

Global vegetation patterns of the past 140,000 years

Judy R.M. Allen¹, Matthew Forrest², Thomas Hickler², Joy S. Singarayer³, Paul J. Valdes⁴ and
Brian Huntley^{1*}

¹ Department of Biosciences, Durham University, South Road, Durham DH1 3LE, United Kingdom.

² Senckenberg Biodiversity and Climate Research Centre, Senckenberganlage 25,
D-60325 Frankfurt am Main, Germany.

³ Department of Meteorology, University of Reading, PO Box 243, Reading RG6 6BB, United Kingdom.

⁴ School of Geographical Sciences, University of Bristol, University Road, Clifton, Bristol BS8 1SS,
United Kingdom.

* Corresponding author: brian.huntley@durham.ac.uk

Dataset generation supported in part by a Leverhulme Trust Research Grant to BH (RPG-2014-338) and in part by a William Evans Fellowship awarded to BH by the University of Otago, Dunedin.

Directory listing of folder deposited:

Ascii_Grid_Files
LAI_&_Cmass
Biome_assignments_V1.1_89_time-slices.csv
Biome_extents_V1.1_89_time-slices
Ice-free_land_fraction_89_time-slices
PFT_Cmass_by_biome_V1.1_89_time-slices
Readme_first.pdf

The first two items listed are folders, the remainder are individual files, including this file (Readme_first.pdf). Descriptions are given below of the four individual data files, followed by descriptions of the two folders and of the individual files therein.

Biome_assignments_V1.1_89_time-slices.csv

A comma-delimited file. Header line names the fields given on each subsequent line. Subsequent 68,665 lines give biome assignments for half-degree grid cells for 89 time slice experiments as listed in the header line. Experiments are identified by the time slice, in ka BP, to which they relate, followed by a two or three character code indicating the type of experiment; these codes are as follows: 'DV' – indicates the experiment was performed using a dynamic vegetation model coupled to the atmosphere–ocean GCM; 'h' indicates a 'hosing' experiment; 'I' indicates an experiment using a revised ice-sheet specification (for details of these experiments see Allen *et al.*, 2020). Biomes assigned are indicated by an integer numeric code, as shown in the table overleaf.

Fields:

Cell-ID.....Sequence number for grid cell (0 – 68,664).

Lon.....Longitude of lower-left corner of grid cell (decimal degrees east of Greenwich Meridian).

Lat.....Latitude of lower-left corner of grid cell (decimal degrees north of Equator).

000kDVbiome assignment for 0 kyr BP from 000kDV GCM experiment.

001kDVbiome assignment for 1 kyr BP from 001kDV GCM experiment.

⋮
⋮
⋮
⋮

136kDVI.....biome assignment for 136 ka BP from 136kDVI GCM experiment.

140kDVI.....biome assignment for 140 ka BP from 140kDVI GCM experiment.

Biome assignment codes

Code	Acronym	Biome
0	No biome assigned, i.e. no ice-free land area in the grid cell at that time.	
1	Des	Desert
2	Tun	Tundra
3	TrEF	Tropical Evergreen Forest
4	TrRF	Tropical Raingreen Forest
5	Sav	Savanna
6	TrG	Tropical Grassland
7	TeMxF	Temperate Mixed Forest
8	TeSF	Temperate Summergreen Forest
9	TeBEF	Temperate Broad-leaved Evergreen Forest
10	BPk	Boreal Parkland
11	TePk	Temperate Parkland
12	WTeWo	Warm Temperate Woodland
13	TeSh	Temperate Shrubland
14	BENF	Boreal Evergreen Needle-leaved Forest
15	BWo	Boreal Woodland
16	BSNF	Boreal Summergreen Needle-leaved Forest
17	BSBF	Boreal Summergreen Broad-leaved Forest
18	ShT	Shrub Tundra
19	St	Steppe
20	TeNEF	Temperate Needle-leaved Evergreen Forest
21	Se-des	Semi-desert
22	UNC	Unclassified

Biome_extents_V1.1_89_time-slices

A fixed format file. File comprises six blocks of data, relating in turn to:

Extents.....global extent (km²);

% Extglobal extent as a fraction of the contemporary total global land area (%);

n cellsnumber of half-degree grid cells occupied globally;

% cellsfraction of all global cells with some ice-free land area occupied (%);

CMassglobal biomass (kg carbon); and

% Cmassfraction of total global biomass (%)

of the 21 biomes, plus unclassified grid cells, and also the total across biomes in the cases of values not expressed as fractions.

Each block begins with a line identifying the nature of the data presented, followed by a header line identifying the experiment (column 1) and the biomes for which data are given in each of 21 columns (columns 2 – 22), using the biome acronyms given above, a column giving values for unclassified grid cells (UNC) and, where relevant, a final 'Total' column. This is followed by 89 rows of data, each row commencing with the experiment identifier, constructed as described above and occupying the first 8 character positions, followed by 22 values, or 23 values in cases where a total is given, each occupying 11 characters, with the first commencing in character position 9.

Data values are given as real numbers to three decimal places (Extents, % Ext, % cells and % Cmass), integers (n cells) or in exponential format (CMass).

Blocks are separated by two blank lines.

This multi-block file can be read in R using the standard `read.table()` function with the 'fill' argument set to TRUE.

Data in the Extents block were used to generate Figure 6 of Allen *et al.* (2020), whilst the Total column of the Cmass block was used to draw the Global C-Mass line in Figure 7 of that paper.

Ice-free_land_fraction_89_time-slices

A fixed-format file. No header line. 68,665 lines, each of which gives, for a half-degree grid square, the overall area (km²) and ice-free land fractions (%) for the 89 time slices (for details of how these values were estimated, see Supplementary Information, Appendix S2, of Allen *et al.*, 2020). Note that the Cell-ID field is specific to this file and does not provide a cross reference into any other file.

Fields:

1. Cell-ID.....Sequence number for grid cell; 5-digit integer (0 – 68,664).
2. Global -ID..Grid cell sequence number with respect to global half-degree grid; 6-digit integer.
3. Lon.....Longitude of centre of grid cell; 8 character signed real value with two decimal places (decimal degrees east of Greenwich Meridian).
4. Lat.....Latitude of centre of grid cell; 7 character signed real value with two decimal places (decimal degrees north of Equator).
5. AreaOverall area of grid cell; 8 character real value with two decimal places (km²).
- 6 – 94.Ice-free land fractions (%) for 89 time slices; 7 character real values with two decimal places. Time slices are in the same order as in **Biome_assignments_V1.1_89_time-slices.csv**.

PFT_CMass_by_biome_V1.1_89_time-slices

A fixed format file. File comprises 22 pairs of blocks of data, i.e. 44 blocks of data in all. Each pair of blocks relates to a biome, or to the unclassified grid cells. The first block of each pair gives the global total biomass (kg carbon), and the second the fractional biomass (%), for each of the 20 individual plant functional types used in the LPJ-GUESS simulations, the overall sum of the individual plant functional type values, and summed values for 11 aggregates of plant functional types.

Each block begins with a line identifying the biome, using the acronyms given above, and either 'CMass' or '% CMass', according to whether biomass or fractional biomass values are given in the block. A header line for the columns then follows, indicating the experiment (column 1) and for columns 2 – 33 the plant functional types, overall total or aggregate total given in the column. The header line is followed by 89 rows of data, each row commencing with the experiment identifier, constructed as described above and occupying the first 8 character positions, followed by 32 values, each occupying 11 characters, with the first commencing in character position 9.

Data values are given in exponential format (CMass) or as real numbers to three decimal places (% Cmass). Note that in the case of the % CMass values for unclassified grid cells, some rows of values are given as 'NaN' (i.e. 'not a number'); these values relate to time slices for which no grid cells were unclassified and hence the total CMass for unclassified grid cells was zero, resulting in division by zero when percentage values were calculated.

Blocks are separated by two blank lines.

This multi-block file can be read in R using the standard `read.table()` function with the 'fill' argument set to TRUE.

Acronyms used for plant functional types and aggregates are listed in the table overleaf.

Acronyms used for plant functional types and aggregates

Acronym	Plant Functional Type
BNE	Boreal Needle-leaved Evergreen Tree
BINE	Shade-intolerant Boreal Needle-leaved Evergreen Tree
BNS	Boreal Needle-leaved Summergreen Tree
BIBS	Shade-intolerant Boreal Broad-leaved Summergreen Tree
TeNE	Temperate Needle-leaved Evergreen Tree
TeBS	Temperate Broad-leaved Summergreen Tree
TeIBS	Shade-intolerant Temperate Broad-leaved Summergreen Tree
TeBE	Temperate Broad-leaved Evergreen Tree
TrBE	Tropical Broad-leaved Evergreen Tree
TrIBE	Shade-intolerant Tropical Broad-leaved Evergreen Tree
TrBR	Tropical Broad-leaved Raingreen Tree
BESh	Boreal Evergreen Shrub
BSSh	Boreal Summergreen Shrub
TeESh	Temperate Evergreen Shrub
TeRSh	Temperate Raingreen Shrub
TeSSh	Temperate Summergreen Shrub
TrESh	Tropical Evergreen Shrub
TrRSh	Tropical Raingreen Shrub
C3G	C3 Grass
C4G	C4 Grass
PFT Aggregate	
B-tree	Sum of Boreal Trees (BNE + BINE + BNS + BIBS)
Te-tree	Sum of Temperate Trees (TeNE + TeBS + TeIBS + TeBE)
Tr-tree	Sum of Tropical Trees (TrBE + TrIBE + TrBR)
B-shrub	Sum of Boreal Shrubs (BESh + BSSh)
Te-shrub	Sum of Temperate Shrubs (TeESh + TeRSh + TeSSh)
Tr-shrub	Sum of Tropical Shrubs (TrESh + TrRSh)
BE_tree	Sum of Boreal Evergreen Trees (BNE + BINE)
BS_tree	Sum of Boreal Summergreen Trees (BNS + BIBS)
TeE_tree	Sum of Temperate Evergreen Trees (TeNE + TeBE)
TeS_tree	Sum of Temperate Summergreen Trees (TeBS + TeIBS)
TrE_tree	Sum of Tropical Evergreen Trees (TrBE + TrIBE)

LAI & CMass

A folder containing two sub-folders, CMASS and LAI.

CMASS

A folder containing 89 .csv files, one for each time slice. File names comprise the experiment code, as in the header line of **Biome_assignments_V1.1_89_time-slices.csv**, followed by '_cmass.csv'. Each comma-delimited file has a header line naming the 40 fields given on each subsequent line, followed by 68,665 lines, one for each grid cell, grid cells being in a consistent order corresponding to their order in **Biome_assignments_V1.1_89_time-slices.csv**. The first 4 fields give the location, area and ice-free fraction for the grid cell for the time slice. Fields 5 – 36 give the live plant biomass (expressed as 'carbon mass') of the 20 individual plant functional types used in the LPJ-GUESS simulations, the overall sum of the individual plant functional type values, and summed values for 11 aggregates of plant functional types.

Fields:

Lon..... Longitude of lower-left corner of grid cell (decimal degrees east of Greenwich Meridian).

Lat..... Latitude of lower-left corner of grid cell (decimal degrees north of Equator).

area..... Overall area of grid cell (km²).

% ice-free..... Ice-free land fraction (%).

BNE Boreal Needle-leaved Evergreen Tree biomass (kg carbon).

BINE Shade-intolerant Boreal Needle-leaved Evergreen Tree (kg carbon).

BNS Boreal Needle-leaved Summergreen Tree (kg carbon).

BIBS..... Shade-intolerant Boreal Broad-leaved Summergreen Tree (kg carbon).

TeNE..... Temperate Needle-leaved Evergreen Tree (kg carbon).

TeBS..... Temperate Broad-leaved Summergreen Tree (kg carbon).

TeIBS..... Shade-intolerant Temperate Broad-leaved Summergreen Tree (kg carbon).

TeBE..... Temperate Broad-leaved Evergreen Tree (kg carbon).

TrBE..... Tropical Broad-leaved Evergreen Tree (kg carbon).

TriBE..... Shade-intolerant Tropical Broad-leaved Evergreen Tree (kg carbon).

TrBR Tropical Broad-leaved Raingreen Tree (kg carbon).

C3G C3 Grass (kg carbon).

C4G C4 Grass (kg carbon).

TeESh..... Temperate Evergreen Shrub (kg carbon).

TeRSh..... Temperate Raingreen Shrub (kg carbon).
 TeSSh..... Temperate Summergreen Shrub (kg carbon).
 TrESh..... Tropical Evergreen Shrub (kg carbon).
 TrRSh Tropical Raingreen Shrub (kg carbon).
 BESH..... Boreal Evergreen Shrub (kg carbon).
 BSSH..... Boreal Summergreen Shrub (kg carbon).
 Total..... Sum of all plant functional types (kg carbon).
 B-tree Sum of Boreal Trees (BNE + BINE + BNS + BIBS) (kg carbon).
 Te-tree Sum of Temperate Trees (TeNE + TeBS + TeIBS + TeBE) (kg carbon).
 Tr-tree Sum of Tropical Trees (TrBE + TrIBE + TrBR) (kg carbon).
 B-shrub Sum of Boreal Shrubs (BESH + BSSH) (kg carbon).
 Te-shrub..... Sum of Temperate Shrubs (TeESH + TeRSh + TeSSH) (kg carbon).
 Tr-shrub Sum of Tropical Shrubs (TrESH + TrRSh) (kg carbon).
 BE_tree..... Sum of Boreal Evergreen Trees (BNE + BINE) (kg carbon).
 BS_tree..... Sum of Boreal Summergreen Trees (BNS + BIBS) (kg carbon).
 TeE_tree Sum of Temperate Evergreen Trees (TeNE + TeBE) (kg carbon).
 TeS_tree Sum of Temperate Summergreen Trees (TeBS + TeIBS) (kg carbon).
 TrE_tree Sum of Tropical Evergreen Trees (TrBE + TrIBE) (kg carbon).

LAI

A folder containing 89 .csv files, one for each time slice. File names comprise the experiment code, as in the header line of **Biome_assignments_V1.1_89_time-slices.csv**, followed by '_lai.csv'. Each comma-delimited file has a header line naming the 38 fields given on each subsequent line, followed by 68,665 lines, one for each grid cell, grid cells being in a consistent order corresponding to their order in **Biome_assignments_V1.1_89_time-slices.csv**. The first 2 fields give the location of the grid cell. Fields 3 – 34 give the leaf area index (leaf area per unit ground area – $m^2 m^{-2}$ – i.e. no units) of the 20 individual plant functional types used in the LPJ-GUESS simulations, the overall sum of the individual plant functional type values, and summed values for 11 aggregates of plant functional types.

Fields:

Lon..... Longitude of lower-left corner of grid cell (decimal degrees east of Greenwich Meridian).

Lat..... Latitude of lower-left corner of grid cell (decimal degrees north of Equator).

BNE Boreal Needle-leaved Evergreen Tree biomass.

BINE Shade-intolerant Boreal Needle-leaved Evergreen Tree.

BNS Boreal Needle-leaved Summergreen Tree.

BIBS..... Shade-intolerant Boreal Broad-leaved Summergreen Tree.

TeNE..... Temperate Needle-leaved Evergreen Tree.

TeBS..... Temperate Broad-leaved Summergreen Tree.

TeIBS..... Shade-intolerant Temperate Broad-leaved Summergreen Tree.

TeBE..... Temperate Broad-leaved Evergreen Tree.

TrBE..... Tropical Broad-leaved Evergreen Tree.

TriBE..... Shade-intolerant Tropical Broad-leaved Evergreen Tree.

TrBR Tropical Broad-leaved Raingreen Tree.

C3G C3 Grass.

C4G C4 Grass.

TeESh..... Temperate Evergreen Shrub.

TeRSh..... Temperate Raingreen Shrub.

TeSSh..... Temperate Summergreen Shrub.

TrESh..... Tropical Evergreen Shrub.

TrRSh Tropical Raingreen Shrub).

BESh..... Boreal Evergreen Shrub.

BSSh..... Boreal Summergreen Shrub.

Total..... Sum of all plant functional types.

B-tree Sum of Boreal Trees (BNE + BINE + BNS + BIBS).

Te-tree Sum of Temperate Trees (TeNE + TeBS + TeIBS + TeBE).

Tr-tree Sum of Tropical Trees (TrBE + TrIBE + TrBR).

B-shrub Sum of Boreal Shrubs (BESh + BSSh).

Te-shrub..... Sum of Temperate Shrubs (TeESh + TeRSh + TeSSh).

Tr-shrub Sum of Tropical Shrubs (TrESh + TrRSh).

BE_tree Sum of Boreal Evergreen Trees (BNE + BINE).

BS_tree..... Sum of Boreal Summergreen Trees (BNS + BIBS).

TeE_tree Sum of Temperate Evergreen Trees (TeNE + TeBE).

TeS_tree Sum of Temperate Summergreen Trees (TeBS + TeIBS).

TrE_tree Sum of Tropical Evergreen Trees (TrBE + TrIBE).

Ice_fraction

A folder containing 89 .asc files, one for each time slice. File names comprise the time slice age followed by '_icefr.asc' (e.g. '3ka_icefr.asc'), with the addition of '_Hn' after the age in the case of those relating to 'hosing' experiments designed to mimic Heinrich Events (e.g. '13k_H0_icefr.asc'). Files are in ArcGIS ASCII grid format, the first six lines defining their *x* and *y* dimensions (i.e. numbers of columns and of rows respectively), their geographical extent, the cell size and the value used for no data. Subsequent lines list the values for cells in the order defined for an ArcGIS ASCII grid file, i.e. 'row-major' order, the first row being the topmost (i.e. northernmost) row; this is alternatively referred to as 'English reading order', i.e. left to right and top to bottom. Values are space-delimited.

See:

http://resources.esri.com/help/9.3/arcgisengine/java/GP_ToolRef/spatial_analyst_tools/esri_ascii_raster_format.htm

Grid cells are 0.1 x 0.1 degrees (i.e. 6-minute cells).

Data values are real numbers, given to one decimal place, in the range 0.0 to 100.0, and are interpolated ice-fraction values. Ice fraction values are interpolated from the one degree ice fraction values given by ICE-6G (Peltier *et al.*, 2015); further details are given in the Supplementary Information to Allen *et al.* (2020).

First 10 lines of one such file:

```
ncols 3600
nrows 1800
xllcorner -180.0
yllcorner -90.0
cellsize 0.1
NODATA_value 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```


References

- Allen, J.R.M., Forrest, M., Hickler, T., Singarayer, J.S., Valdes, P.J. & Huntley, B. (2020) Global vegetation patterns of the past 140,000 years. *Journal of Biogeography*, (accepted).
- Peltier, W.R., Argus, D.F. & Drummond, R. (2015) Space geodesy constrains ice age terminal deglaciation: The global ICE-6G_C (VM5a) model. *Journal of Geophysical Research-Solid Earth*, **120**, 450-487.