Global Land Use and Anthropogenic Land Cover Changes over the HOLOCENE for Climate Research

New PAGES working group endorsed by PAGES in November 2014
Focus of LandCover6k: Reconstructions of past anthropogenic land-cover change over the globe for climate modelling

Contribution to:

• Evaluation of models of past anthropogenic land-cover change used in climate modelling

• Study of land cover – climate interactions in general
• Study of anthropogenic land-cover change as climate forcing via biogeo-chemical and –physical processes

• Evaluation of climate models

• Will also be useful for many other scientific questions on past environmental changes and their implications for the understanding of current environments and their possible future development
Note the difference in open land!

Kaplan et al. (2009) **KK10**
standard scenario

Klein Goldewijk et al. (2011)
**HYDE 3.1**

Pongratz et al. (2008)
**maximum** scenario

Kaplan et al. (2009)
**KK10**
technology scenario

Review in Gaillard et al. (2010)

AD 800
Late Iron Age

Fraction of grid cell under woodland/forest

NEEDS EVALUATION!!!!!
MOREOVER....

• These land-cover change scenarios are limited to a single variable: estimate of deforestation.

• However...

• Human activities cause a variety of other land-cover changes relevant to climate e.g.
  – fire-managed savannas
  – densely populated irrigated and semi-urbanized settlements

• “Thus the currently available scenarios of past ALCCs do not allow an effective assessment of human impacts on the environment, and preclude hypothesis testing on climate feedbacks, and societal vulnerability and resilience to environmental change” (Kay and Kaplan, 2015)
Evaluation of anthropogenic land-cover change ALCC scenarios

- Needs **Independent descriptions of past land-cover based on empirical data**

- **Pollen records** have this potential: represent VEGETATION

- **Difficulties:**
  - plants produce different amounts of pollen depending on the species, pollen are dispersed in different ways depending on their form, size and weight (different **pollen productivity** and **dispersal properties**), etc...;
  - pollen grains can **seldom be identified to species**;
  - plant species (groups of species) are not always **representative of human influenced vegetation only**
What more can we use?

+ historical written sources and maps !!!!
+ archaeological data !!!!

LandCover6k: will use both pollen- and hist/arch - based reconstructions
Example Europe: LAND COVER
Pollen-based reconstructions

1. Modern Analogue Technique (MAT): papers by e.g. Williams – tree vegetation
2. Biomization: e.g. Davis et al. (2014) reconstruction of the distribution of climate-induced biomes (no human-induced vegetation) – inferred landscape openness
   - 3-4: ”fast” methods, can already be applied globally: rough quantification of REGIONAL vegetation, not yet validated properly, theoretically not entirely sound
4. REVEALS and LOVE models: Sugita 2007 a & b
   - Time-consuming method, cannot be applied globally yet: the most precise quantification so far, validated in many parts of the world
   - REVEALS: REGIONAL vegetation
   - LOVE: LOCAL vegetation
Example Europe: LAND COVER
Pollen-based reconstructions

• **Pseudobiomization**: Fyfe et al.
  – ”fast” method, can already be applied globally: rough quantification, not yet validated

• **REVEALS model**: Sugita et al.
  – Time-consuming method, cannot be applied globally yet: the most precise quantification so far, validated in many parts of the world
  – **LandClim project** (Gaillard et al., VR, NordForsk, MERGE): REVEALS estimates of vegetation cover briefly....
Pseudo-biomization (Fyfe et al. 2015, Global Change Biology)

• Involves a VERY ROUGH CORRECTION OF POLLEN VALUES accounting for differences in pollen productivity between plants
  – Rough estimate of the relative abundance of Land Cover Classes at a site and a time period in the past
  – LCCs: needle-leaf trees, broadleaf trees, pasture/natural grassland, arable/disturbed land, etc.)
  – Each LCC gets a score (≠ % cover)

IT IS NOT A PROPER QUANTIFICATION OF THE COVER OF EACH LAND COVER CLASS
Pseudobiomization
Example: LCC Pasture/natural grassland

NOTE!!: "The spatial interpolation of the PBM scores should be viewed as a first-order approximation of land cover across Europe, and the values are not intended to be read as a quantified measure of landscape openness"
Grasses, sedges, weeds, meadow – pastureland herbs

REVEALS estimates of cover for PFT ”Grassland”

Grasses, sedges, weeds, meadow – pastureland herbs

- Grid-based pollen-based reconstructions of land cover
  - Grid size: 1°x 1°;
  - % cover of 25 individual taxa, 10 plant functional types (PFTs) and 3 land-cover types

Trondman et al. (2014 Global Change Biology)
25 taxa

<table>
<thead>
<tr>
<th>Land-cover types</th>
<th>PFT</th>
<th>PFT definition</th>
<th>Plant taxa/ Pollen-morphological types (25 taxa)</th>
<th>PPE.st²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen tree canopy</td>
<td>TBE1</td>
<td>Shade-tolerant evergreen trees</td>
<td><em>Picea</em></td>
<td>2.62 (0.12)</td>
</tr>
<tr>
<td></td>
<td>TBE2</td>
<td>Shade-tolerant evergreen trees</td>
<td><em>Atriplex</em></td>
<td>6.88 (1.24)</td>
</tr>
<tr>
<td></td>
<td>IBE</td>
<td>Shade-intolerant evergreen trees</td>
<td><em>Rumex</em></td>
<td>6.38 (0.45)</td>
</tr>
<tr>
<td></td>
<td>TSE</td>
<td>Tall shrub, evergreen</td>
<td><em>Quercus</em></td>
<td>2.07 (0.04)</td>
</tr>
<tr>
<td>Summer-green tree canopy</td>
<td>IBS</td>
<td>Shade-intolerant summer trees</td>
<td><em>Carpinus</em></td>
<td>9.07 (0.10)</td>
</tr>
<tr>
<td></td>
<td>TBS</td>
<td></td>
<td><em>Salix</em></td>
<td>3.09 (0.27)</td>
</tr>
<tr>
<td>Open land (other)</td>
<td>AL</td>
<td>Agricultural land – cereals</td>
<td><em>Avena</em></td>
<td>1.99 (0.20)</td>
</tr>
</tbody>
</table>

12 trees, 3 shrubs/dwarf shrubs, 10 herbs

Pollen productivity estimates, fall speed of pollen
Pirzamanbein et al. (2014, Ecological Complexity)

Modern time window

FILLING THE GAPS!

REVEALS estimates

+ model-simulated Climate-induced Vegetation (LPJGUESS)

2 Spatial statistical models

Modern forest data European Forest Institute

Coniferous Broadleaved Unforested

RM=regression model

IGMRF=Intrinsic Gaussian Markov Random Field

+ Kaplan et al’s scenarios of deforested land
Fig. 8. Reconstructions for the 6k time window. From top to bottom, the GB-REVEALS data, the RM reconstruction, and the IGMRF reconstruction. 

Pirzamanbein et al. (2014, Ecological Complexity)
Land cover–climate interactions at the regional spatial scale, RCA3 regional climate model

Effects of human deforestation onto climate

- Strandberg et al. 2014, *Climate of the Past*
- *Land-cover= simulated climate-induced (natural) vegetation + Kaplan et al’s KK10*
  - Summer and winter temperatures and precipitations at 6000 and 200 yrs BP
  - Analysis of the biogeophysical effects
  - Two major effects of land-cover changes:
    - Albedo effect
    - Evapo-transpiration effect
  - Results: anthropogenic land-cover change ALCC matters!
    - ALCC between 6000 and 200 BP implies various climate changes at the regional spatial scale
Note the difference in open land!

AD 1 ca. 2000 BP
Early Iron Age

Kaplan et al. (2009)
standard scenario

Klein Goldewijk et al. (2010)
HYDE 3.1

Olofsson & Hickler (2008)

Review in Gaillard et al. (2010)
Pollen-based LAND-COVER (REVEALS)

• Except Europe, what so far?
Traditional agricultural landscapes

Steppes

Meadows

Temperate forests

Legend
- Cities
- Completed survey areas
- Alternative survey areas

China publ. & in progr. (NW) and planned
IN PROGRESS – Pollen productivities and REVEALS reconstr.
Pollen productivities REVEALS reconstructions
LAND-USE Change on global scale

• What so far?
  – GLOBE: Widgren, Myrdal, Doolittle, unpublished
    • Categorization of land-uses
    • Mapping of categories at AD 1000, 1500, 1800
  – AFRICA: Kay and Kaplan
    • Categorization of land-uses, published 2015
    • Mapping of categories: to be done
Kay & Kaplan (2015) in *Anthropocene*, http://dx.doi.org/10.1016/j.ancene.2015.05.001

• “Human subsistence and land use in sub-Saharan Africa, 1000 BC to AD 1500: A review, quantification, and classification”
  – Categorisation and upscaling of archaeological and historical information
  – AIM:
    • Quantify the cover of categories
      – Calculations based on hist/arch data & assumptions
    • Map the cover of categories: not done yet!
Pastoralism

- visually represent the several levels of intensity used on the landscape

- the slices represent the physical area in m² that would be required for each type of land use to produce the amount of a product needed by that society in one year
New PAGES working group
Check the website!!!!
– http://www.pages-igbp.org/ini/wg/landcover6k/intro

Global Land Use and Anthropogenic Land Cover Changes over the HOLOCENE for Climate Research

Coordinator MJ Gaillard (land cover)
Co-coordinator K Morrisson (land use)

5 regional & 3 thematic subgroups with coordinators
Expected products

Product A: Largely improved HYDE and KK models for the Holocene using land-use and land-cover reconstructions from paleoecological data and historical/archeological data (Products B below)

Product B: Land-cover and land-use maps for time windows and/or periods of the Holocene.

Land Cover and Land Use represent the two activities of LandCover6k, Phase 1 (2015-2017) for three priority time windows of the Holocene, 6k, 0.45k (AD 1500), and 0.1k cal. BP (AD 1850):

• Pollen-based land-cover reconstructions / maps from key regions of all continents
• Global land-use maps based on archeological and historical data
• First revision of ALCC (Anthropogenic Land-Cover Change) scenarios (KK and HYDE)
The group is organized into 3 main activities, which are implemented by 8 subgroups:

1) Land Cover (pollen-based reconstructions of vegetation cover)
   Coordinator: Marie-José Gaillard

2) Land Use
   Coordinator: Kathleen Morrison and Sub-coordinators: Carsten Lemmen and Nicki Whitehouse

3) Anthropogenic Land Cover Change modeling
   Coordinators: Jed O Kaplan, Kees Klein Goldewijk, and Carsten Lemmen
Steering Group
Core members

**Marie-José Gaillard** WG and Land Cover Coordinator

**Kathleen Morrison** Land Use Coordinator, Coordinator subgroup 6; Co-coordinator subgroup 5 (India)

**Eric Grimm** Coordinator Pollen Databases
**Sandy Harrison** Climate modeling, PMIP link, Co-coordinator subgroup 5 (Australia)
**Jed O Kaplan** ALCC modeling Coordinator (subgroup 8), Global Land Project (GLP) link
**Kees Klein Goldewijk** ALCC modeling Coordinator (subgroup 8), Global Land Project (GLP) link
**Shinya Sugita** REVEALS model
**Boris Vannière** PAGES Global Paleofire Working Group
**Peter Verburg** Global Land Project (GLP)
Subgroups and their coordinators

1. N America
   Land Cover Coordinators: Konrad Gajewski and Jack Williams
   Land Use Coordinators: William Doolittle and Thomas Foster

2. Latin America
3. Europe
4. Africa
5. Asia + Australia + Oceania

6. Land use from historical and archeological information
   Coordinator: Kathleen Morrison
   Co-coordinators: Carsten Lemmen, Nicki Whitehouse together with regional
   Land Use Coordinators from subgroups 1-5.

7. Methodology focused on the tropics
   Coordinators: Anupama Krishnamurthy and Bronwen Whitney

8. Anthropogenic Land Cover Change (ALCC) modeling
   Coordinators: Jed O Kaplan, Kees Klein Goldewijk, and Carsten
   Lemmen together with representatives from subgroups 1-7.
• List of key participants
  – Land cover
  – Land use
• List of Climate/Earth system modelers following LandCover6k's activities
• List of PAGES' Global Paleofire Working Group members following LandCover6k's activities

http://www.pages-igbp.org/ini/wg/landcover6k/intro

• You can learn more and get involved in the working group by signing up to the mailing list via the webpage.