves a biomass carbon balance for both living vegetation and soil organic matter.

This paper aims to use a time-series version of PESERA-PEAT to investigate how fluvial blanket peat erosion may react to different possibilities of future climate change, land management shifts and their interactions, taking Great Britain as a case study. We adopt a multi-site study to establish whether there are spatial differences in predicted fluvial erosion responses to climate change in blanket peatlands.

2. Study sites

The spatial distribution of blanket peatlands over Great Britain was compiled from results of blanket peat maps from Natural England and the No. 8 (bog (deep peat)) land-use type of the UK Land Cover Map 2000 (1-km map). The areas, which were covered by either Natural England-defined blanket bog or No. 8 from the LCM2000, were classified as blanket peatlands (Fig. 1). Ten blanket peat-covered sites were selected to represent major regions with blanket peatlands in Great Britain. The characteristics of selected sites are given within Fig. 1. Each study site was located at a UK Met Office Integrated Data Archive System (MIDAS) weather station, where climate data were available between 1961 and 1990 (baseline period) ensuring baseline climate for the study was determined by field measurements.

3. Methods

3.1 The PESERA-PEAT model

In PESERA-PEAT (Li, 2014; Li et al., in review) the hydrology and vegetation growth modules are directly inherited from PESERA-GRID. However, significant modifications to PESERA-GRID, developed in our paper, focused on erosion calculations and on land management representations suitable for blanket peatlands.

Sediment yield in PESERA-PEAT is dependent upon both sediment production and runoff transporting capacity. A sediment supply index was defined as the sediment concentration per unit discharge and employed to parameterize the sediment supply capacity from blanket peatlands. The sediment supply index was then negatively related to temperature and water table, based on long-term empirical data from field studies. These were used to drive sediment production via freeze-thaw and desiccation. Transporting capacity was estimated in the same way as in PESERA-GRID (Kirkby et al., 2008). Both sediment supply and transport were considered to be impacted by surface vegetation coverage. A storage component was defined to indicate a surplus when erodible materials exceeded transporting capacity. The stored, weathered peat was added to the erodible materials produced by freeze-thaw and desiccation in subsequent time steps.

Land management practices (i.e. artificial drainage, managed burning and grazing) were incorporated into PESERA-PEAT for their influences on surface vegetation and soil moisture condition. A drainage model was employed to parameterize artificial drainage. The model adopted a 'ditch level' value, which increased with drainage depth and decreased with drain spacing negatively related to drainage density, to account for the impacts of drainage on the soil water dynamics. Vegetation removal was estimated as a function of drainage density. Both prescribed burning and grazing were represented as vegetation removal. Vegetation removed by prescribed burning was a function of the reciprocal of burning interval. Grazing was classified at two levels: light grazing and overgrazing, which were parameterized as a reduction of vegetation by 15% and 30% according to Chapman et al. (2009) on the response of blanket peatland vegetation to low and high stocking densities (i.e. 0.5 and 3 ha^{-1}).

The model has previously been tested with long-term field data from different blanket peat-covered catchments sitting within regions 7 and 9 shown in Fig. 1, which are under different eroding status and management intensity (Li, 2014). Modelling results have demonstrated that the model is capable of reproducing blanket peat erosion well, and methods employed for parameterization of sediment supply and management options are reasonable. In this study we applied the time-series version of the model which considers climate data and erosion for every single month over time at individual sites, and can therefore capture extreme conditions.

3.2 Climate data

The climate variables input into the time-series version of PESERA-PEAT are monthly total precipitation, mean precipitation per precipitation day, coefficient of variation of precipitation per precipitation day, monthly temperature range, monthly temperature, and monthly potential evapotranspiration. They were based on monthly statistics for every single month through time derived from daily values except for potential evapotranspiration (PET). PET was calculated with a temperature-based model originally proposed by Oudin et al. (2005). The model was modified to include wind speed and vegetation height, as used in the blanket peatland PET estimation by Clark (2005) for our study site 7 (see Fig. 1).

Four periods of climate were utilized to forecast the future climate change for the selected blanket peatlands. They are "Baseline", "2020s", "2050s" and "2080s", covering 30-year periods of 1961-1990, 2010-2039, 2040-2069 and 2070-2099 respectively. Since MIDAS records between 1961 and 1990 sometimes have missing values, baseline climate was established using baseline predictions of UKCP09, which was then adjusted using the monthly average of the MIDAS data. The climate scenarios for each future time period were established using UKCP09 projections which developed probabilistic climate change projections resulting from an ensemble of global climate models (UKCP09 2009). UKCP09 projections are based on Met Office meteorological data between 1961 and 1990, and future projections consider different probabilities to account for uncertainties in climate change. They estimate future UK climate based on different carbon-emission scenarios from the IPCC Special Report of Emission Scenarios (SRES, AR4). Three of the SRES scenarios are involved, which are high emission (A1F1), medium emission (A1B) and low emission (B1). The medium-emission scenario was selected as the context of climate change in this study. One hundred model realizations of the UKCP09 weather generator under the medium-emission condition were employed. Seven climate scenarios at different probability levels were established based on these projections. They are median climate scenarios and the 10th, 50th and 90th percentile precipitation and temperature scenarios. Median climate scenarios were established by determining median values of each climate input variable from the 100 UKCP09 outputs for every single month over the corresponding 30-year period. The precipitation / temperature scenarios were composed of climate variables corresponding to a UKCP09 model realization, of which the average precipitation / temperature was at the 10th, 50th, and 90th position for the 100 model realizations for each time period.

The seven future climate scenarios consist of a climate envelope, which covers both median and extreme climate conditions, and accounts for the uncertainties in future climate change at the selected sites.

The time-series of UKCP09-estimated climate variables were transferred to relate to the baseline measurements by:

$$\mathrm{UKCP}_m = \mathrm{BASE}_m + (\mathrm{UKCP} - \mathrm{BASE}_u)$$

where, UKCP_m is the future climatic variables based on MIDAS baseline climate; BASE_m is the MIDAS baseline climatic variables; UKCP is the future climatic variables derived from UKCP09 projections; BASE_u is the baseline climate calculated from UKCP09 projections. The resulting "UKCP_m " data were directly assigned to 100-m grid cells, without considering the scaling difference between different data sources.

Climate for the chosen sites falls into three groups (Fig. 2). Site 8 is much drier than other sites. Sites 1, 4, 5 and 9 have similar precipitation and fall into a second category, while sites 2, 3, 6, 7 and 10 are categorized into a third group with high precipitation. The range of mean annual temperature for sites within each group during the chosen periods becomes wider from dry to wet groups. In most cases, mean annual precipitation is increased between baseline and future periods (2020s, 2050s and 2080s) by 0.1 to 28.1 %. However, a 0.1 to 6.0 % decrease of mean annual precipitation sometimes happens between baseline and future time periods such as at sites 2 (Sutherland, N Scotland), 7 and 9 (North and South Pennines). Changes in mean annual temperature show a simpler pattern than that in mean annual precipitation as temperature always increases from baseline to future periods, although the magnitude of the increase varies among sites between 0.6 and 5.8 °C.

3.3 Land use, management, local relief and soil

Land use, management, topography and soil properties are required by PESERA-PEAT. Local relief was calculated based on a 100-m DEM. As each site represents a blanket peat-covered region, the relief for a site was the average value for the blanket peatlands within the corresponding region rather than for the sampling point itself (Fig. 1). Soil parameters were set according to Kirkby et al. (2008) and the PESERA manual (Irvine and Kosmas, 2003). The erodibility in PESERA-PEAT refers to the sensitivity of soil to erosive agents after weathering processes, and it was set to 2.5 mm, being 2-3 times greater than for intact peat (Mulqueen et al., 2006).

The vegetation growth model, under climate scenarios and land management options, impacted vegetation cover and biomass. The related parameters were set in terms of the PESERA manual (Irvine and Kosmas, 2003). Specific values of land management parameters are shown in Table 1. For each site, eight environmental scenarios were established for each climate scenario (Table 1). Two land management scenarios were adopted: carbon storage and food security (Reed et al., 2013). The carbon storage scenario assumes no pro-active land management practices. In the food security scenario overgrazing is represented by 30% vegetation cover and biomass removal per month. Vegetation burning in patches across the landscape is undertaken on upland catchments in Great Britain to increase grouse populations for gun sports and to support grazing conditions (Holden et al. 2012). Typical prescribed burning frequencies for upland environments in Great Britain are between once every 7 and 25 years (Holden et al., 2007). In the food security scenario we increased the frequency to once every 5 years. Drainage ditches have been dug in many upland peat catchments in the UK (Holden et al., 2004). The food security scenario also involves intensified upland drainage, using a drainage density of 16 km km^{-2}, which is double the current average drainage density of the blanket peatlands in the North Pennines of northern England.

The “Base Condition” scenario was built using baseline climate and carbon storage management conditions. Modelling results from all other scenarios were compared with outputs based on the “Base Condition” scenario. Climate impact was investigated with the carbon storage scenario and climate conditions at baseline, 2020s, 2050s and 2080s. Then food security scenarios were applied with climate conditions in baseline and future time periods to examine the impact of land management shifts and interactions between climate and management change.

4. Results

The difference of cumulative sediment yield with land management intensity was found to be higher than that with climate change alone, demonstrating that land management shifts between carbon storage and food security have more impacts on the total sediment yield between 2010 and 2099 than climate change (Fig. 3). However, at site 8 (North York Moors, NE England) the variation of cumulative sediment yield under different climate scenarios is closer to that caused by land management change than at other sites. The highest predicted annual sediment yield for site 8 was found to be 1.6 to 11.2 times that for other sites suggesting enhanced vulnerability to climate change than at other sites.

Under climate change alone, the predicted relative erosion change, mean annual sediment yield and total cumulative sediment yield were all greatest at site 8. For sites in northern Scotland (i.e. sites 1-3) the relative erosion change at site 1 (most eastern site) was predicted to be higher than that at sites 2 and 3 (western sites) (Fig. 4a). Sites 6, 8, 9 and 10 had predicted relative erosion increases that were usually higher than sites at more northerly locations (i.e. sites 1, 2, 3, 4 and 5). However, at site 7 the mean value of relative erosion change was 3.6% (with negative changes sometimes predicted, up to -9.3%). These predicted changes are smaller than that at the two other sites of a similar latitude (sites 6 and 8), where all relative erosion changes were positive. Mean annual sediment yield and cumulative sediment yield at the study sites for future periods followed a similar spatial pattern as that for relative erosion change (Fig. 4b and c). However, the relative erosion change for site 5 was lower than that of sites further south (i.e. sites 6, 8, 9 and 10), while mean annual sediment yield and cumulative sediment yield at site 5 were about the same as that of the southern sites. Overall, with the exception of the response shown by site 7, the relative changes and absolute values of sediment yield, under response to climate change, tended to be greater in the southern and eastern parts of Great Britain rather than in the north and west.

The mean annual sediment yield was determined for each of the seven precipitation and temperature scenarios for each 30-year period at each site (Fig. 5). The predicted mean annual sediment yield for sites 1 and 8 (the two most eastern sites) was found to be increase under wetter conditions (Fig. 5). At sites 2, 3, 4 and 6 (Scottish mainland and northwest England) the predicted mean annual sediment yield was generally larger under the warmest conditions, while sites 9 and 10 (the two most southern sites) had mean annual sediment yield that was greatest under the warmest and wettest conditions. Mean annual sediment yield tended to increase under warmer and drier conditions at site 7. Sediment yield for Site 5 appeared to increase under medium warm, dry conditions and under medium wet, warm conditions. Overall, for the study sites (except site 8) a warmer temperature was coincident with increased sediment yield but this was not always the case for increased precipitation. For example, at sites 2, 3, 5 and 7, higher precipitation often resulted in less sediment yield. It is therefore inferred that temperature is more important than precipitation in shaping the long-term change of blanket peat erosion across Great Britain.

We examined the climate conditions for particular years when each site produced its peak sediment yield (Fig. 5). The highest predicted annual sediment yield at sites 1 and 2, being 1.8 and 1.2 t ha^{-1} respectively, occurred in a year with medium precipitation and temperature. Sites 3, 6 and 7 were found to have highest predicted annual sediment yield in a dry and warm year, with the highest yield being 1.2, 8.5 and 3.0 t ha^{-1} respectively. The predicted annual sediment yield from sites 4, 5, 9 and 10 peaked at 3.3, 2.9, 4.2 and 4.4 t ha^{-1} respectively, in a warm and wet year. Site 8 had its highest predicted annual sediment yield of 13.4 t ha^{-1} during a moderately wet year with a medium temperature.

Sediment storage at all sites peaked during summer and then decreased in autumn and winter in years with the highest predicted annual sediment yield (Fig. 6). Thus sediment yield was found to be “big event dominated” and usually peaked in autumn or winter. Transport-limited processes were found to be dominant in summer erosion, while stored erodible material is washed out in autumn and winter. Hence, summer desiccation could be a major source of erodible material for future blanket peat erosion, even though most sediment is likely to be delivered out of the catchment during autumn and winter.

5. Discussion

5.1 The future of blanket peat erosion in Great Britain under climate change

The general spatial patterns of the relative change and absolute values of peat erosion under future climate variations (Fig. 4) are consistent with results from previous bioclimatic envelope modelling for blanket peatlands. Both Gallego-Sala et al. (2010) and Clark et al. (2010) demonstrated that the geographical distribution of bioclimatic space suitable for blanket peatlands may gradually retreat towards the north and west of Great Britain. The low rate of the relative change and the absolute value of mean annual erosion at site 7 do not follow the general spatial pattern across Great Britain. This may be because site 7 (North Pennines) is located at a higher altitude than all other sites, and it is subject to higher precipitation and low temperature, which are conducive to active peat growth (Chaman, 2002). Model-based studies in Canada have suggested that peatlands in Canada may “migrate” northwards as a result of elevated temperatures and drought (Gignac et al., 1998). Previous studies suggested that peatland ecosystems at higher latitudes may be less sensitive to a warmer climate in Europe and North America in the future (Bragazza, 2008; Meehl and Tebaldi, 2004). These bioclimatic modelling results do not determine the eventual fate of existing blanket peatlands left outside of their bioclimatic space since the resilience of blanket peatlands to such climate change needs to be accounted for. Modelling results from our study confirm that with future climate change, blanket peatlands outside the suitable bioclimatic space will probably be subject to more erosion and degradation.

5.2 Climatic drivers of changes in blanket peat erosion

Temperature was found to be more dominant than precipitation in driving changes in fluvial blanket peat erosion for the chosen sites (except site 8). Interestingly, Gallego-Sala et al. (2010) found that temperature tended to be more important than precipitation and moisture index in the variation of the areal extent of the peat bioclimatic envelope through a sensitivity analysis of their PeatStash model.

At site 8 (the driest site, NE England), blanket peat erosion was found to be dominated by increased precipitation. The highest predicted annual sediment yield was also coincident with relatively high precipitation. This is unusual in the context of the findings from other sites, and is possibly because the relatively dry and warm site conditions ensured sediment yield was transport limited (Fig. 6). Francis (1990) investigated blanket peat erosion in the Upper Severn catchment, mid Wales during two drought years in the 1980s. The eroding peat surfaces exhibited maximum recession during the summer, but the peat surface sediment trap indicated that highest rates of sediment loss from peat faces were coincident with high precipitation which occurred during autumn and early winter. The Francis (1990) results also imply that summer desiccation could be a major source of sediment erosion. This indirectly confirms the modelling results shown in Fig. 6, where summer desiccation is closely related to the highest predicted annual sediment yield for the selected sites.

5.3 Interactions between climate change and land management shifts

Management shifts were more influential than climate change in altering rates of blanket peat erosion across Great Britain. Management options usually impact vegetation cover and the connectivity of sediment source areas to stream channels (Evans et al. 2006) (e.g. drainage channels or burning the vegetation up to watercourses). Our study examined only two extreme land management scenarios, and not the many other future possibilities. Nevertheless, modelling results confirm that careful land management could be used to help partly mitigate the future impact of climate change on blanket peat erosion, enhancing the resilience of these systems.

5.4 Implications for inference from single-site studies

The impact of climate change on blanket peat erosion varies between different sites over Great Britain. For example, erosion change in the North Pennines (site 7) was negative (less erosion) under some climate change scenarios, while greater than 140 % increase of sediment yield was predicted for the North York Moors (site 8) under climate change scenarios. Such results clearly indicate that examining environmental change modelling results from one site or catchment area and assuming these findings may apply elsewhere would be a mistake. Climate conditions such as temperature and precipitation have high local variability, and spatially distributed climate variables need to be employed for future blanket peat erosion predictions. It is thus suggested that modelling such as the type we have undertaken needs to be conducted across different spatial regions nationally and internationally.

5.5 Limitations of climate projections and modelling approach

UKCP09 climate projections are subject to uncertainties caused by the limits of the current ability to understand and model the climate system (UKCP09, 2009). In order to partly overcome the uncertainties, UKCP09 estimates future climate change as probabilistic projections based on three possible carbon emissions (low, medium and high) introduced from IPCC SRES (AR 4). In this study, seven climate scenarios covering both median and extreme conditions were established based upon the medium-emission condition to account for the uncertainties in future climate projections, without considering the climate change under low and high emission scenarios. Additionally, in UKCP09 some climate variables are predicted with greater confidence than others (UKCP09, 2009). For example, there is relatively higher confidence in temperature projections than precipitation projections. Less confidence in precipitation projections, especially summer precipitation, suggests that there could be a reduced confidence, for example, in peak erosion predictions for the peatland sites studied. Hence, the accuracy of the modelling results in this paper is limited by the inherent uncertainties of UKCP09 projections.

Although UKCP09 projections are generated based on the IPCC AR4 emission scenarios, they are not simply the downscaling of AR4 results since the modelling approaches employed in UKCP09 and AR4 are not the same. Therefore, although the IPCC AR5 has now been released, adopting new scenario frameworks and updated modelling approaches, this does not invalidate our results. In fact, AR5 climate projections appear to further confirm the UKCP09 results with similar warming predictions (for all seasons) for the parts of northern Europe in which Great Britain sits (Christensen et al., 2013). Precipitation is projected to increase in the winter half year (Oct-Mar) while decreasing in the summer half year (Apr to Sep) during the 21st century which broadly conforms to UKCP09. Hence, our PESERA-PEAT erosion modelling results are unlikely to change significantly if the more recent climate projections of IPCC AR5 were adopted. Noteably, PESERA-PEAT is capable of adopting most types of climate projections and so future erosion modeling can be conducted as new climate projections become available.

Unlike PESERA-GRID which focuses on hillsope erosion estimation, PESERA-PEAT was established and evaluated with data originally collected at catchment outlets. This means that the sediment yield predicted by PESERA-PEAT is a lumped version of erosion caused by both hillslope and channel processes such as rill, interill and stream bank erosion. This was a compromise due to the lack of long-term peatland hillslope erosion measurements, although the suitability of such a simplification is supported by previous erosion studies on blanket peatlands and other soil systems (Evans and Warburton, 2007; Wynn et al., 2008). Further work is also required to include wind erosion processes within PESERA-PEAT in the future so that both fluvial and wind erosion driven changes can be evaluated together.

6. Conclusions

The PESERA-PEAT model was run for a series of climate and interacting climate and land management scenarios for ten blanket peat sites across Great Britain. The modelling suggested that as climate changes in the future, the response of blanket peat erosion will be highly variable in space. Both the relative peat erosion change and absolute erosion risk were predicted to be generally greater in southern and eastern areas than in western and northern parts of Great Britain, with the largest erosion increase and sediment yield occurring in the North York Moors. Summer desiccation may become more important in blanket peat erosion as climate changes in the future. The magnitude of the relative erosion change and absolute erosion risk with climate change to 2099 were predicted to be smaller in wetter and colder locations, and temperature was generally more dominant than precipitation in controlling long-term erosion change. However, in the North York Moors precipitation appeared to be more dominant in driving long-term erosion change. A shift in land management practices that reduce drainage density, grazing and vegetation burning intensity may help buffer the impacts of future climate change on blanket peat erosion. Further work is required to examine the impacts of climate change upon blanket peat erosion in other regions of the world to support regional planners and ecosystem service change assessments. The model could also be used for other types of peatlands, but would require modification to cope with peatlands where the water source was not predominantly precipitation (e.g. fen peatlands). The model would, however, potentially be very suitable for a range of organo-mineral soils that are located in regions where freeze-thaw or desiccation commonly drives surface sediment production.

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Table 1 Environmental scenarios employed to operate PESERA-PEAT.

Name	**Climate**	**Land Management**		
		Drainage ($km\ km^{-2}$)	**Grazing (%)**	**Burning (year)**
Base Condition	Baseline	0[a]	0	0
2020s_Carbon	2020s	0	0	0
2050s_Carbon	2050s	0	0	0
2080s_Carbon	2080s	0	0	0
Baseline_Food	Baseline	16	30	5
2020s_Food	2020s	16	30	5
2050s_Food	2050s	16	30	5
2080s_Food	2080s	16	30	5

[a] "0" indicates no pro-active land management practices exist.

Figure captions

Fig. 1 The distribution of blanket peatlands, selected sites with summary information and their corresponding regions across Great Britain.

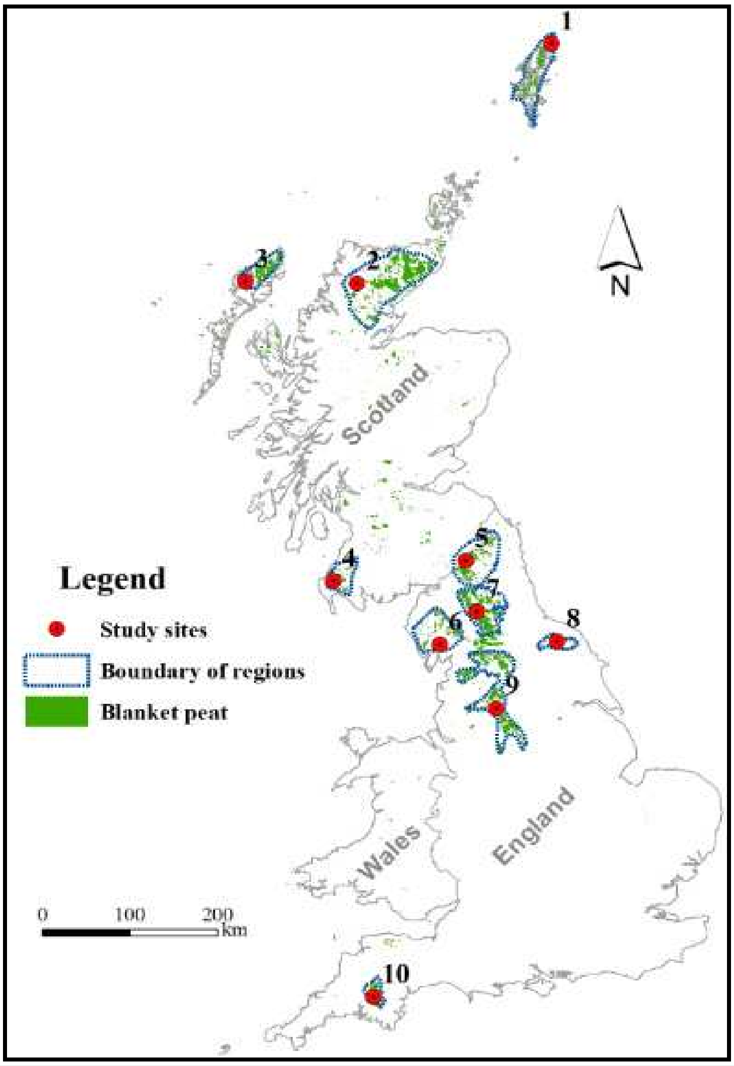
Fig. 2 Clustering of climate for the selected sites based on average annual precipitation and temperature over the baseline and future periods. For each site, an open symbol represents the baseline climate while a solid symbol stands for the future climate, which is derived from the seven future climatic scenarios.

Fig. 3 Cumulative sediment yield between 2010 and 2099 for each site under established environmental scenarios, and time series of annual sediment yield for the scenarios with the highest predicted annual sediment yield. 50% represents the median climatic scenarios, while the 10%, 50% and 90% rf / tm stand for the 10th, 50th, and 90th percentile precipitation / temperature scenarios. Such abbreviation is also used in Fig. 6.

Fig. 4 The impact of climatic change on fluvial blanket peat erosion for the ten selected sites under the carbon storage condition. a) relative changes in mean annual erosion from baseline to future time periods; b) mean annual erosion for future time periods; c) cumulative sediment yield between 2010 and 2099.

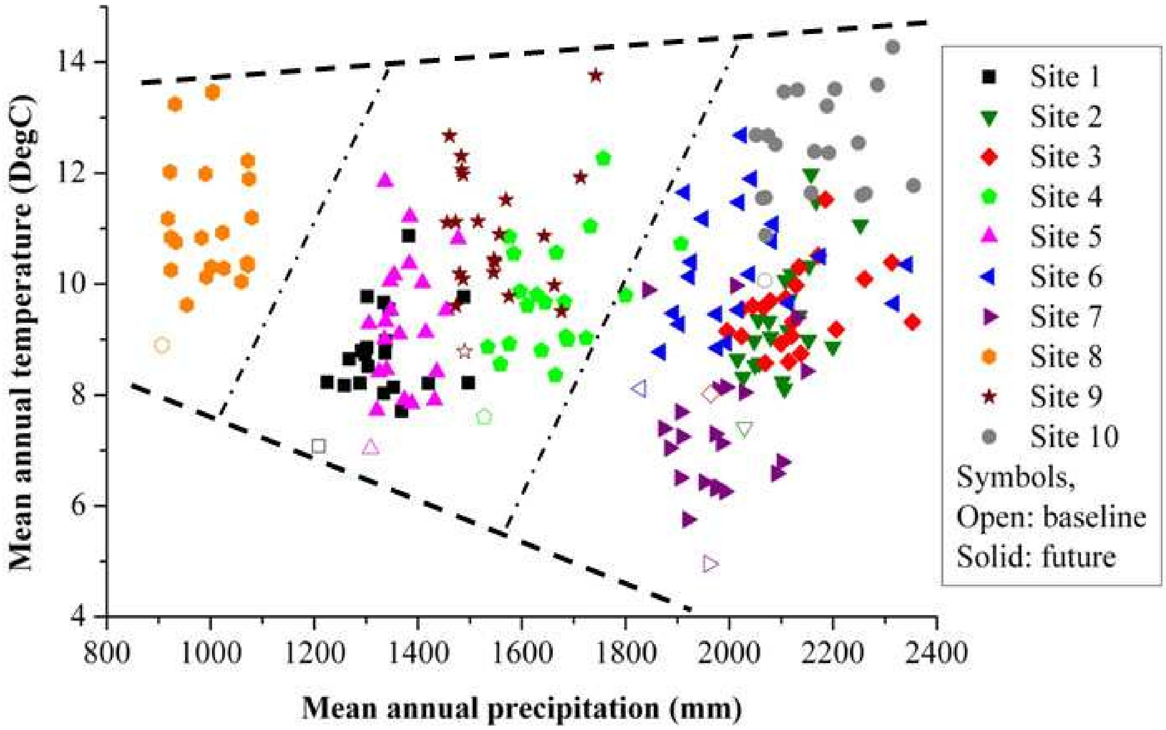
Fig. 5 Mean annual sediment yield for each site under the carbon storage condition against average annual temperature and precipitation. The precipitation / temperature scenarios used average precipitation or temperature at the 10th, 50th, and 90th ranked position for the 100 model realizations, plus the combined median rainfall and temperature condition. Each of these seven climate scenarios was assessed for each 30 year time period of 2020s, 2050s and 2080, plus a baseline climate condition, yielding 22 datasets of mean annual erosion for each site (colour-scale legend). The highest predicted sediment yield for each site for any single year (i.e. not averaged over 30 years) under the carbon storage condition between 2010 and 2099 is also plotted against annual precipitation and temperature associated with that year (pink triangle).

Fig. 6 Monthly sediment yield and storage for each site in the years with the highest predicted annual sediment yield.



Site	Region	Coordinates (Decimal degree)		Precipitation (mm)	Temperature (°C)	Altitude (m)	Relief (m)
		Latitude	Longitude				
1	Shetland	60.76	-0.89	1209	7.1	24	18.7
2	Sutherland	58.17	-4.73	2029	7.4	99	16.32
3	Ross-shire	58.13	-6.88	1964	8	7	7.22
4	Wigtown-shire	54.98	-4.93	1527	7.6	166	11.96
5	Northumberland	55.23	-2.58	1309	7	201	19.87
6	Westmorland	54.34	-3.02	1829	8.1	91	44.85
7	North Pennines	54.69	-2.38	1961	5	556	22.01
8	North York Moors	54.37	-0.96	907	8.9	151	19.07
9	South Pennines	53.66	-2.03	1490	8.8	387	23.97
10	Dartmoor	50.55	-4	2069	10.1	453	18.59

Fig. 1 The distribution of blanket peatlands, selected sites with summary information and their corresponding regions across Great Britain.



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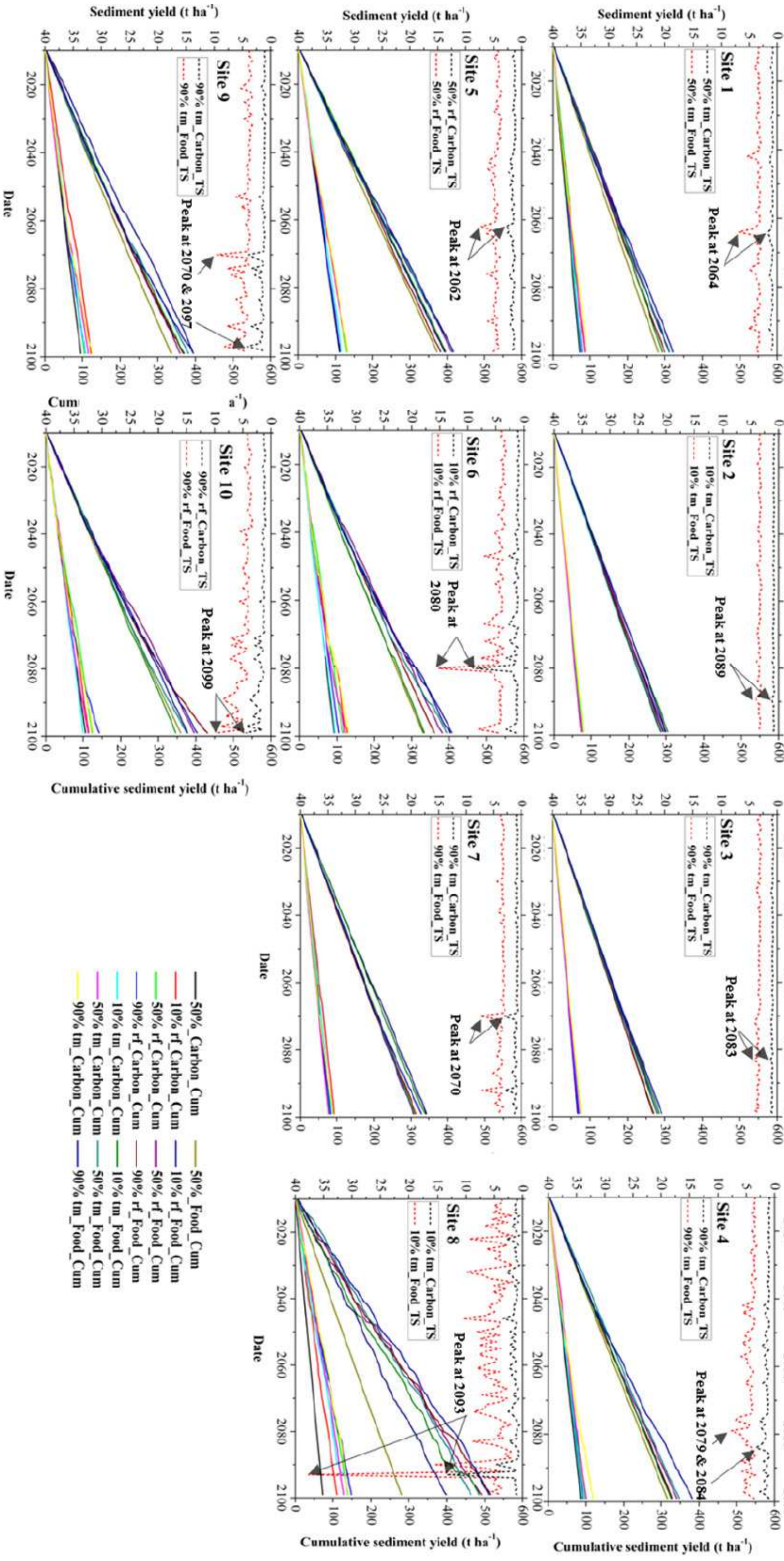

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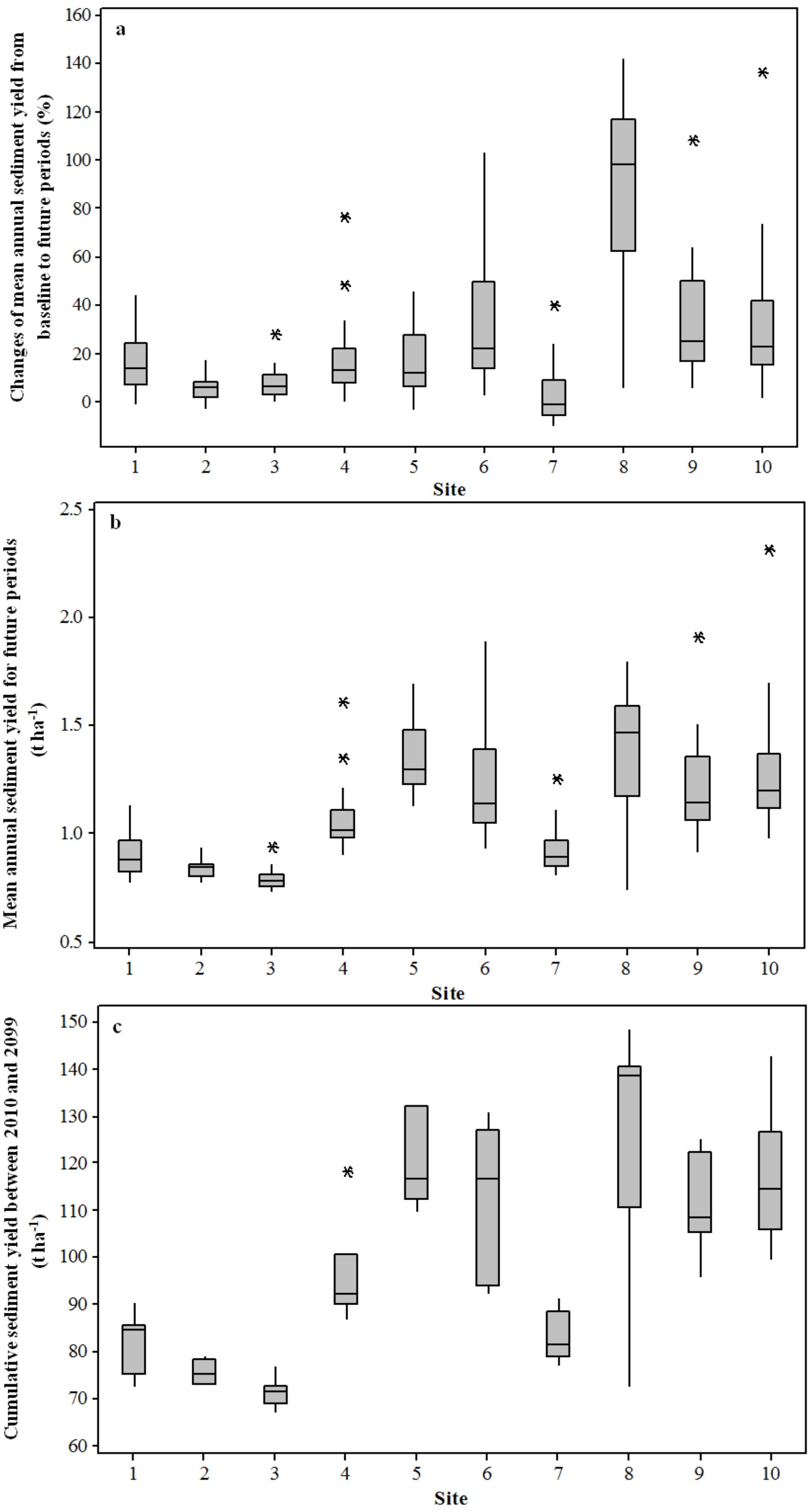

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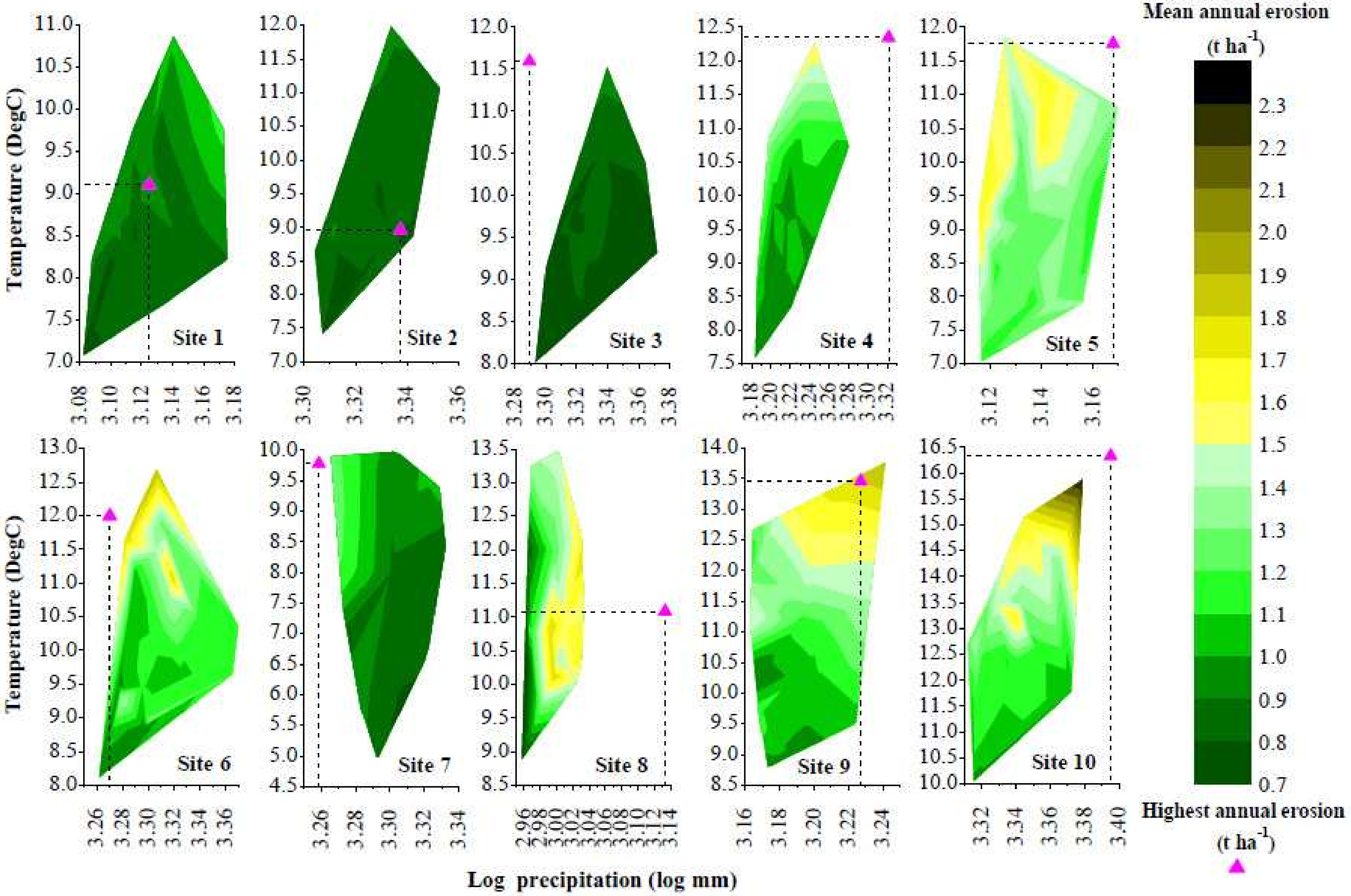

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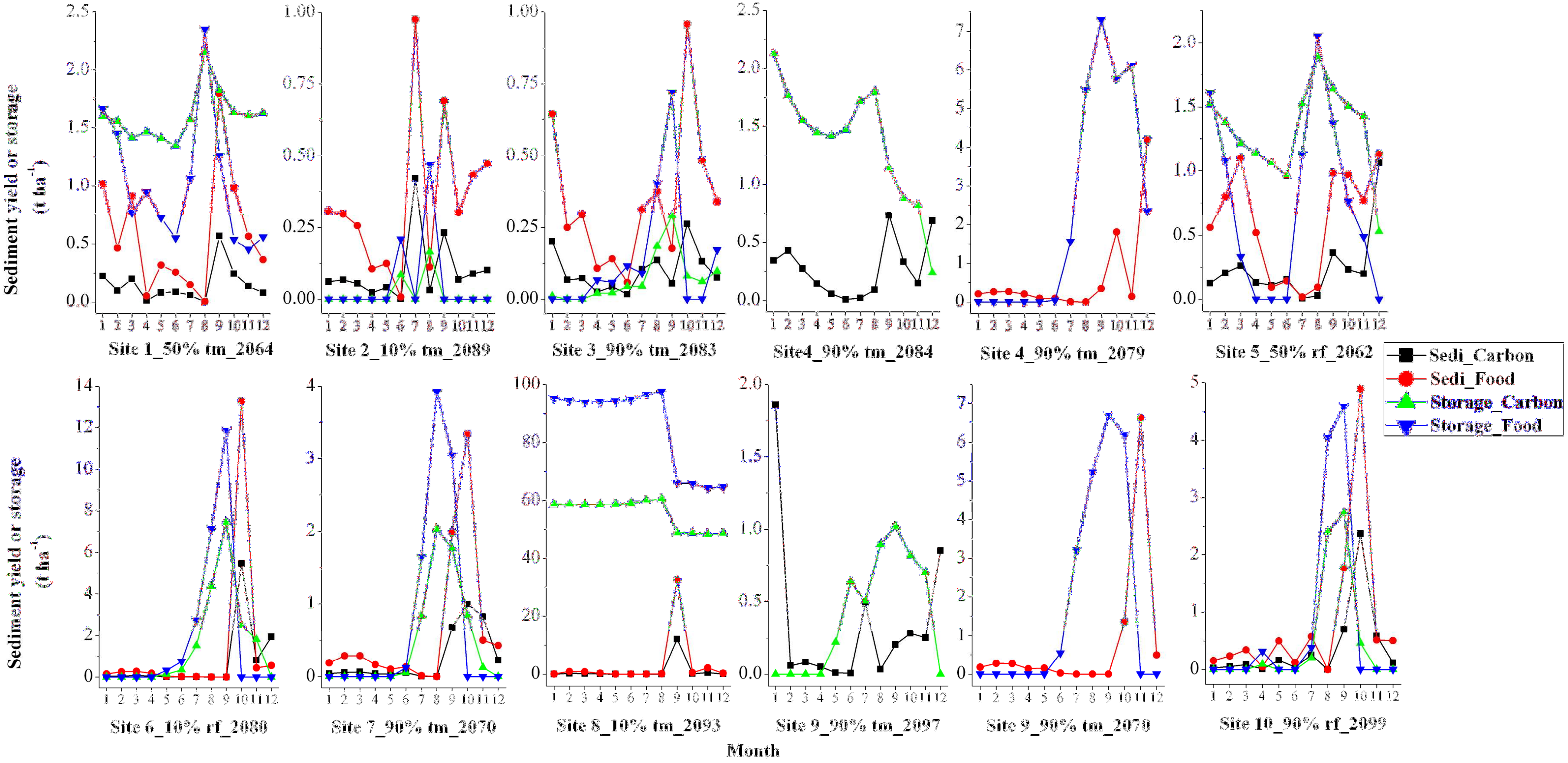

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