Supplement:
Identification of typical eco-hydrological behaviours using InSAR allows landscape-scale mapping of peatland condition

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Supplement contents

1.1 Multichannel Singular Spectrum Analysis (MSSA).

Multichannel Singular Spectrum Analysis (MSSA) was used to extract the seasonal oscillations from the InSAR time series. Each timeseries consisted of 133 data points, each separated by a 12-day time step. MSSA was applied to the data using the SSA-MTM software package (SPECTRA, 2021; Ghil et al., 2002) and method (Vautard and Ghil, 1989). Using this method, the first 10 principal components and first 20 Empirical Orthogonal Functions (EOFs) of the timeseries were calculated with a window (L) of 31 time steps. The results show that the first 6 EOFs account for ~ 72% of variance within the time series. EOFs 1, 2, 3 and 4 are indicative of low frequency multi-annual climatic trends (with cycles of 48.8, 48.8, 26.0 and 26.0 months respectively) as opposed to annual bog breathing. EOFs 5 and 6, each with a period of 11.8 months, define the annual cycle that when reconstructed corresponds to the observed annual cycle of bog breathing (Fig. S1). If all 6 EOFs are used to reconstruct the time series, the low frequency trends can obscure the higher frequency annual cycles as shoulders or merged peaks, which cannot always be detected with the R maximum peak calculation method. Hence, we selected EOFs 5 and 6 to reconstruct the annual cycles for calculating key variables of peak timing and amplitude whilst removing long-term trends and higher frequency noise (Fig 1 main text).

1.2 Sub-site and random polygon creation.

An illustration of how the polygons were created, using the UK OS basemap, Google Earth imagery and annual peak timing (2016-17) is shown for sub-site 3 Munsary (Figure S3).

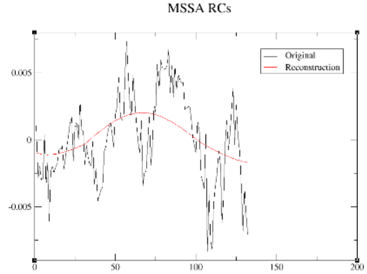
1.3 Topographic attributes.

The STRM DEM (Jarvis et al., 2008) was resampled to the resolution of the InSAR data using the aggregate tool in ESRI ArcGIS to give the altitude. Slope and aspect was then calculated on a pixel-by pixel basis using ‘Surface’ toolbox in ArcGIS. Data was then summarised for all the data points that fell within each polygon to give the topographic attributes.

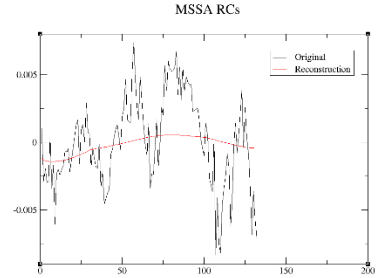
1.4 Hierarchical cluster analysis (HCA)

Using the semi quantitative scores 0, 1, 2, 3, for the sub-sites and random sites the Plant Functional Type (PFT) and then the hydrology classes were grouped. The approach used hierarchical clustering (Hierarchical Cluster Analysis, HCA) to identify polygons with similar combinations in semi quantitative scores. An iterative k-means clustering test indicated that 8-10 classes was sufficient to explain the dissimilarity within the data and this guided the location of the threshold on the hierarchical cluster tree (Figure S4 (A- D)). Once the data had been split into clusters, for each cluster, the average score in the semi-quantitative scale of each PFT in the cluster was calculated. The average scores were ranked and the top three were used to define the name of the Plant Functional Groups. In the case of the hydrology, the top scoring group within each class determined the name (Tables S1 -S4).

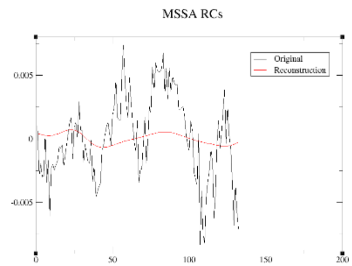
EOF 1



EOF 2



3



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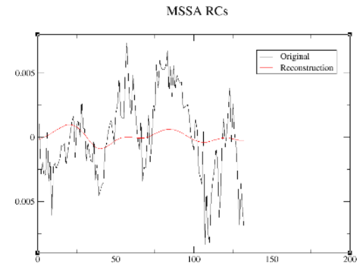

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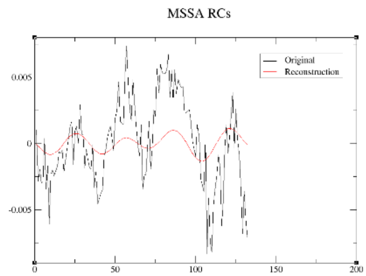

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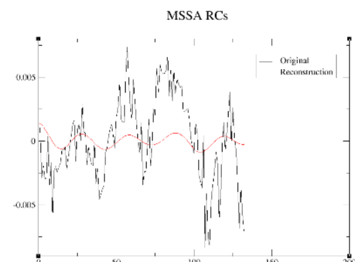
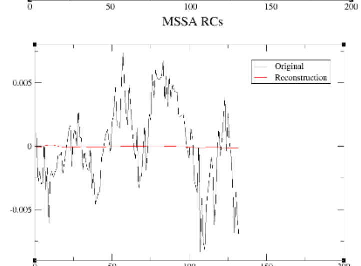


7



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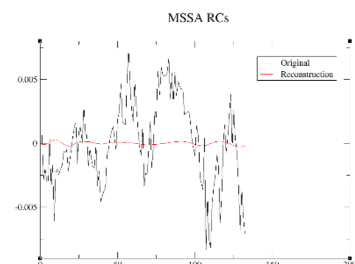
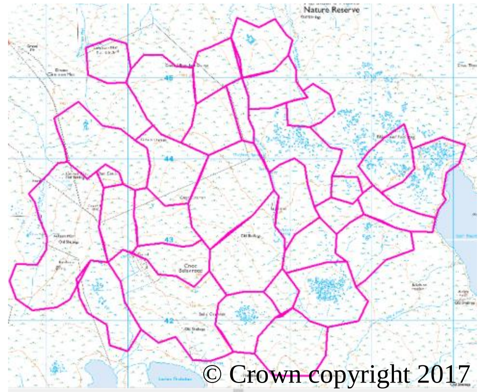


Fig. S1. MSSA reconstructions showing the contribution and periodicity of the first 8 EOFs (1-8) to an example time series from a wet peatland location. EOFs 1 to 4 are calculated to have periodicities greater than 12 months, 5 and 6 correspond to the annual cycle and 7 and 8 have a periodicity greater than 12 months. Axis x is time in days (12-day intervals) from start of time series; axis-y is relative height in metres.

(a)



(b)

(c)

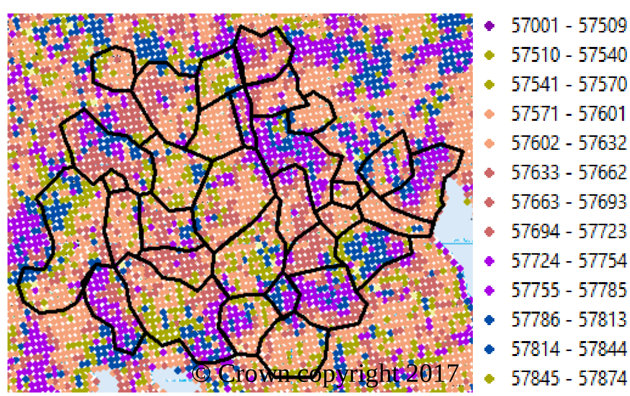
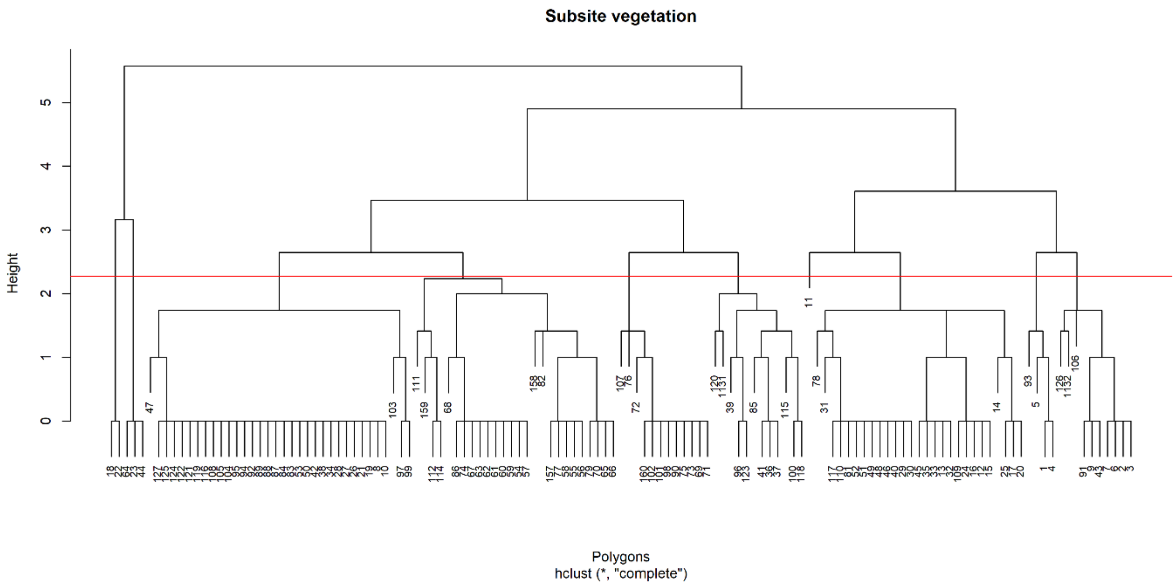
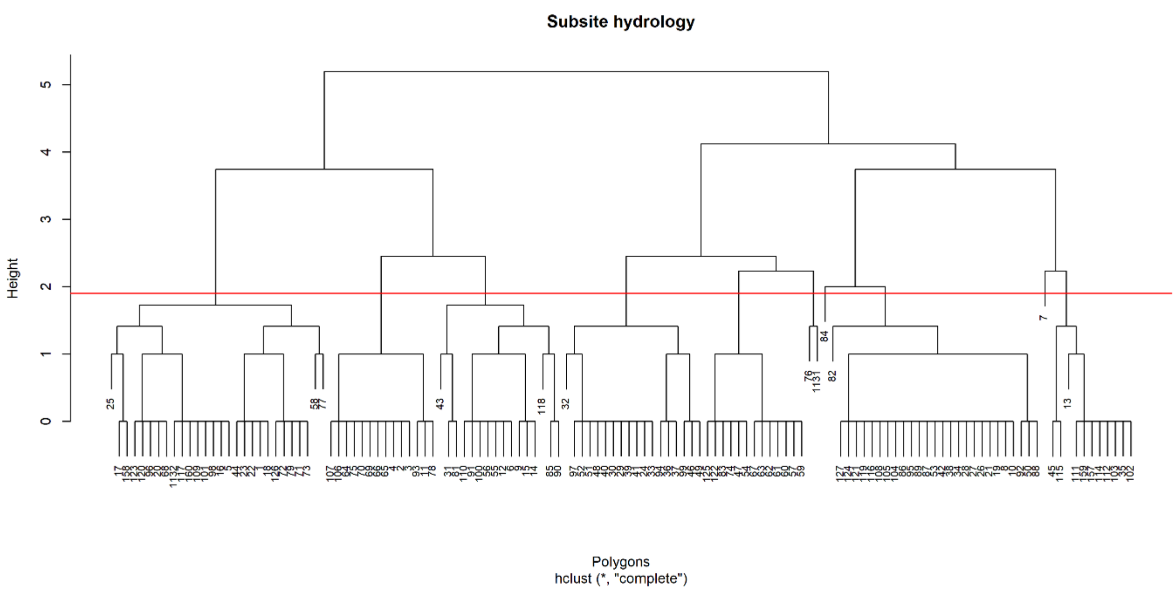


Fig. S2. Example of polygon definition using topographic context, clues to management and vegetation contrasts from, (a) UK Ordnance Survey map (Digimap Licence) © Crown copyright 2017. Distributed under the Open Government Licence (OGL). (b) True colour image, © Google Earth, and (c) Peak timing for 2016-2017 (key: serial date from 01/01/1901), for sub-site 3 Munsary.

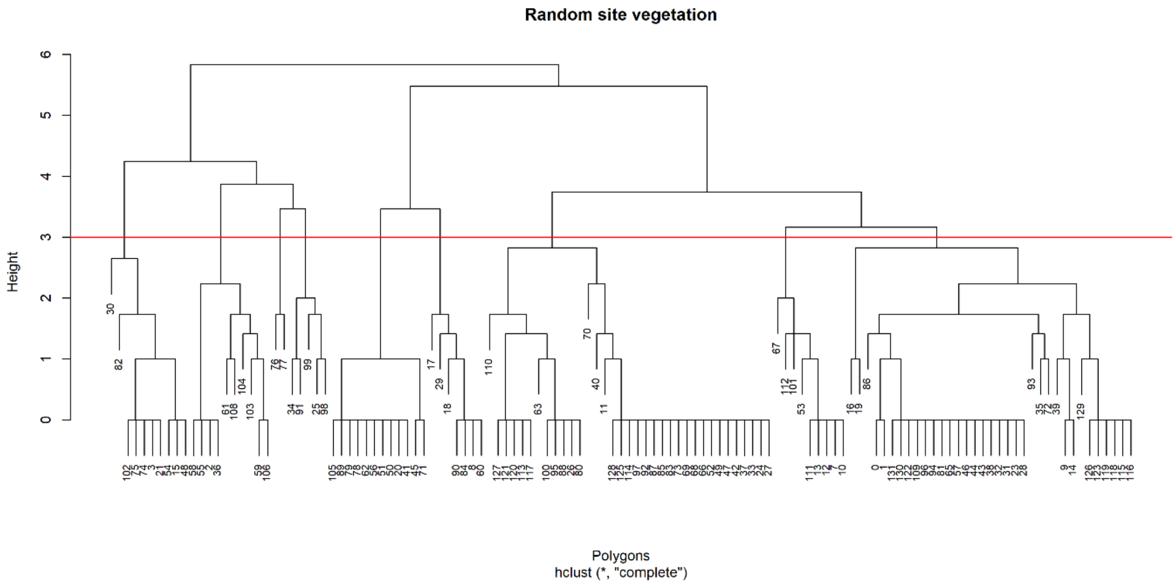
(a)


Subsite vegetation
Height
0
1
2
3
4
5
Polygons
hclust (*, "complete")

(b)


Subsite hydrology
Height
0
1
2
3
4
5
Polygons
hclust (*, "complete")

(c)



(d)

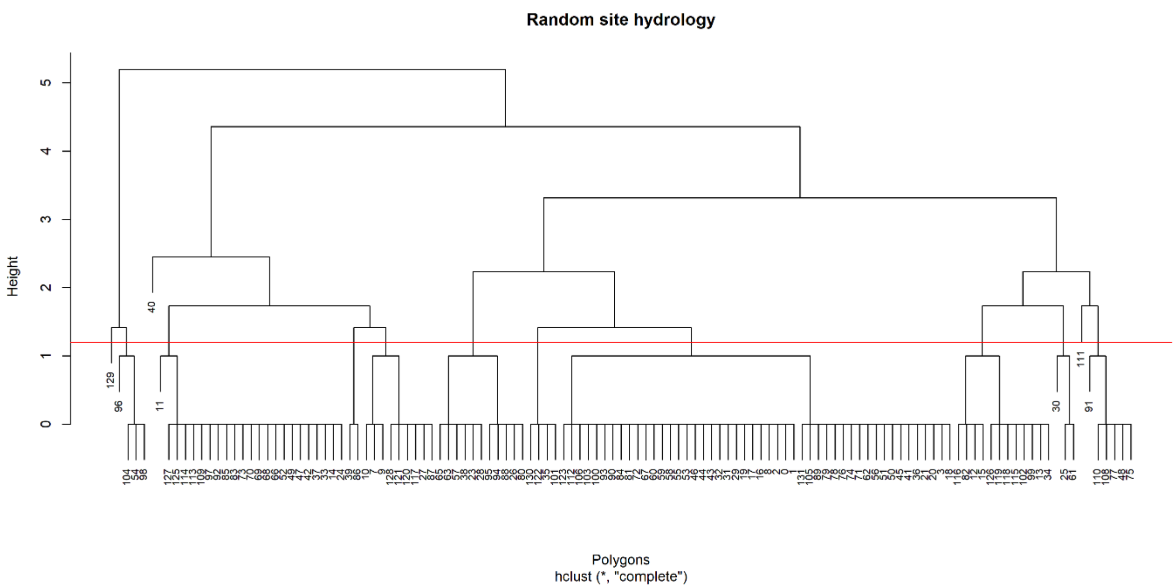


Fig. S3. Hierarchical cluster trees and dominant group averages for the sub site polygons. A) vegetation. B) hydrology, and random polygons. C) vegetation. D) hydrology. Horizontal line defines the threshold for the final clusters.

Table S1. Characteristics of the cluster groups for the sub-sites, showing the average value of the semi quantitative scale for each contributing PFT, Shrub, Sedge, Sphagnum, Moss, Grass, Rush, Forest. Top three scores for each cluster are highlighted, leading to the PFG name.

Cluster	n	SHRU	SEDG	SPHA	MOSS	GRAS	RUSH	FOR	PFG name
1	34	2.0	2.1	2.9	1.1	0.0	0.0	0.0	Sp,S,Sg
2	27	2.4	2.1	1.3	1.0	1.0	1.6	0.0	S,Sg,R
3	10	1.9	1.5	0.9	1.1	2.0	1.7	0.0	G,S,R
4	1	1.0	2.0	1.0	0.0	1.0	3.0	0.0	R,S
5	4	1.0	1.0	0.0	1.0	2.5	2.3	0.0	G,R
6	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	LoA
7	3	0.0	0.0	0.0	1.0	0.0	0.0	3.0	F
8	12	2.4	2.3	2.0	1.2	1.4	0.9	0.0	S,Sg,Sp(G)
9	26	2.5	2.4	1.0	1.8	0.1	0.2	0.0	S,Sg,M
10	12	2.8	2.1	0.9	2.0	1.0	1.0	0.0	S,Sg,M(G)

*Rank 1, rank 2, rank3

Table S2. Characteristics of the cluster groups for the sub-sites, showing the average value of each contributing hydrological feature, POOL, STREAM, DRAINED. Top three scores for each cluster are highlighted, with rank 1 forming the final class name.

Cluster	n	POOL	STREAM	DRAINED	Rank name	HydroName
1	27	3.0	0.1	0.0	p,s	**P**
2	11	0.0	0.2	0.9	d,s	**D**
3	28	0.3	0.7	2.4	d,s,p	**D**
4	16	0.4	2.2	1.6	s,d,p	**S**
5	18	1.2	0.3	1.0	p,d,s	**P**
6	14	0.0	0.0	2.2	d	**D**
7	1	0.0	0.0	2.0	d	**D**
8	13	3.0	0.0	1.5	p,d	**P**
9	2	2.0	2.0	0.5	p,s,d	**P**
10	1.0	3.0	2.0	0.0	p,s	**P**

*Rank 1, rank 2, rank3

Table S3. Characteristics of the cluster groups for the random sites, showing the average value of each contributing PFT, Shrub, Sedge, Sphagnum, Moss, Grass, Rush, Forest. Top three scores for each cluster are highlighted, leading to the PFG name.

Cluster	n	SHRU	SED	SPHA	MOSS	GRAS	RUSH	FOR	PFG name
1	35	2.9	1.9	1.1	1.3	0.0	0.1	0.0	S,Sg,M/Sp, nG
2	10	2.6	0.6	0.2	0.9	2.5	1.4	0.0	S,G,R
3	10	0.9	0.4	0.0	0.0	2.8	2.1	0.2	G,R,S,nSp, nM
4	9	2.1	1.9	0.9	1.0	1.1	0.8	0.0	S,Sg,G,M
5	7	0.1	0.1	0.0	0.0	0.0	0.1	0.1	LoA
6	35	2.0	2.2	2.3	1.1	0.1	0.1	0.0	Sp,Sg,S
7	12	0.0	0.0	0.0	0.8	0.0	0.0	3.0	F
8	7	1.4	1.9	0.4	0.9	0.9	2.0	0.0	R,Sg,S
9	2.0	1.0	2.4	0.5	1.0	2.5	2.0	0.0	G,S,R

*Rank 1, rank 2, rank3

Table S4. Characteristics of the cluster groups for the random-sites, showing the average value of each contributing hydrological feature, POOL, STREAM, DRAINED. Top three scores for each cluster are highlighted, with rank 1 forming the final class name.

Cluster	n	POOL	STREAM	DRAINED	NAME	Hydro name
1	48	0.0	0.0	1.4	d	**D**
2	9	2.7	0.0	1.0	p,d	**P**
3	23	3.0	0.0	0.0	p	**P**
4	12	0.0	1.3	1.0	s,d	**S**
5	11	0.5	0.0	0.0	p	**P**
6	3	1.0	2.0	1.3	s,d,p	**S**
7	4	1.1	0.0	1.0	p,d	**P**
8	2	2.0	0.0	0.0	p	**P**
9	1	3.0	2.0	1.0	p,s,d	**P**
10	6	0.2	2.0	0.0	s,p	**S**
11	4	0.0	2.0	2.8	d,s,	**D**
12	1	0.0	3.0	1.0	s,d	**S**
13	1.0	0.0	3.1	3.0	s,d	**S**

*Rank 1, rank 2, rank 3

Table S5. Number of hits in a search for a *Sphagnum* dominated class point in the buffer zone around the pool systems identified in the study area.

Proportion of *Sphagnum* class hits in buffer zone	Number of buffer zones (n=328)	Proportion of buffer zones (%)	Cumulative total of buffer zones (%)
Up to 1/5th	32	9.8	97.8
Up to 2/5ths	59	17.9	88.0
Up to 3/5ths	69	21.0	70.0
Up to 4/5ths	64	19.5	49.1
Up to 5/5ths	97	29.6	29.6
No hits	7	2.1	2.1
100% - 5/5ths	40	12.2	12.2

References

SPECTRA software available at http://research.atmos.ucla.edu/tcd/ssa/guide/guide4.html, last accessed May 2021.

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Vautard, R., and Ghil, M.: Singular spectrum analysis in nonlinear dynamics, with applications to paleoclimatic time series. *Physica D:* Nonlin. Phenom., 35(3) 395-424, 1989.

Jarvis, A., Reuter, H.I., Nelson, A., and Guevara, E.: Hole-filled seamless SRTM data V4, International Centre for Tropical Agriculture (CIAT), available at http://srtm.csi.cgiar.org, 2008.