Modeling Global Anthropogenic Land Cover Change Over the Preindustrial Holocene
Present State and Future Perspectives

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Acknowledgements

- Andrea Kay, Ryan Hughes, Leanne Phelps, Kristen Krumhardt, Basil Davis
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PAGES PAST GLOBAL CHANGES

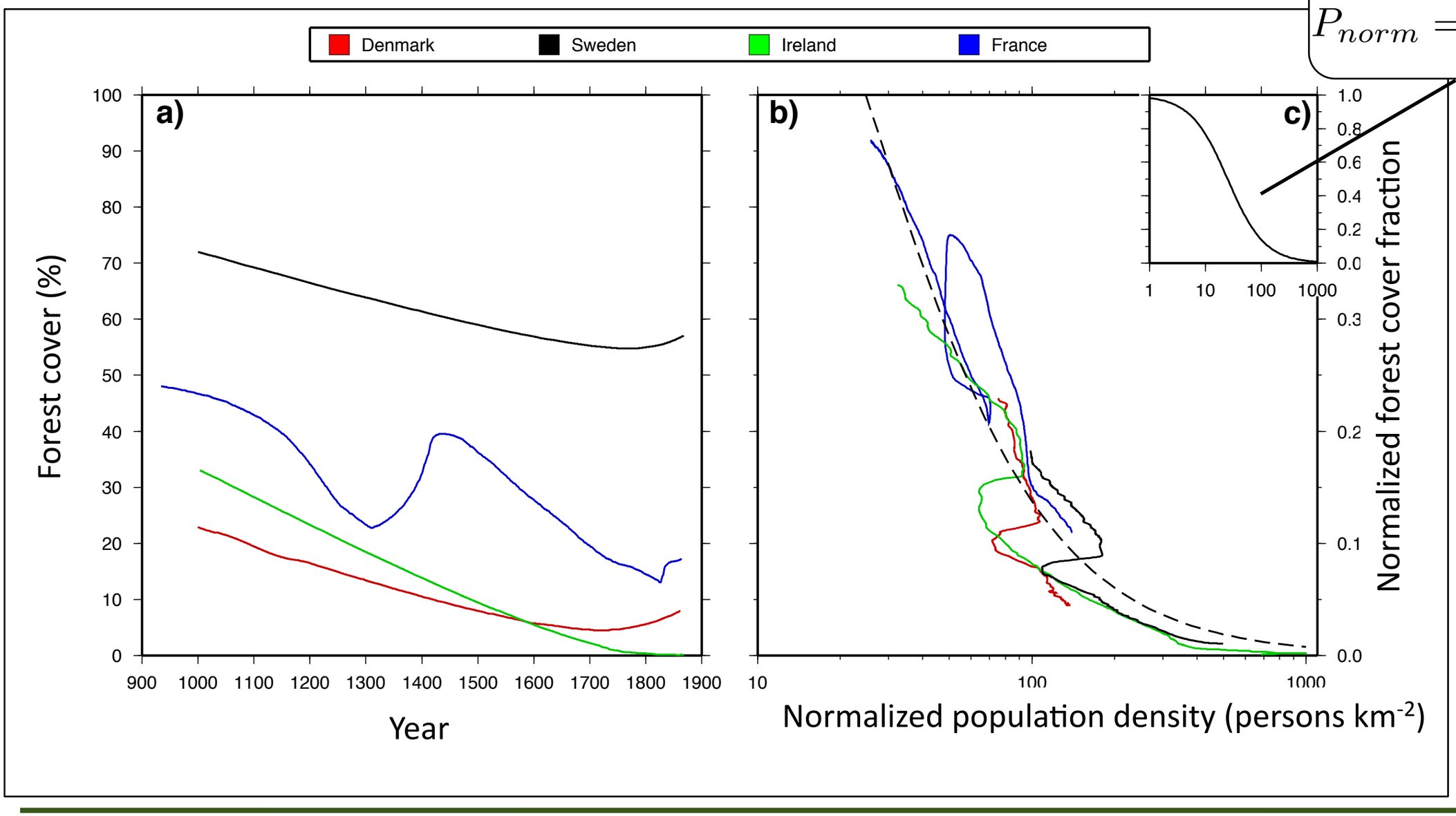
Why do we care about past land use?

- Land cover is an important part of the Earth System
- Human agency may have been one of the largest modifiers of the terrestrial surface over the Holocene (along with, e.g., climate, tectonics),
- This has important implications for current state and sensitivity of the Earth System
- However the subject is controversial and currently central to debates on the “undisturbed preindustrial” and the “anthropocene”

KK10: Empirical population:forest cover relationship

$$P_{norm} = \frac{0.9958}{1 + e^{b(c - FC_{norm})}}$$

sigmoidal relationship

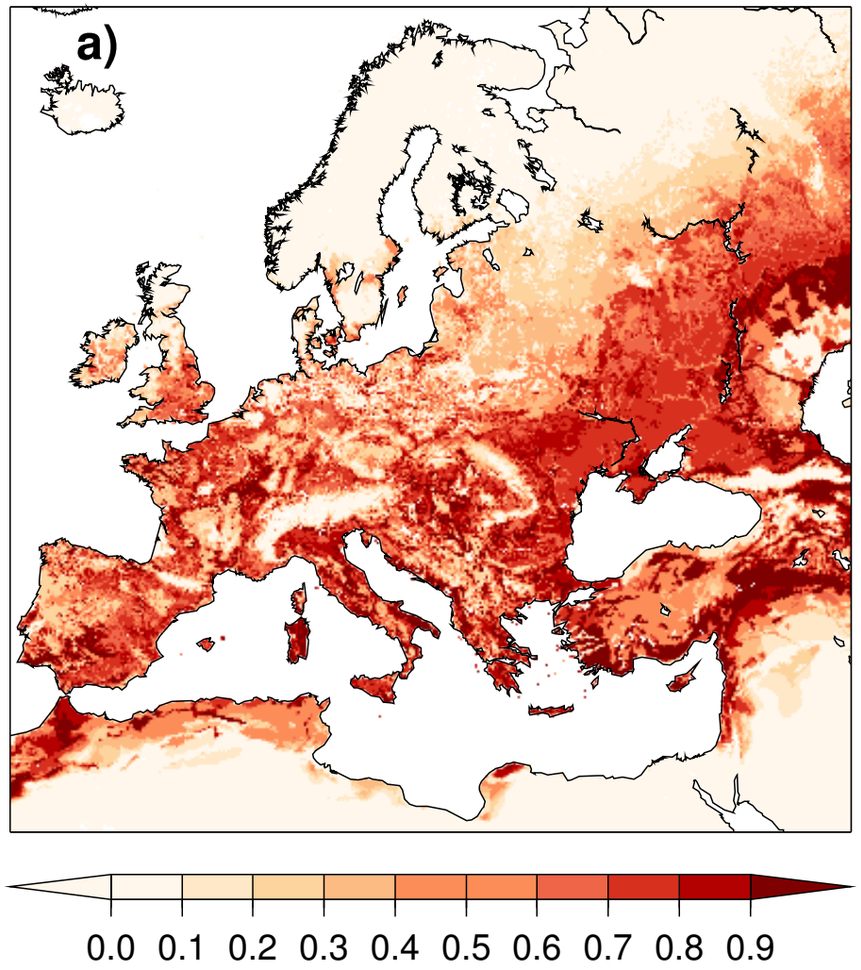


Normalized population density = $\frac{\text{population density on arable land}}{S_{crops}}$

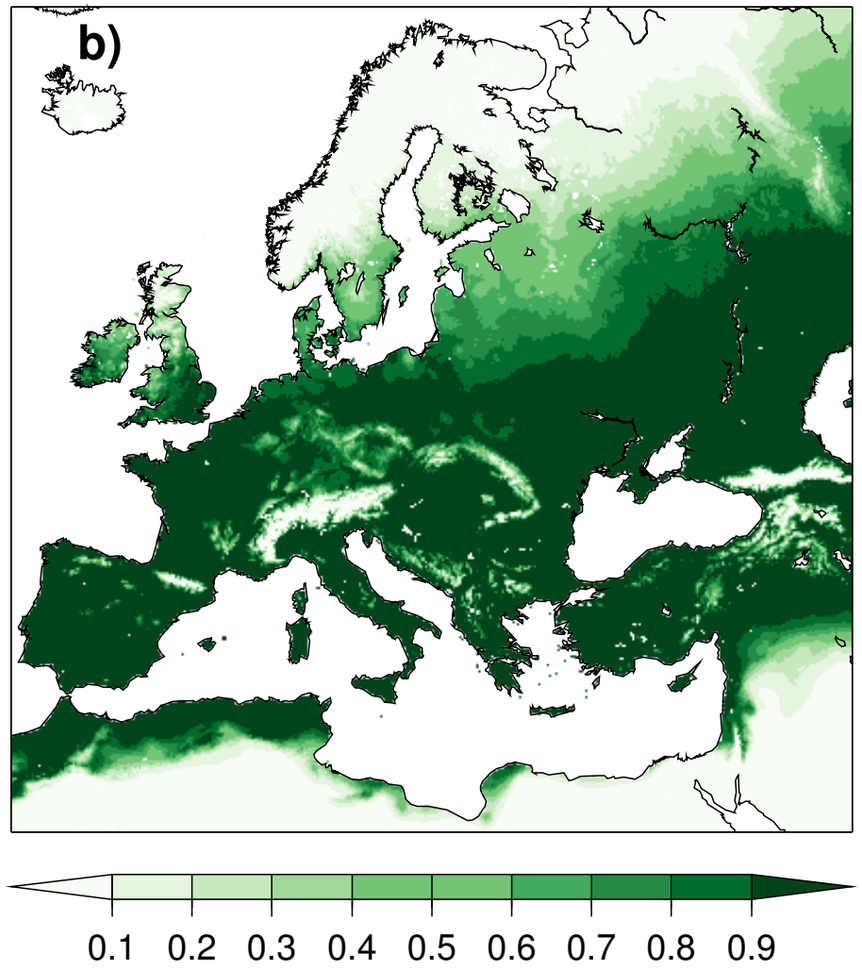
Normalized forest cover = Forest cover *only* on usable land (before forest transitions)

Bradshaw 2004, Mather et al. 1999, Kaplan et al., 2009

KK10: Empirical spatial distribution of land use



Land suitability for cultivation (S_{crops})



Land suitability for pasture (S_{usable})

To account for land under cultivation:

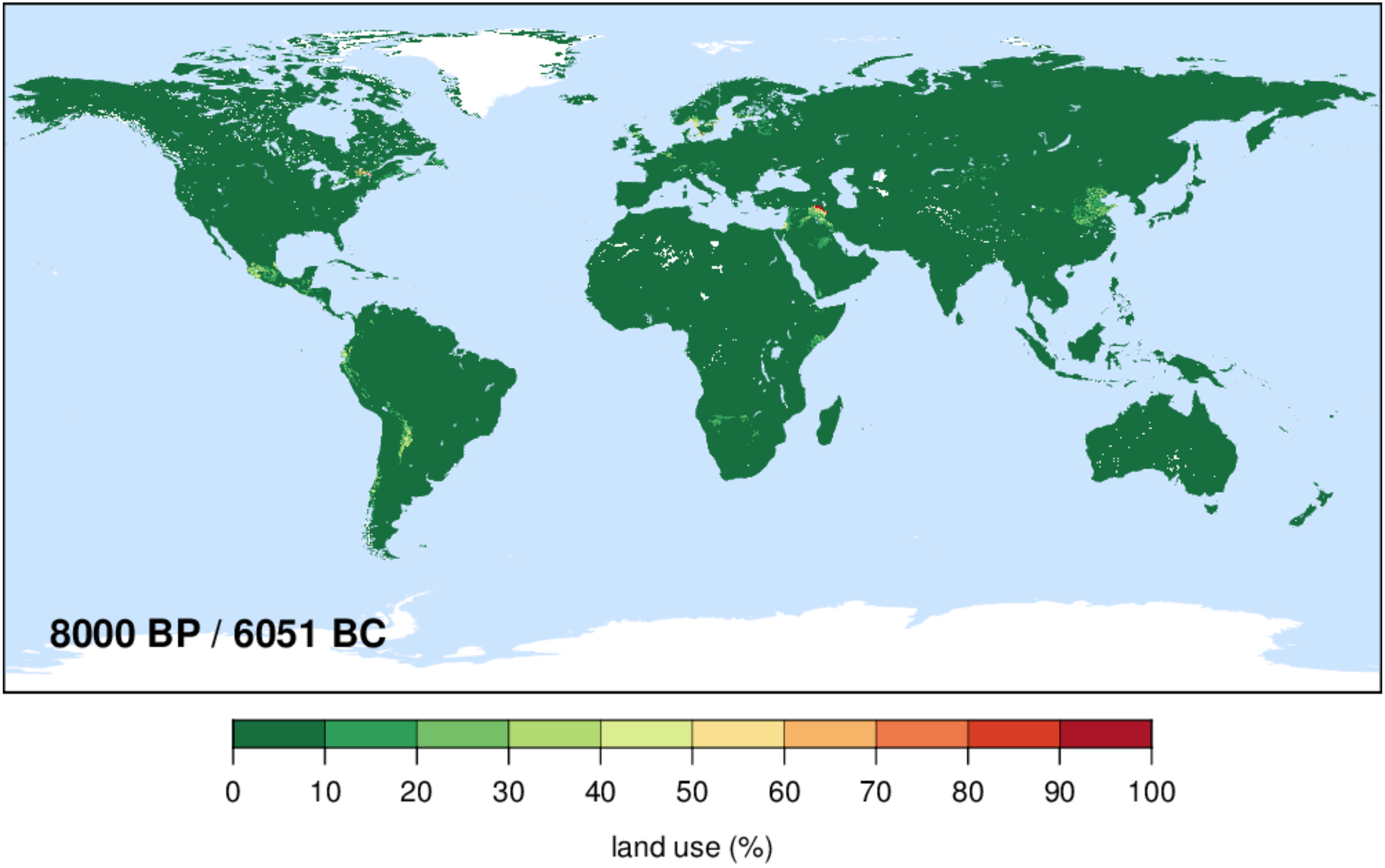
$$S_{crops} = f(\alpha) \times f(GDD) \times f(pH_{soil}) \times f(C_{soil})$$

To account for pasture and other forest uses:

$$S_{usable} = f(\alpha) \times f(GDD)$$

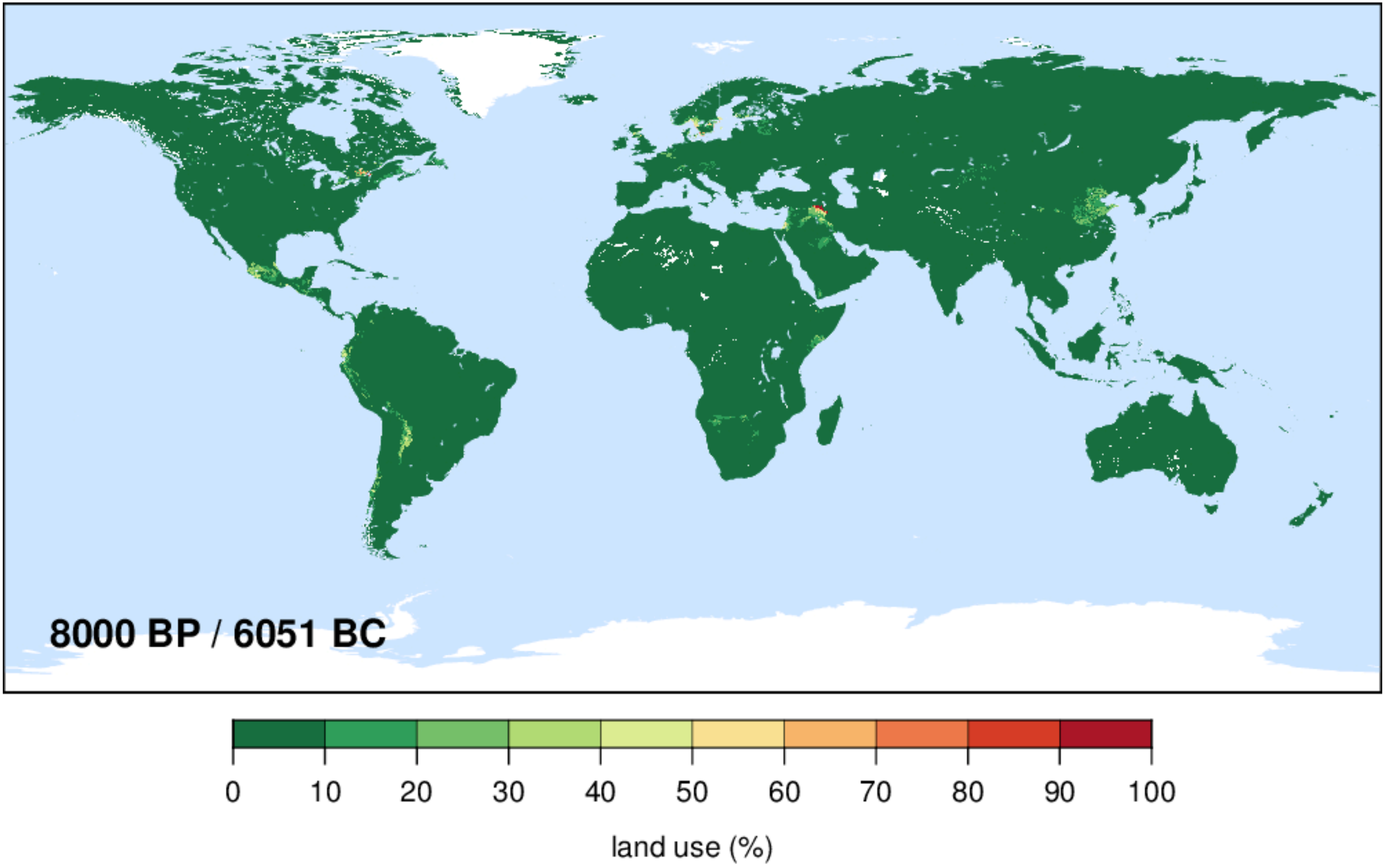
Kaplan *et al.*, *Quaternary Science Reviews*, 2009

Anthropogenic land cover change



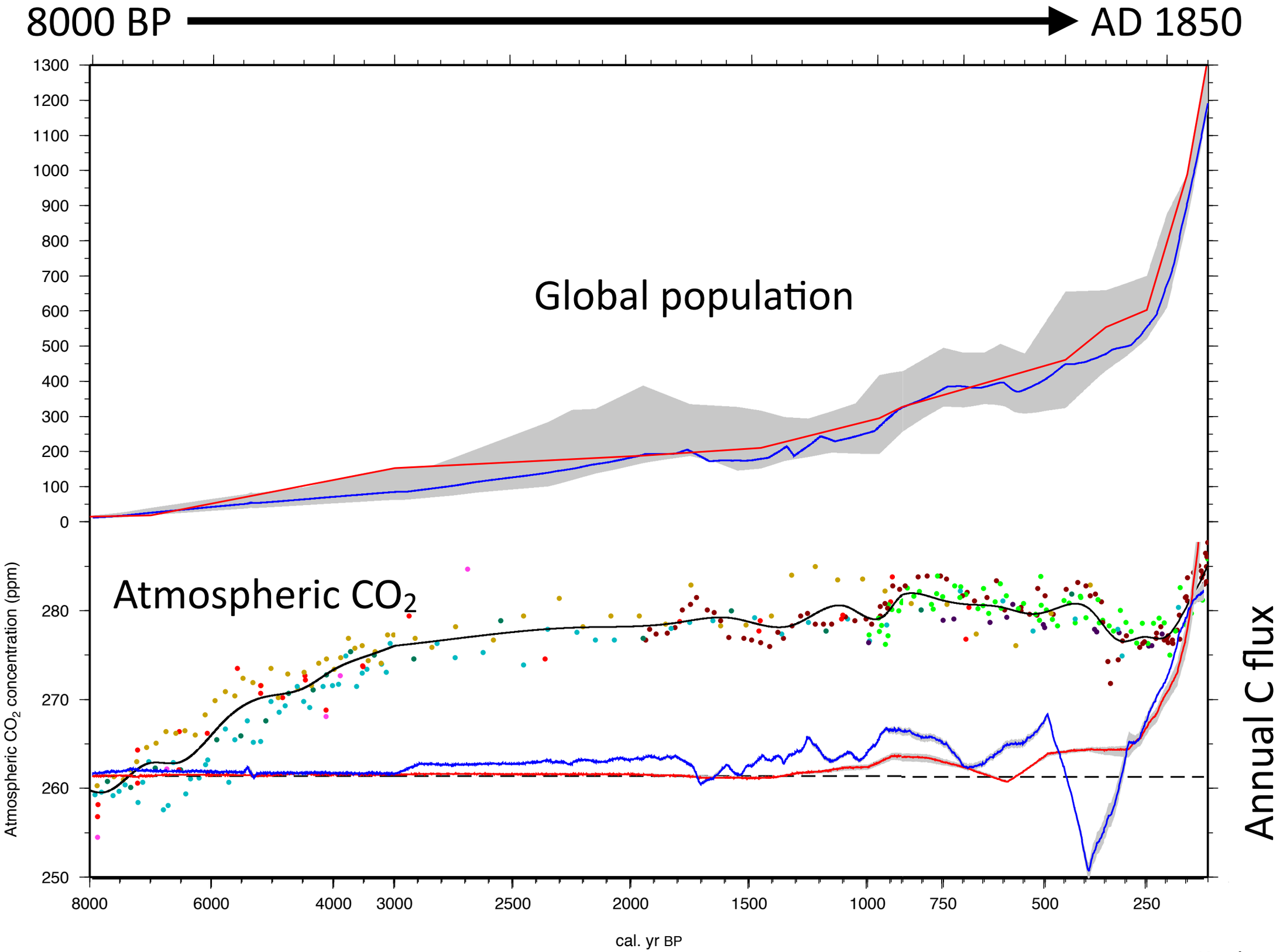
KK10 scenario, Kaplan et al., *The Holocene*, 2011

Anthropogenic land cover change



KK10 scenario, Kaplan et al., *The Holocene*, 2011

Holocene Population and Atmospheric CO_2



Kaplan *et al.*, 2011

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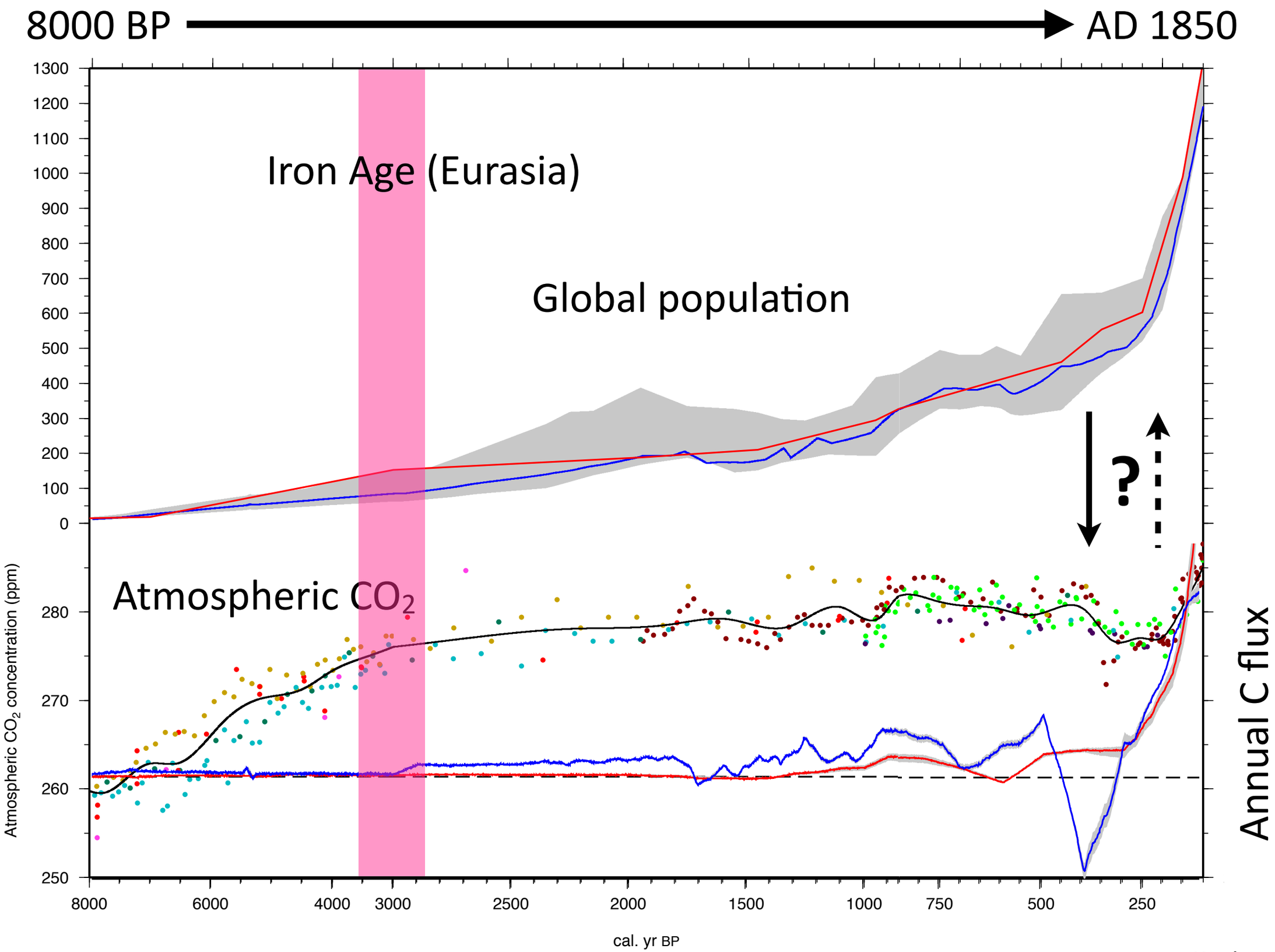
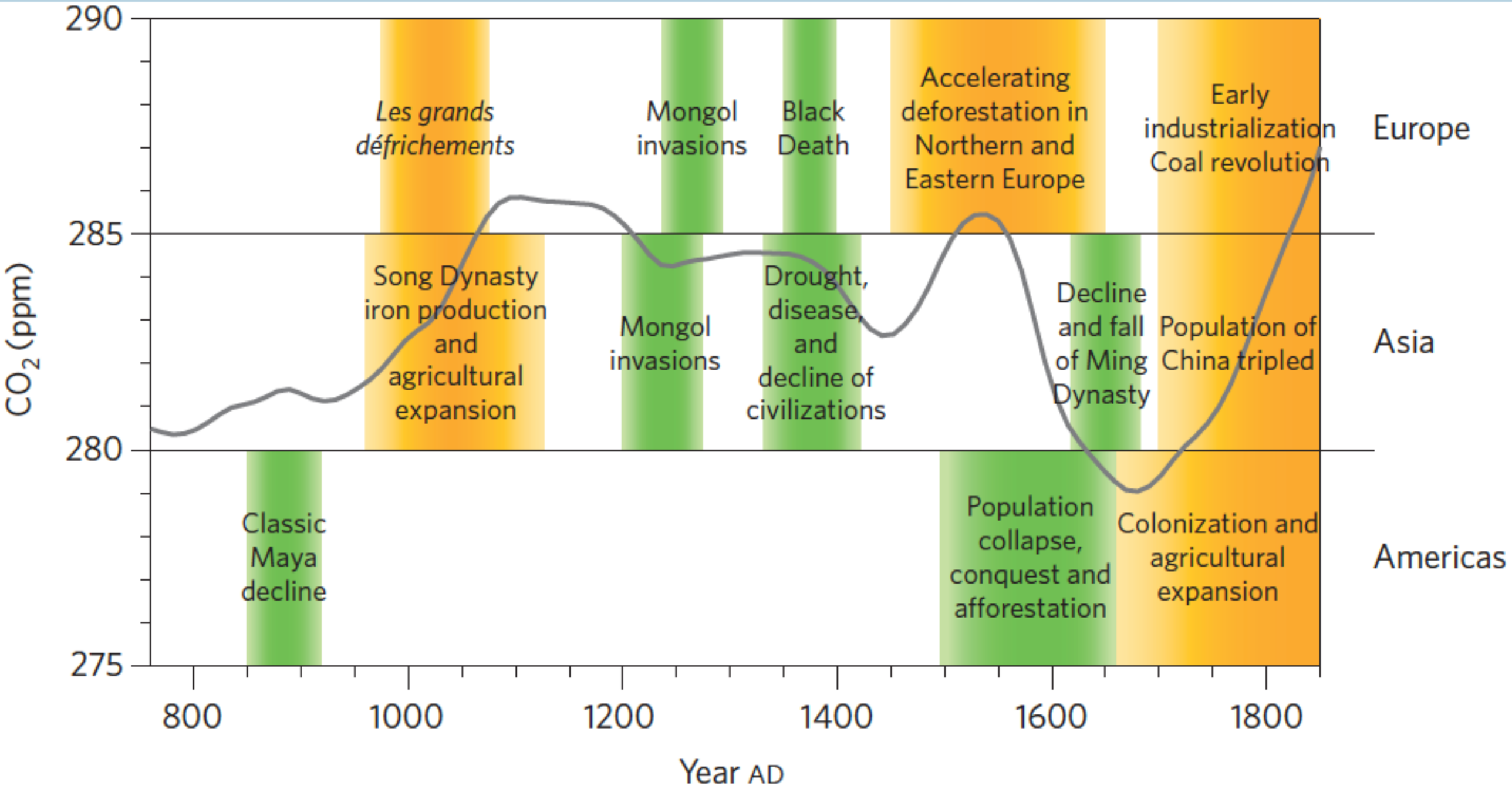


Kaplan *et al.*, 2011

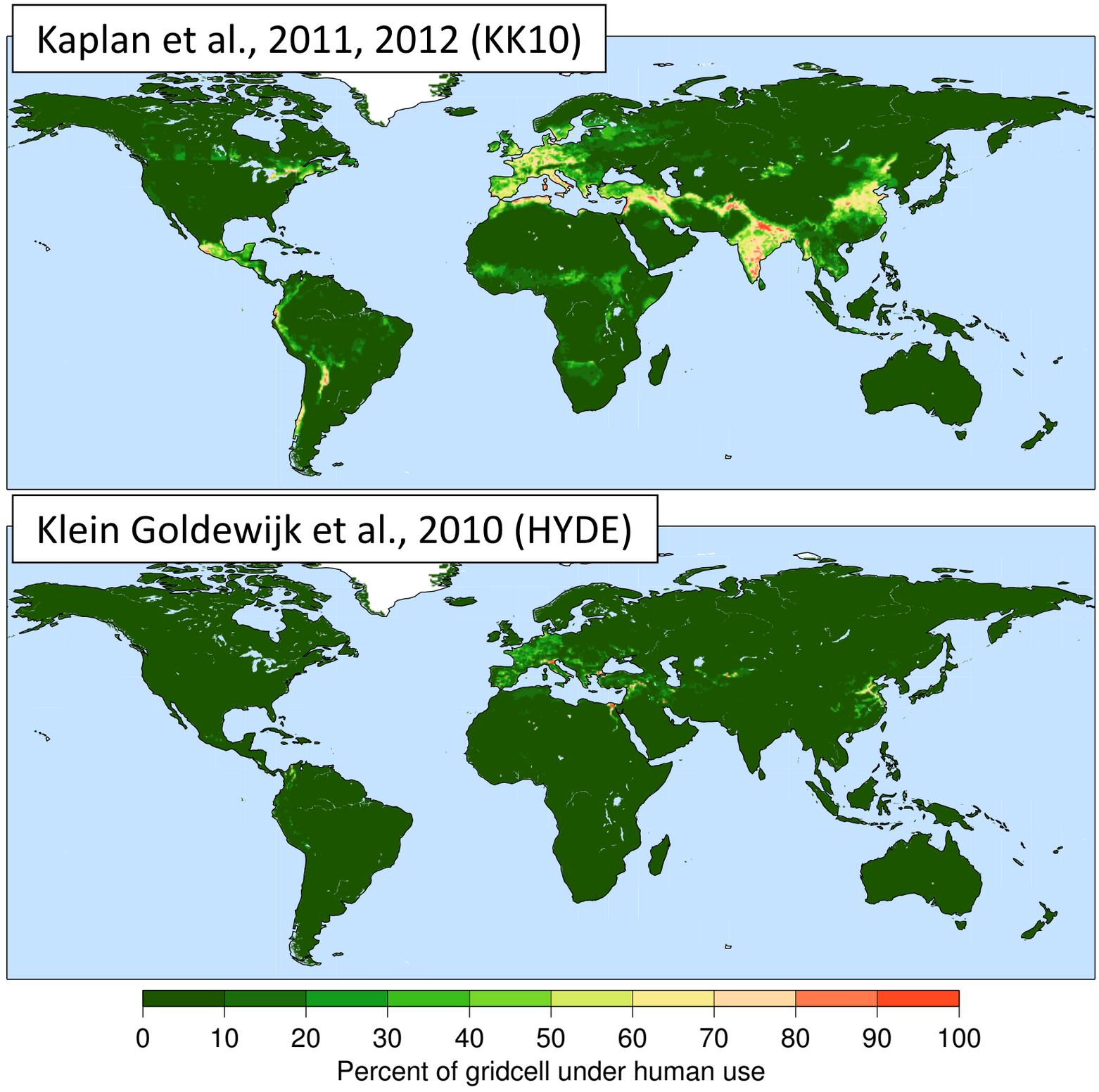
CO_2 and human history



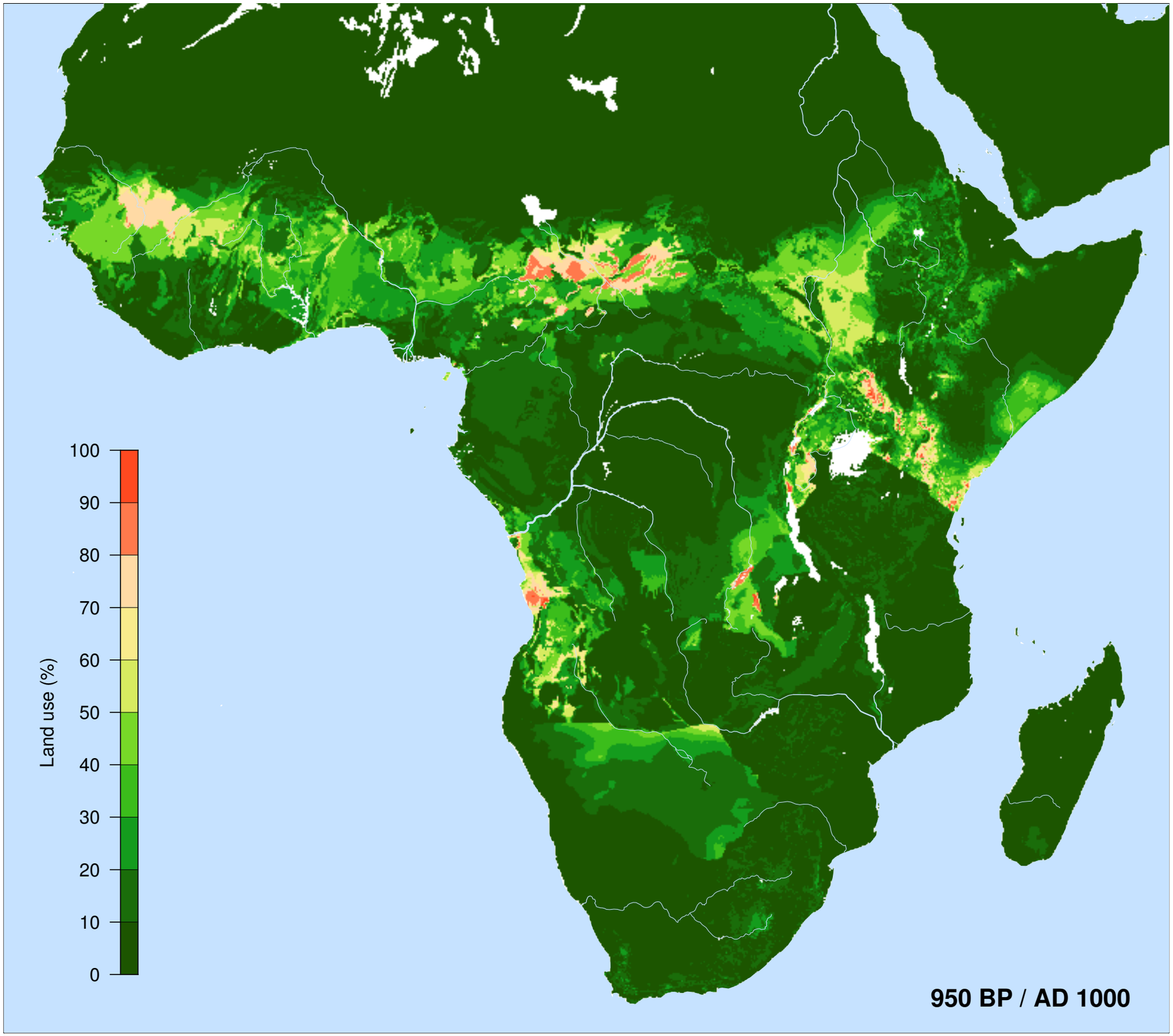
Kaplan, *Nature Geoscience*, 2015

Current land use scenarios disagree

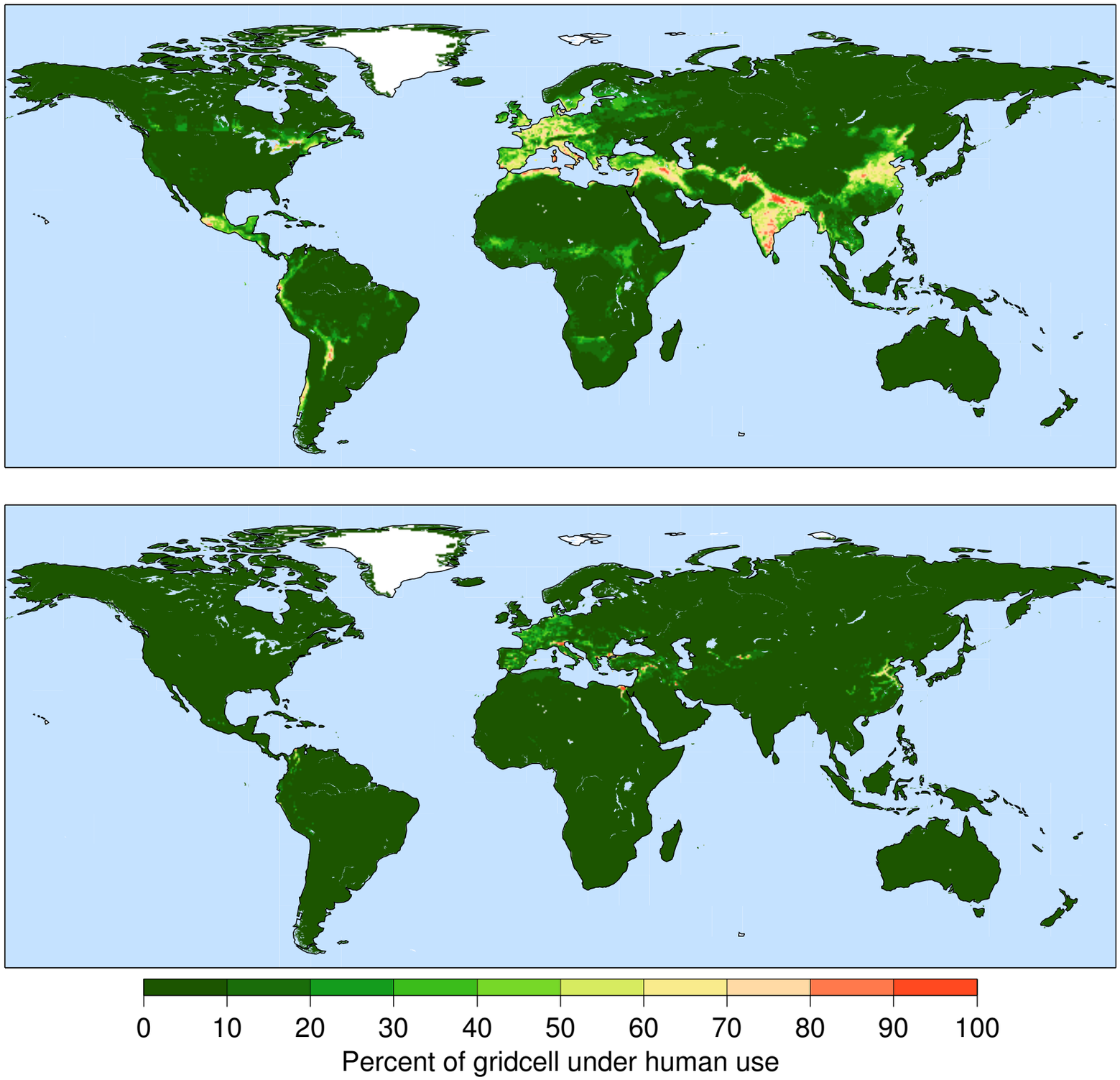
e.g., AD 1
Roman Period



Problems at finer scale

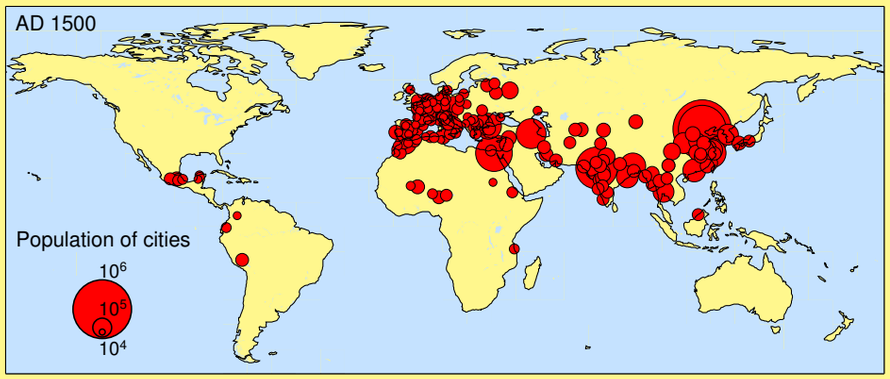


One way forward

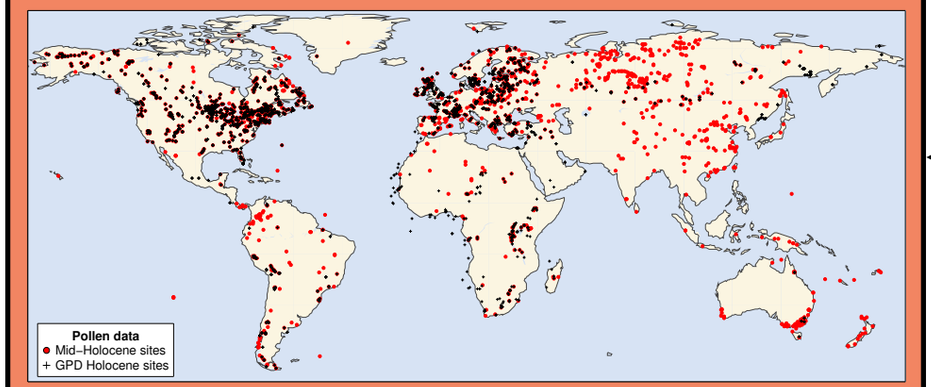


One way forward

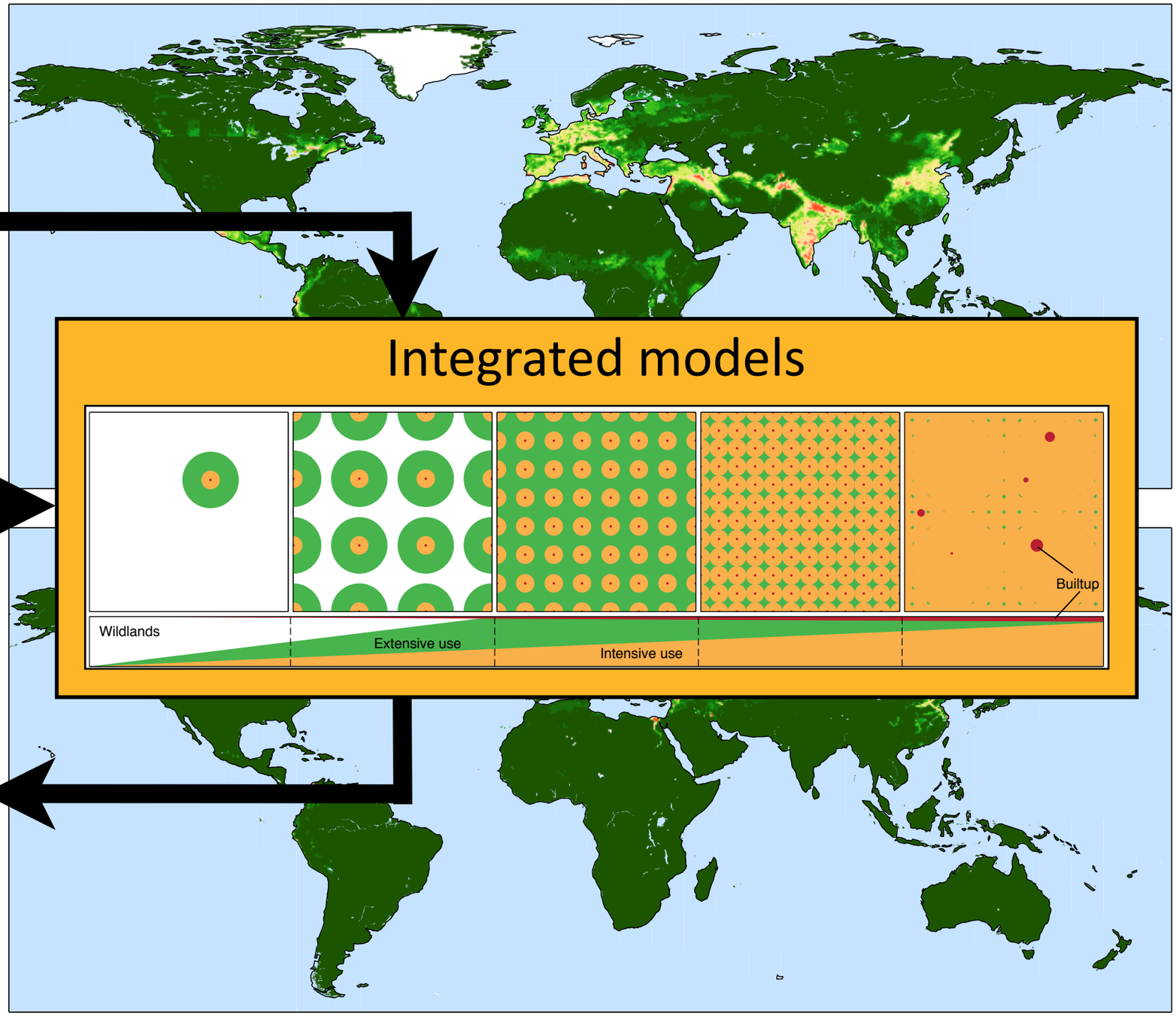
Socioeconomic history



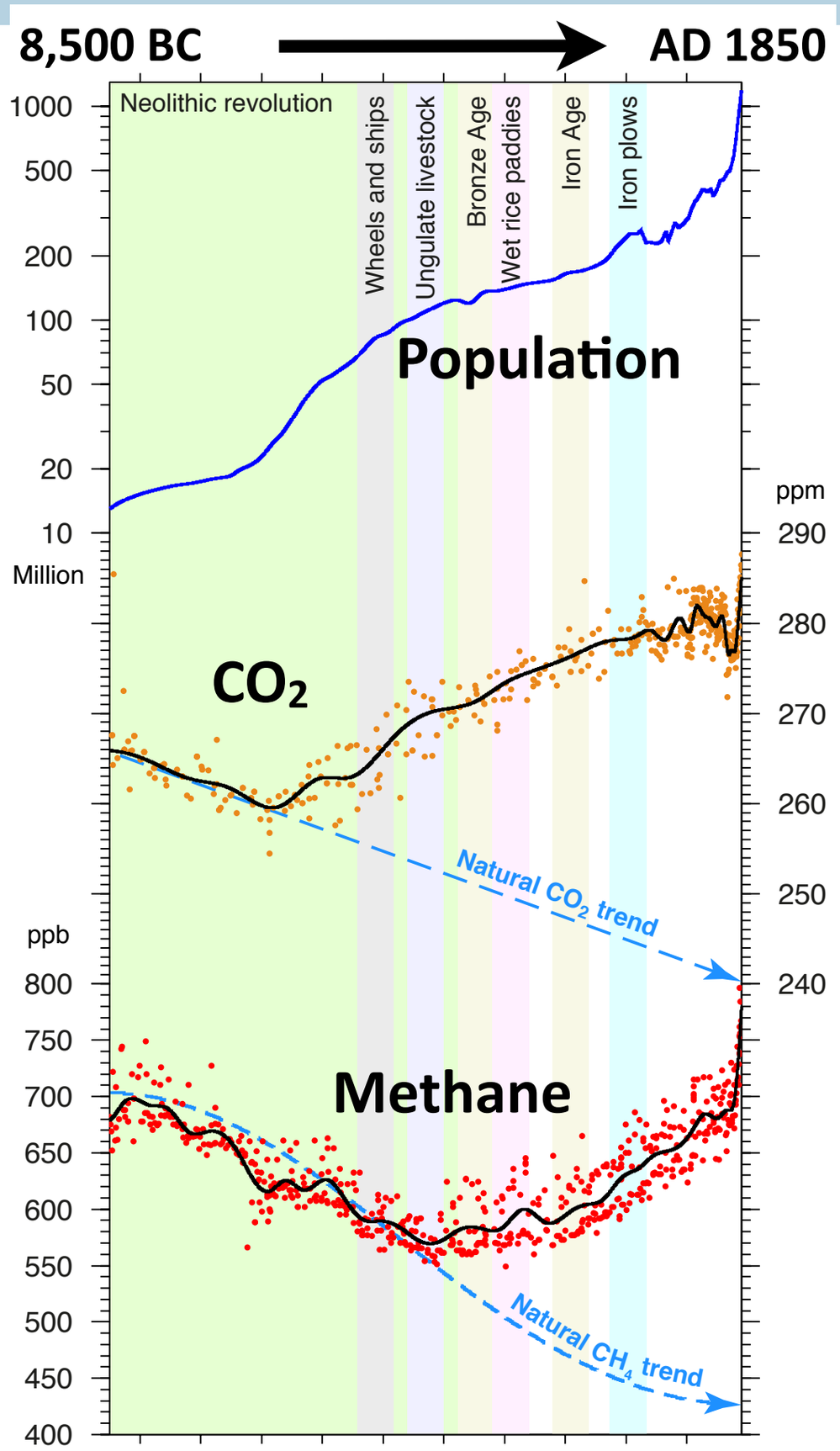
Paleoenvironmental archives



Integrated models



Human activities emit greenhouse gases



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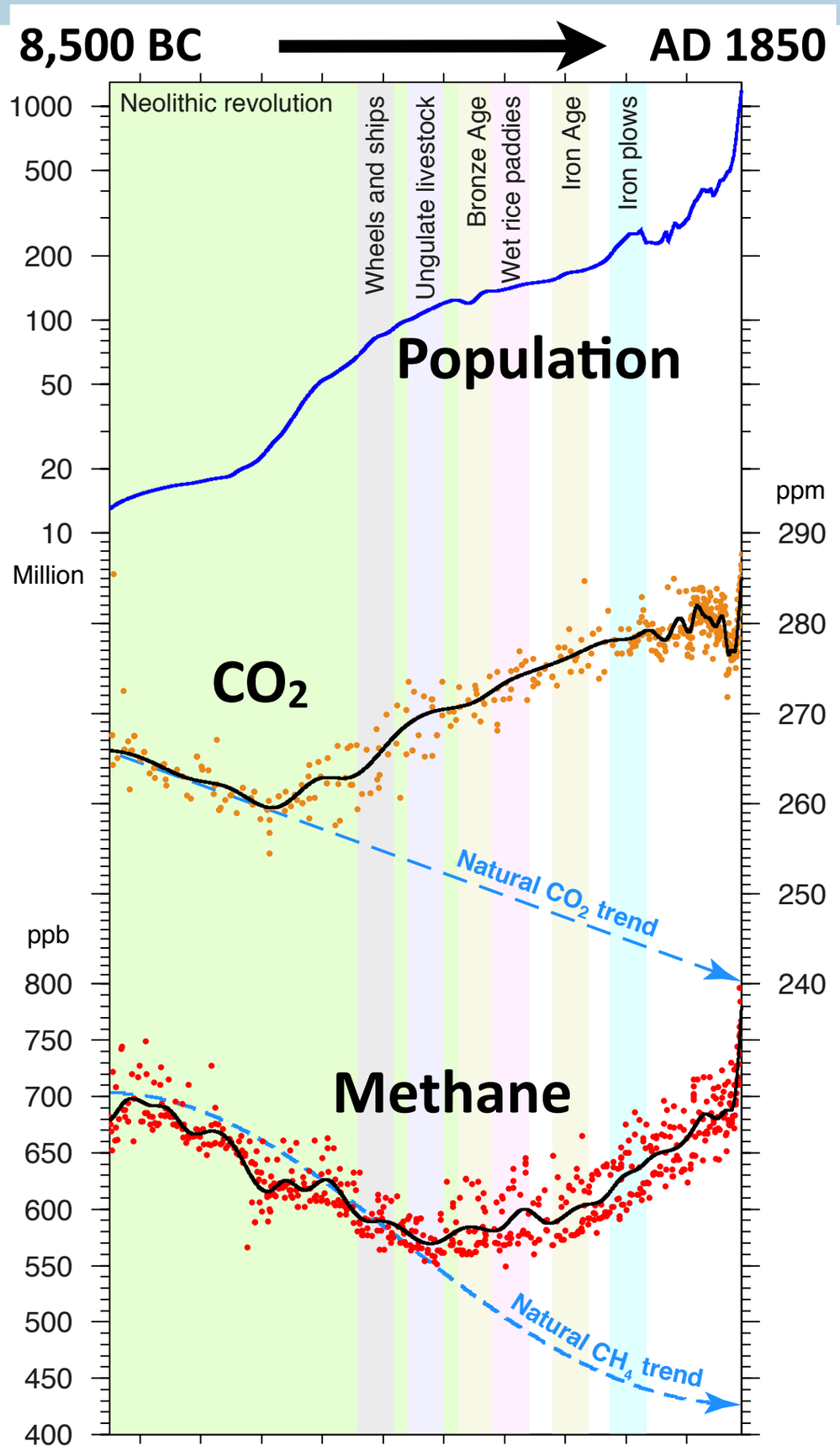

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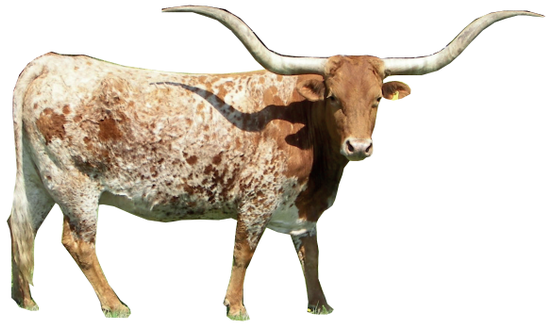

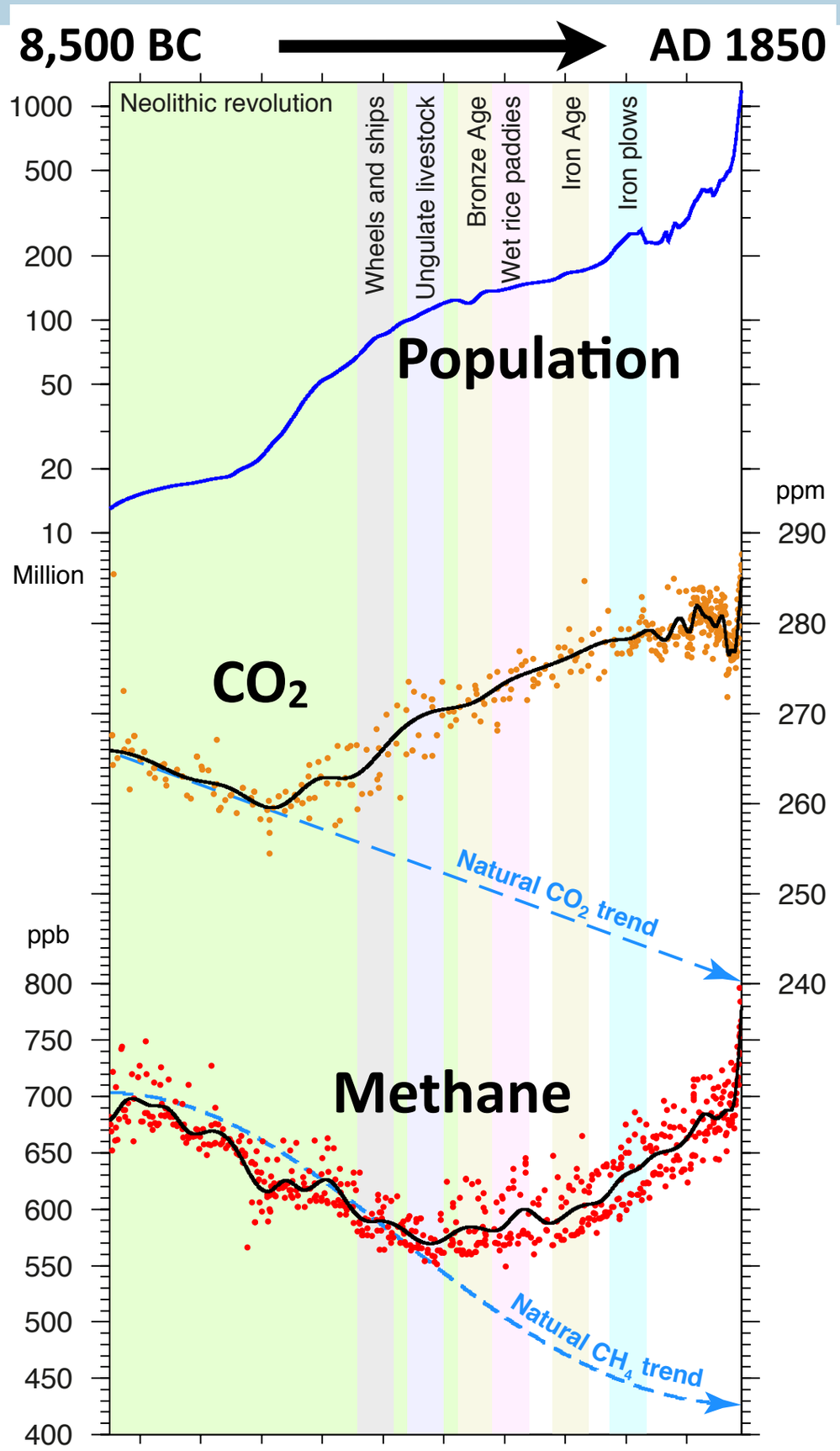

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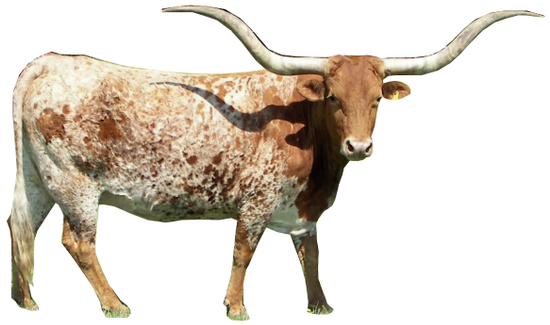

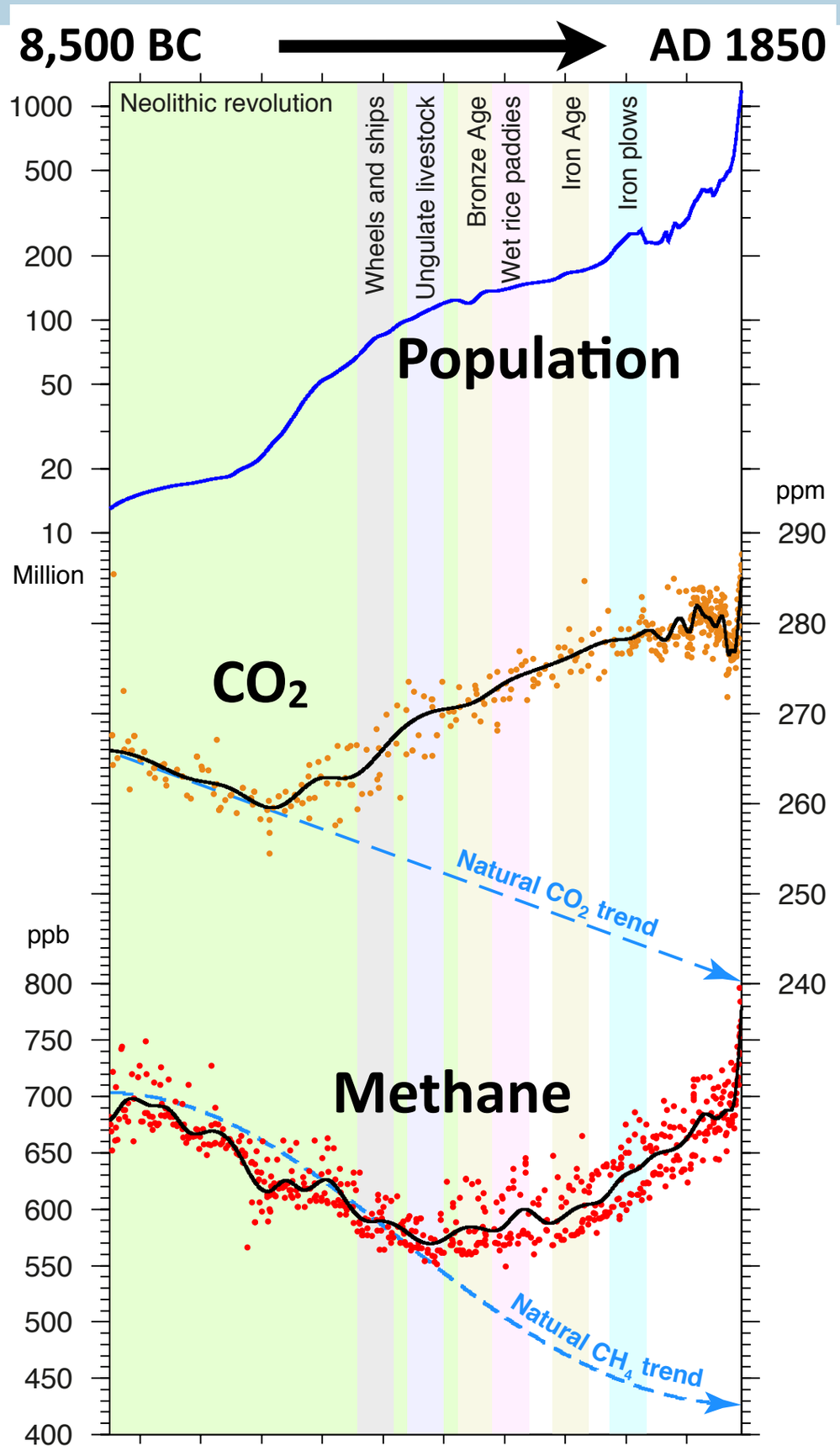

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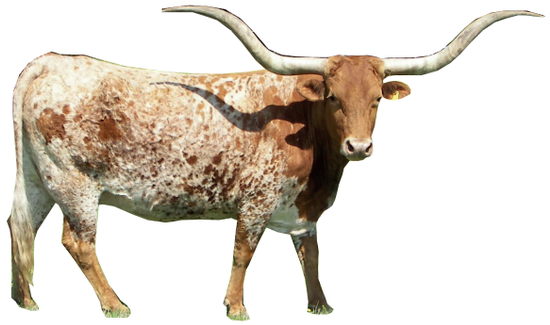

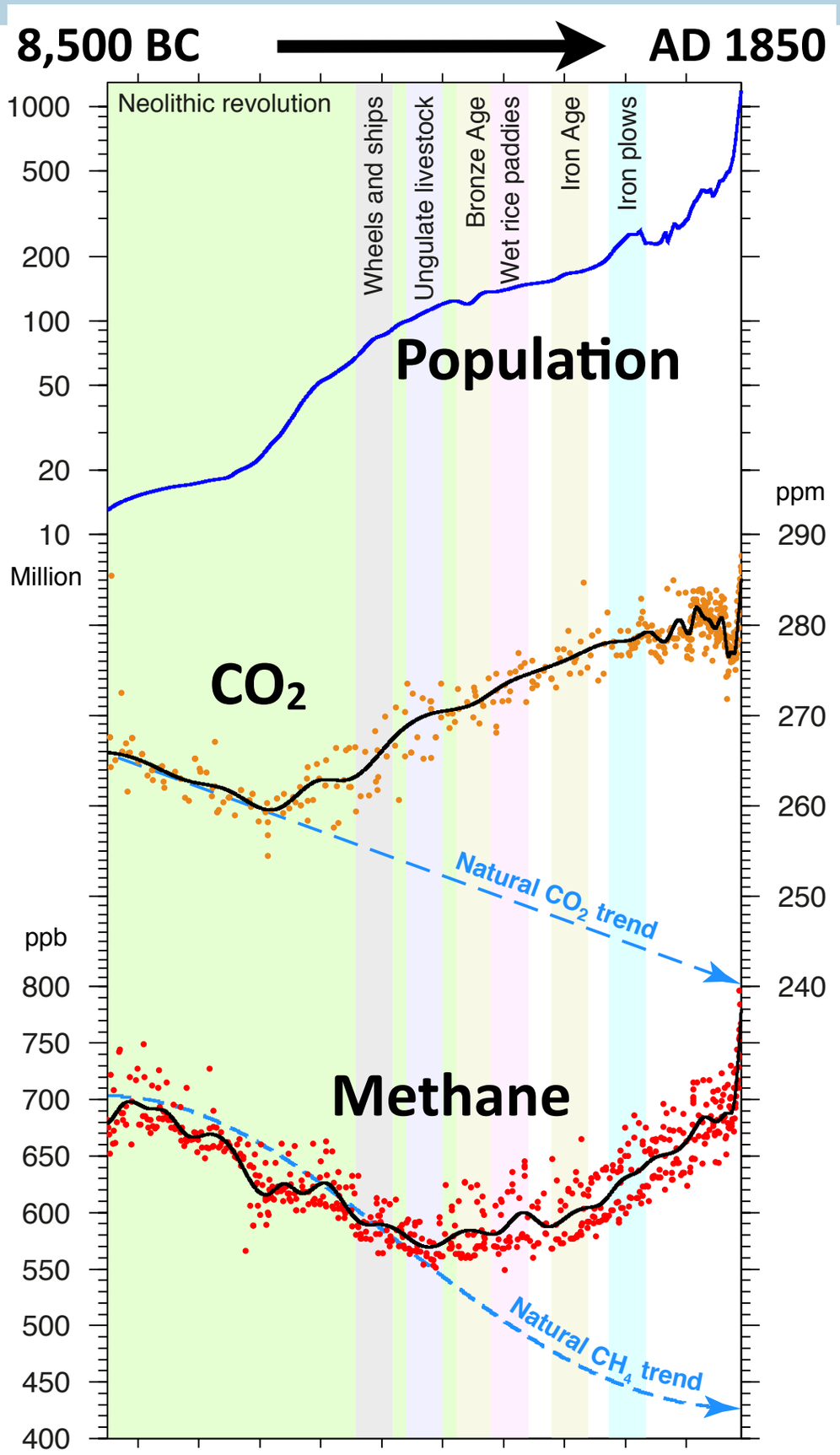

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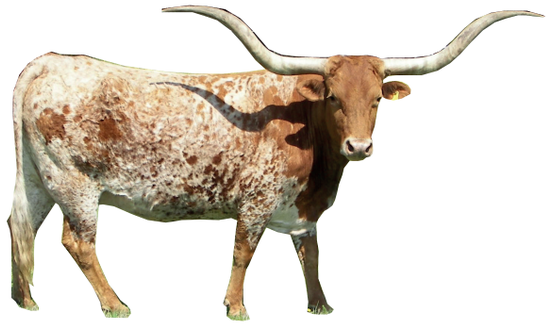
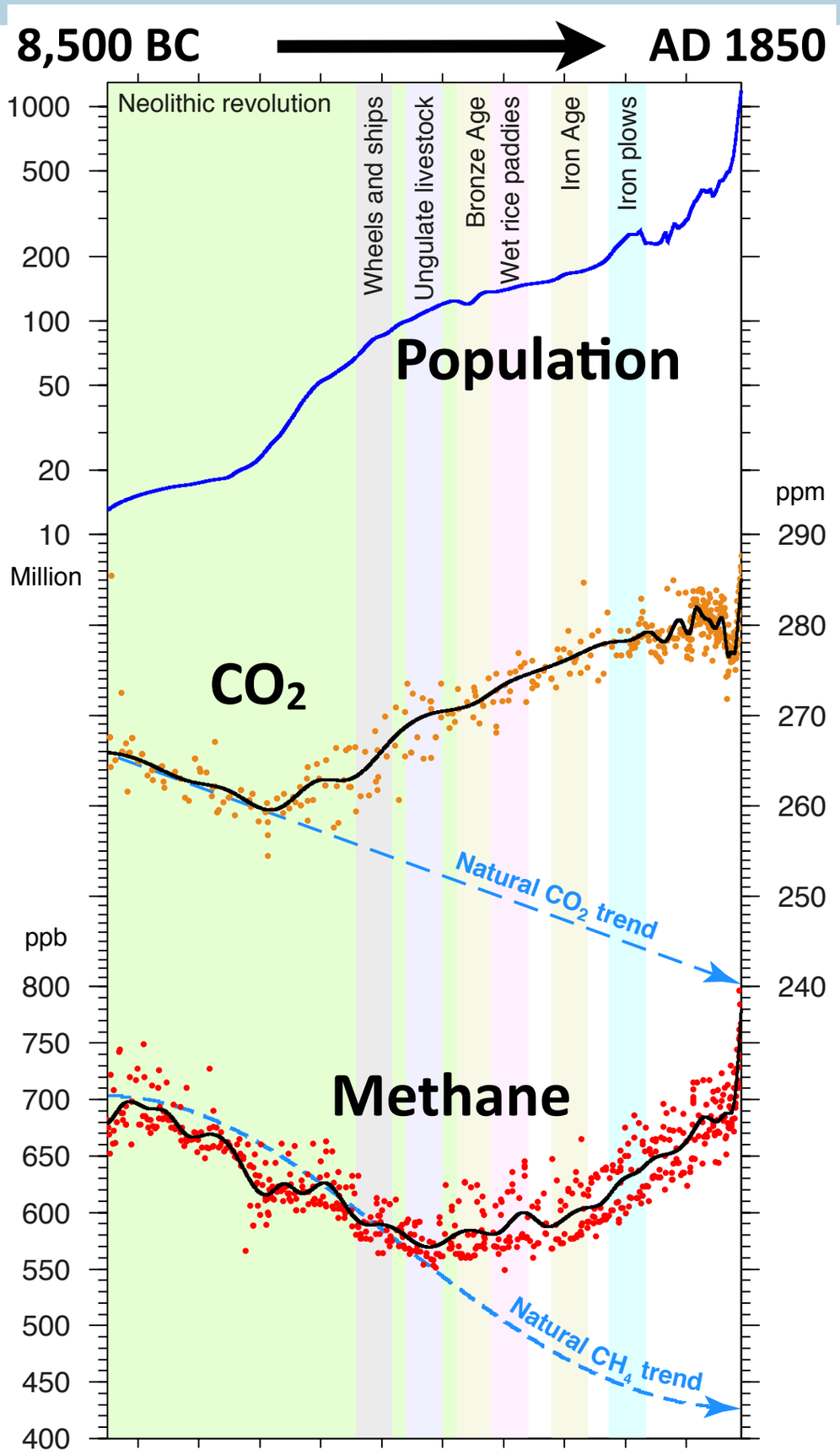
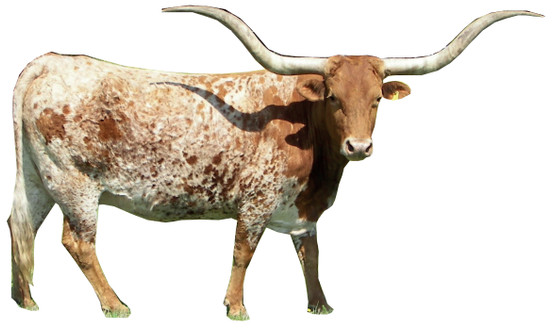
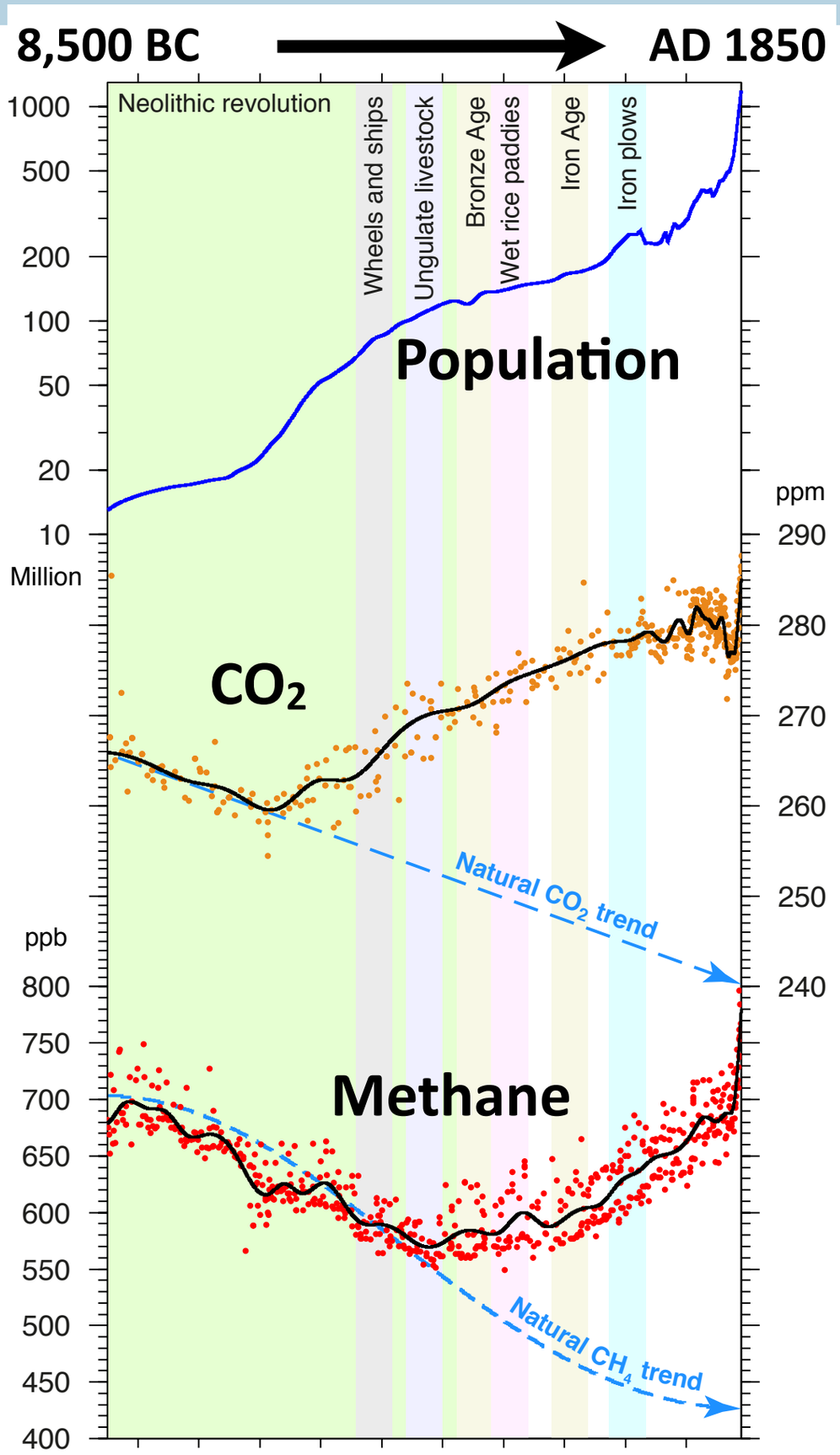




Human activities emit greenhouse gases

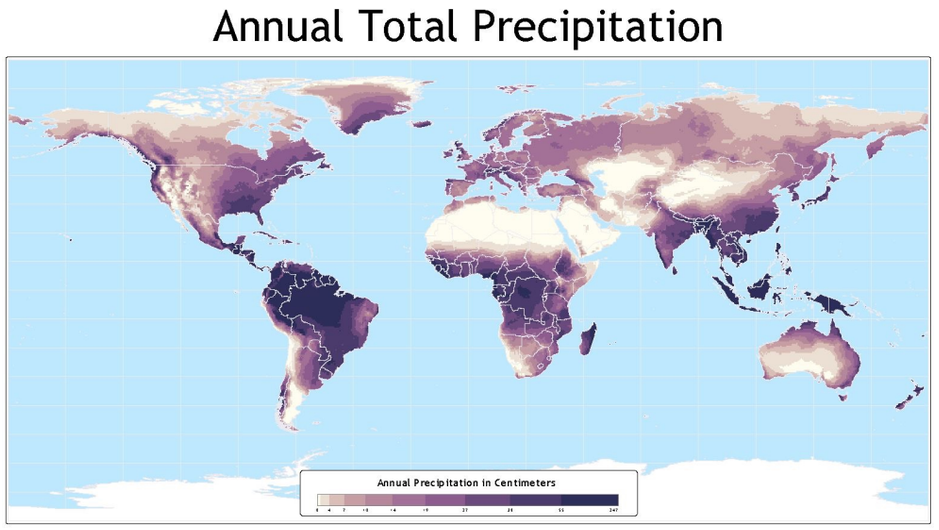




What can we predict on the basis of environment?

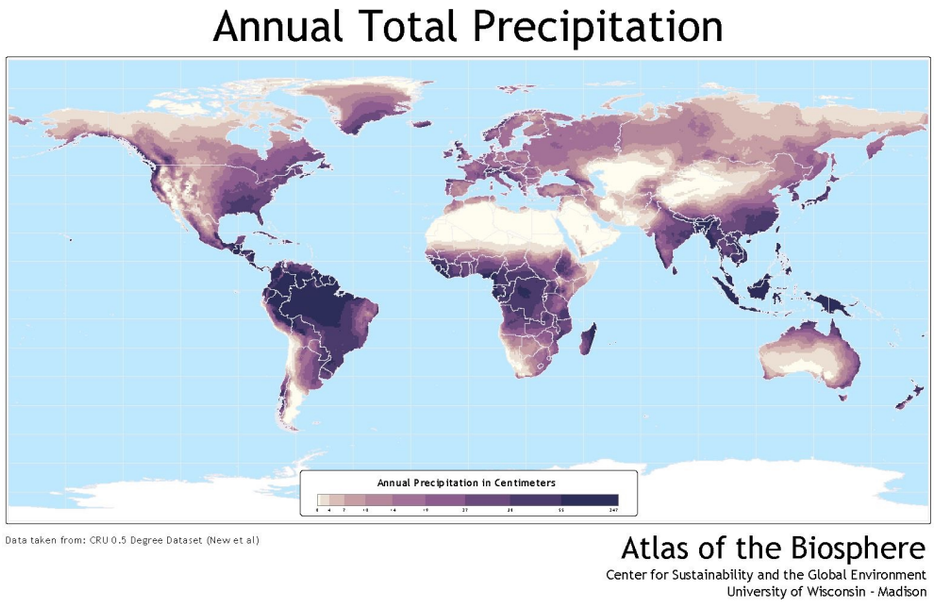
- Terrain suitability for cultivation
  - slope/aspect
  - chemical properties of the soil

What can we predict on the basis of environment?



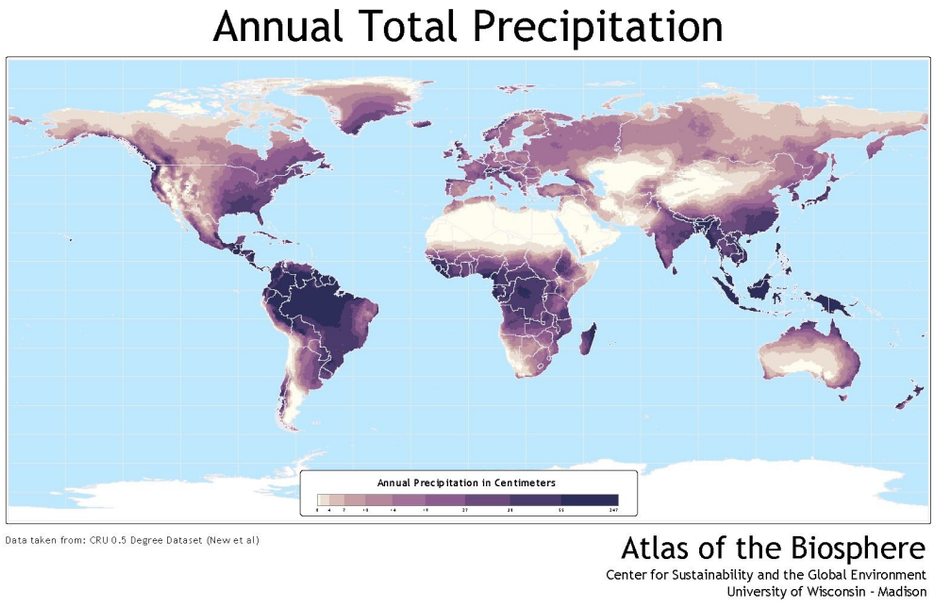
What can we predict on the basis of environment?

- Long-term soil fertility



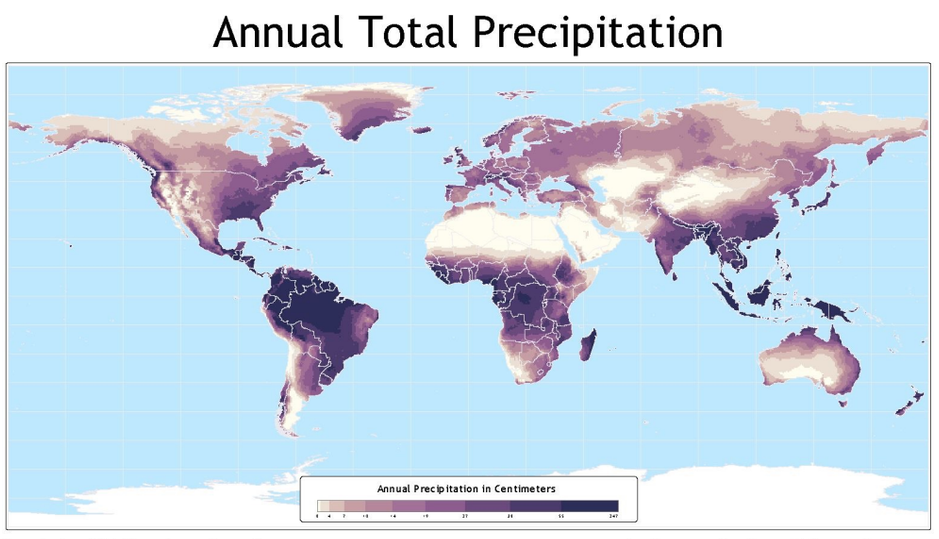
What can we predict on the basis of environment?

- Long-term soil fertility
- Water resources



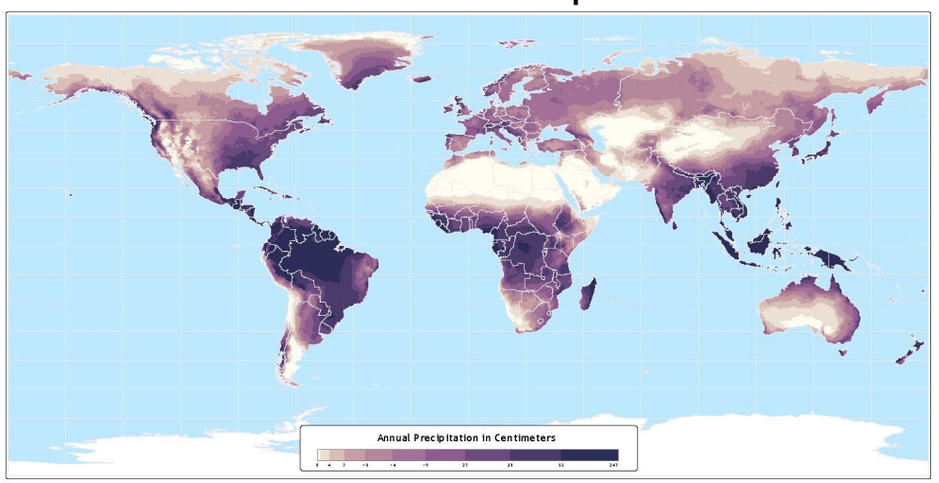
What can we predict on the basis of environment?

- Long-term soil fertility
- Water resources
- Microclimate and potential vegetation

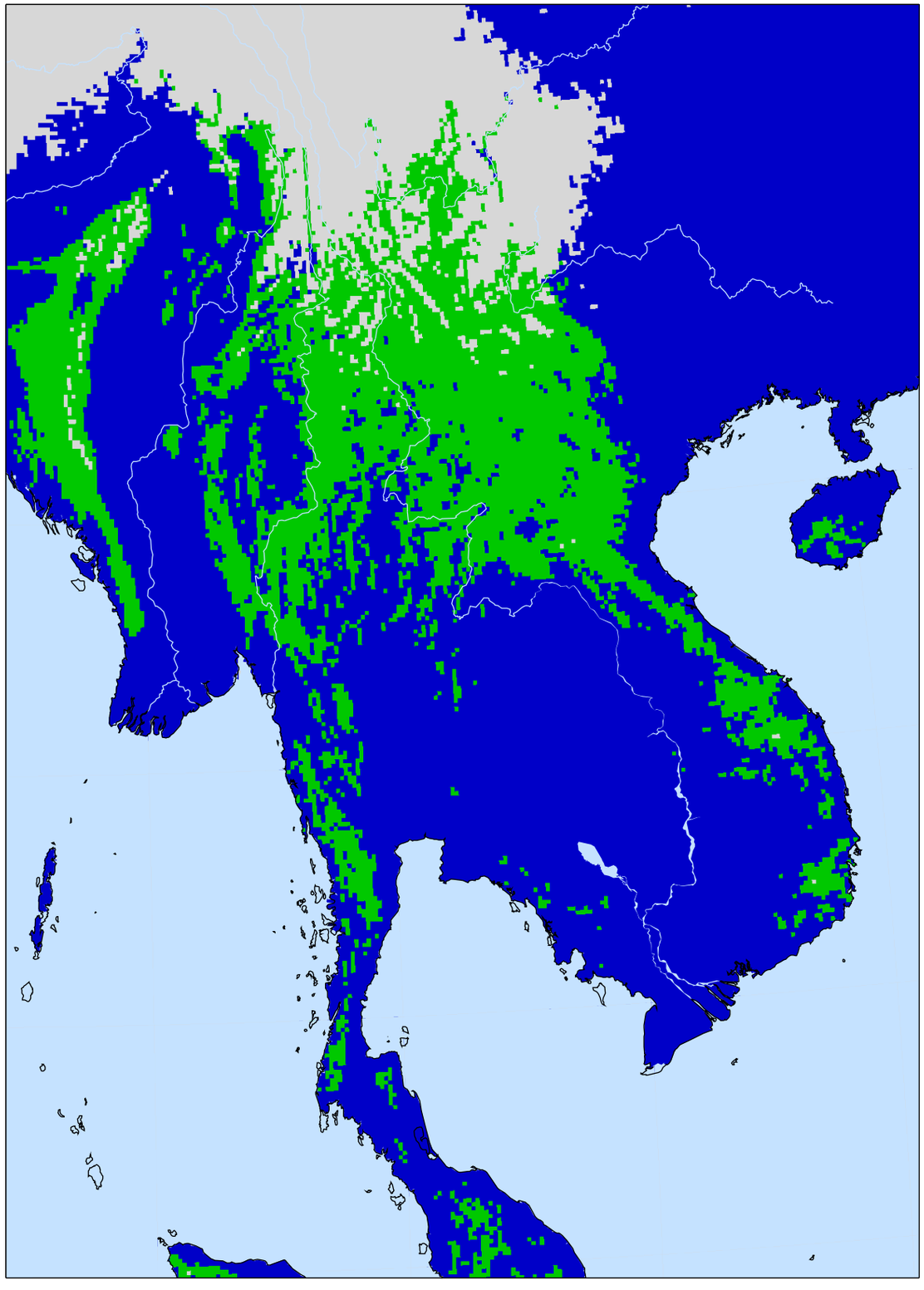


What can we predict on the basis of environment?

- Long-term soil fertility
- Water resources
- Microclimate and potential vegetation
- Species suitable for cultivation



Physical suitability for rice cultivation



Upland rice

Wetland rice

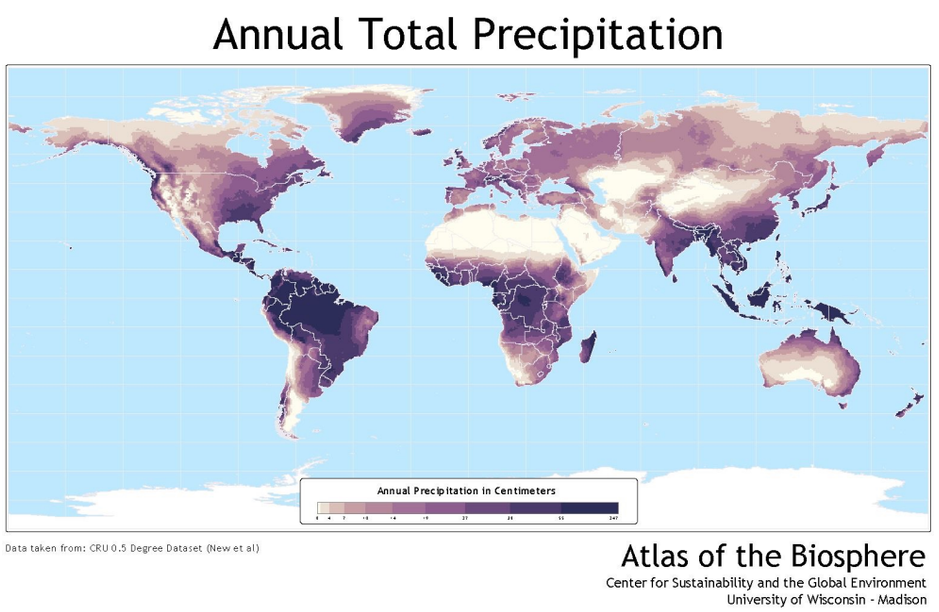
Rice cultivation not possible

Based on FAO GAEZ
Kaplan et al., *in prep*.

What can we predict on the basis of environment?

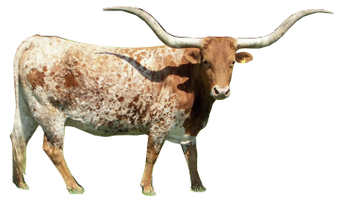
- Long-term soil fertility
- Water resources
- Microclimate and potential vegetation
- Species suitable for cultivation

- **Crop yield**, variability, vulnerability, etc…

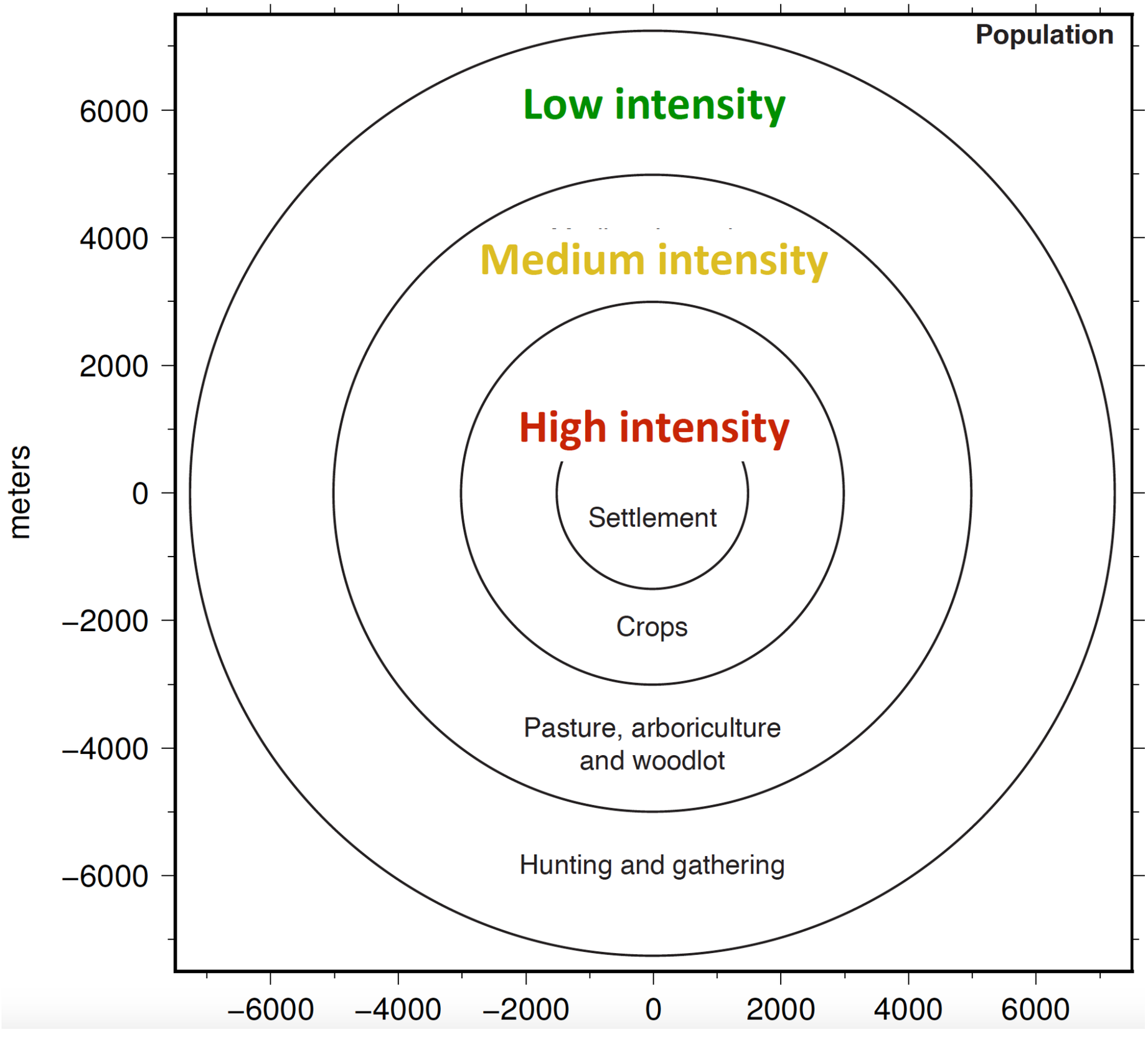


What **cannot** be predicted on the basis of environment?

- Subsistence livelihood and diet
- Technology
  - Tools: stone, bronze, iron, etc.
  - Ceramics and primary construction materials
  - Transport: Draft animals, wheel, etc.
  - Irrigation
- Social organization
  - Settlement size and distribution
  - Tribute and trade



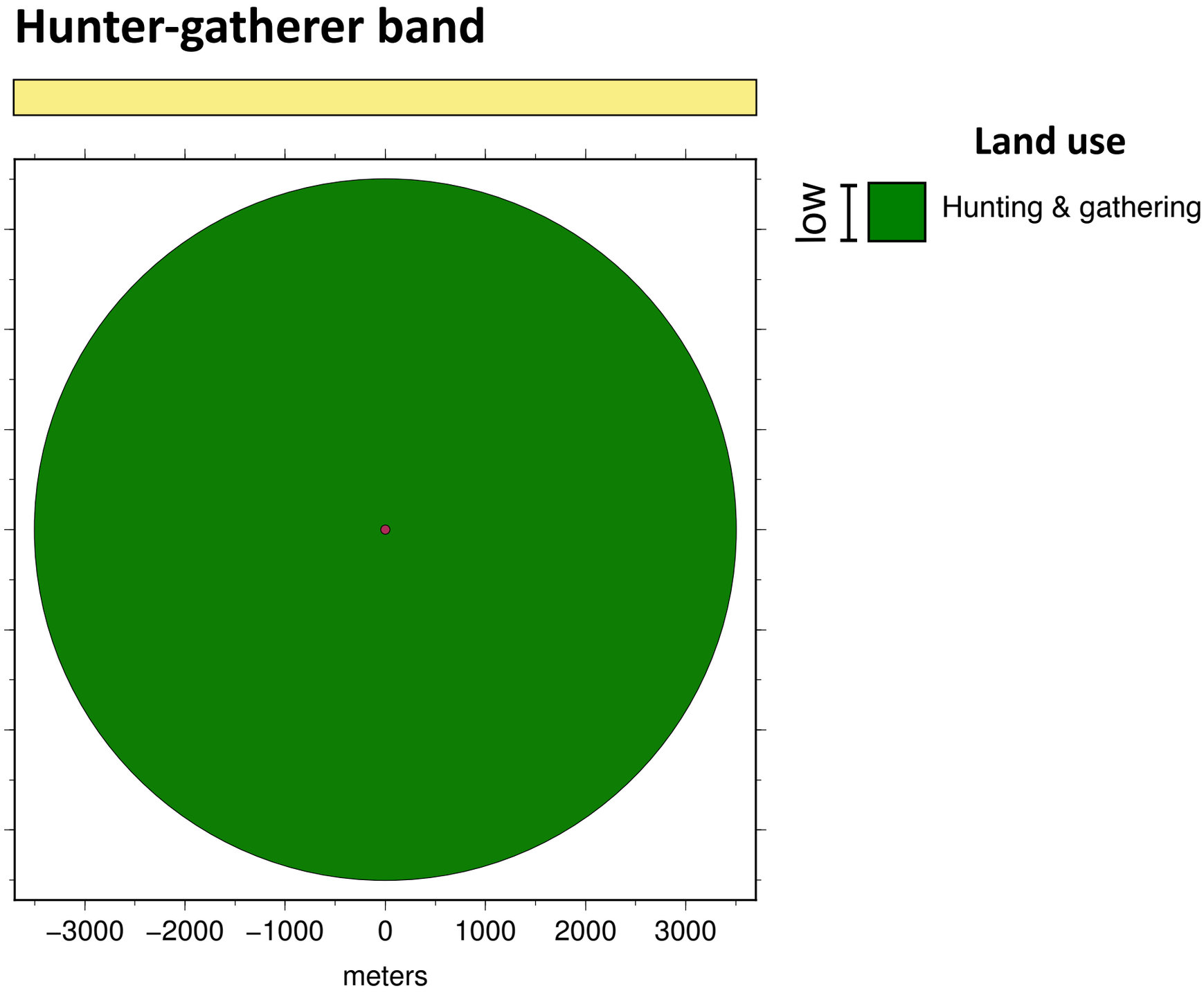
(1) Subsistence livelihood, diet, and land use



Subsistence livelihood, diet, and land use

Number of individuals: 5

Diet: 100% wild game and plants



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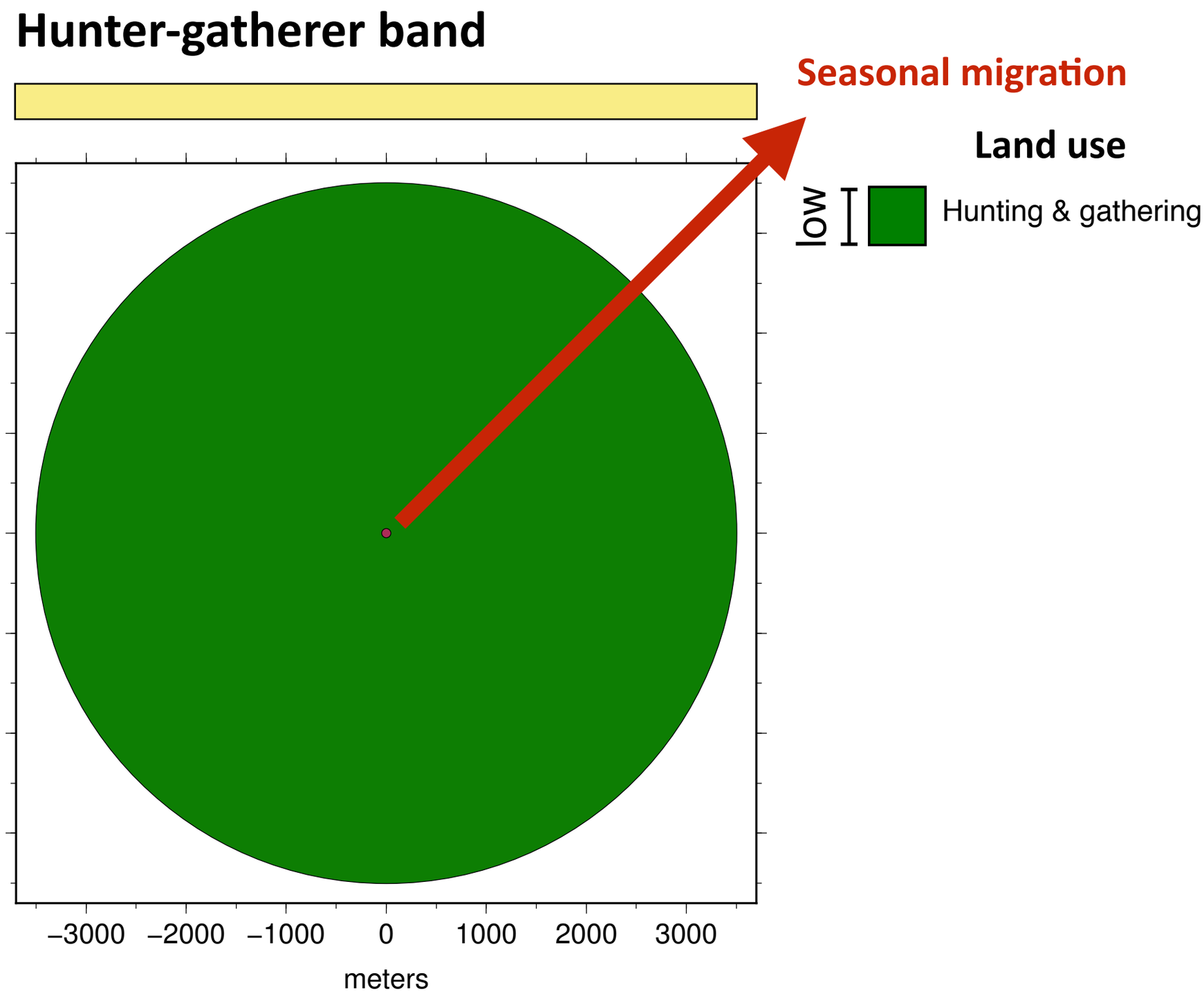
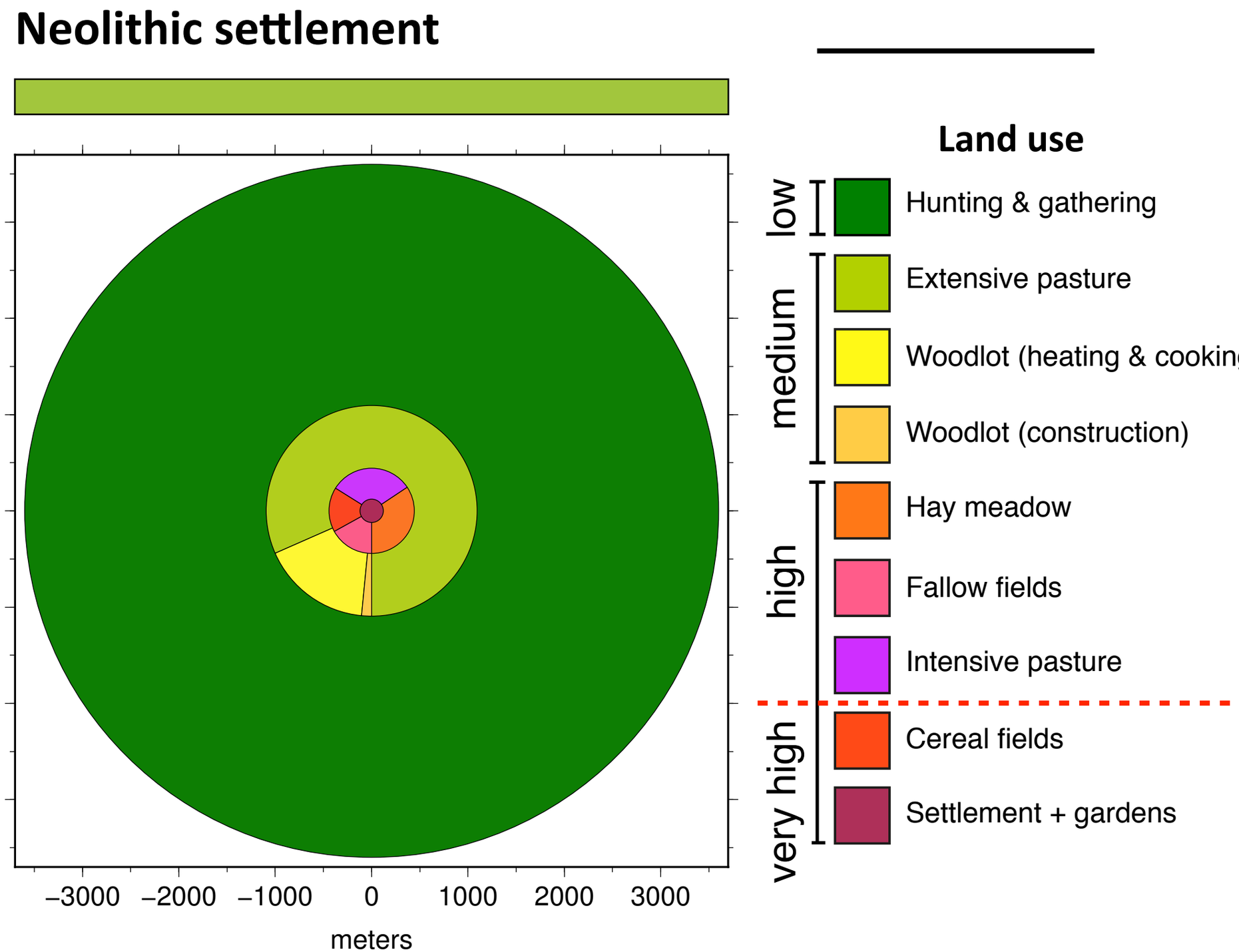


Subsistence livelihood, diet, and land use

Number of individuals: 34

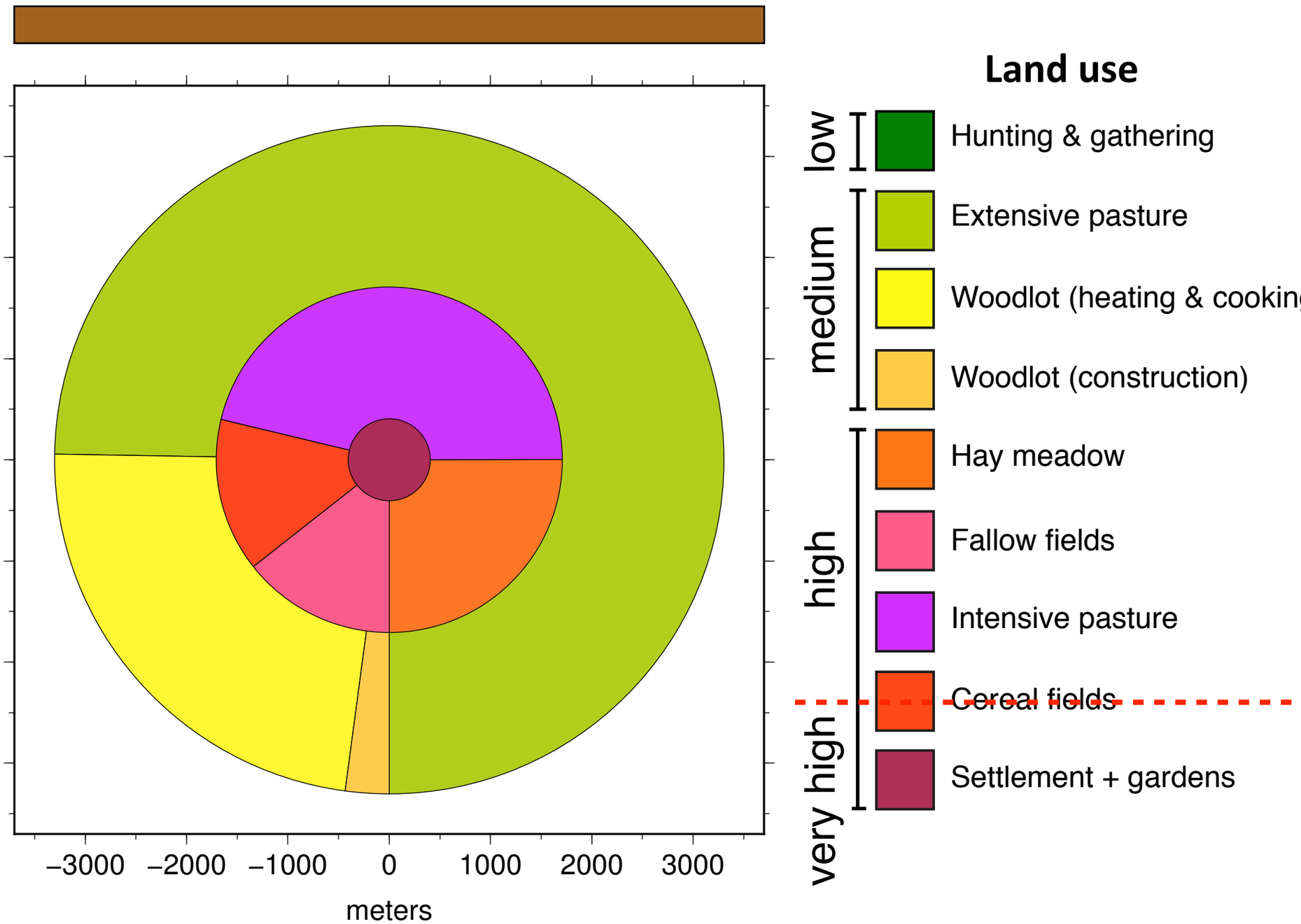
Diet:
60% wheat
18% cow meat/milk
2% goat meat/milk
2% sheep meat/milk
1% pork
3% peas and lentils
14% wild game and plants



Subsistence livelihood, diet, and land use

Number of individuals: 375

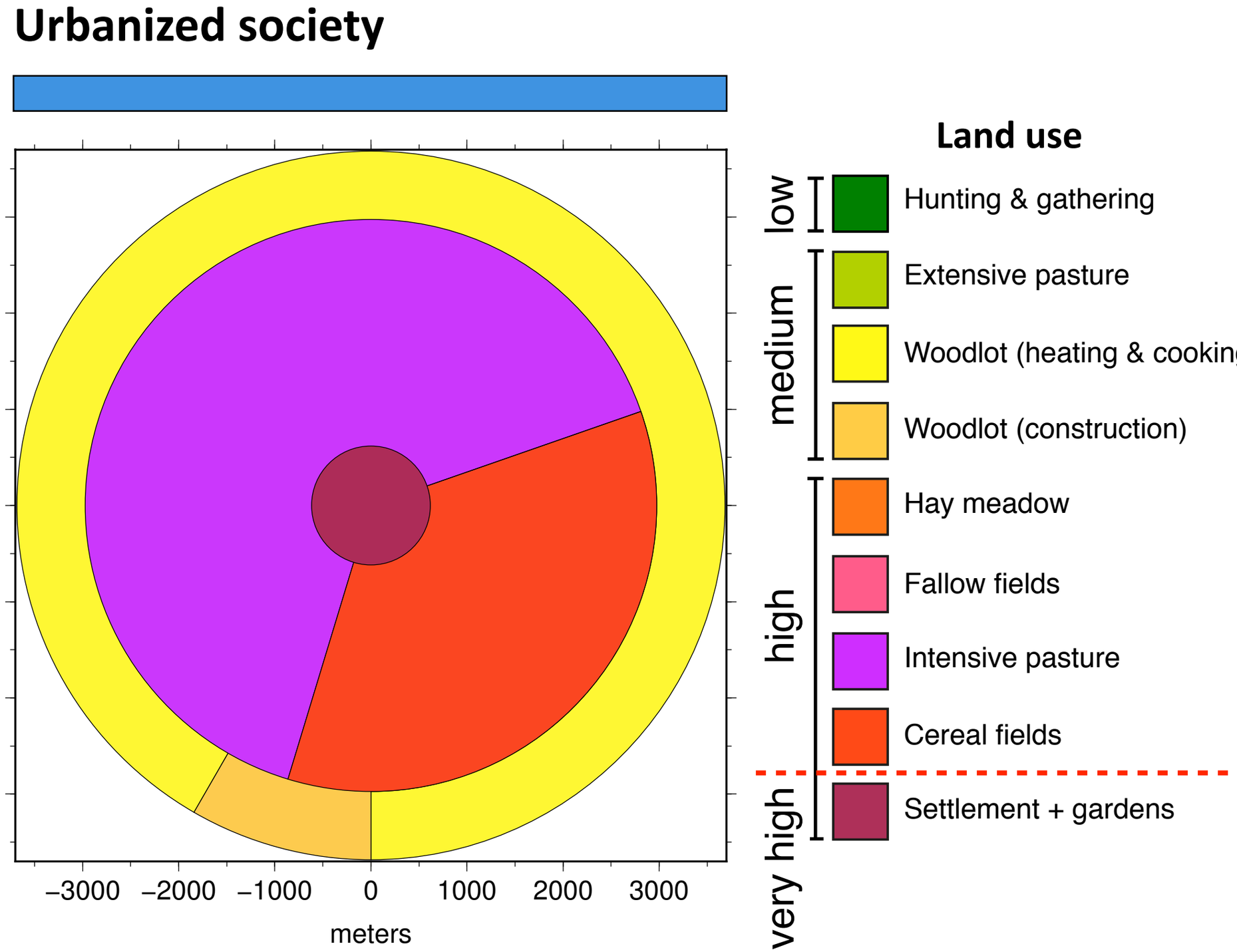
Diet:
69% wheat
22% cow meat/milk
2% goat meat/milk
2% sheep meat/milk
1% pork
4% peas and lentils



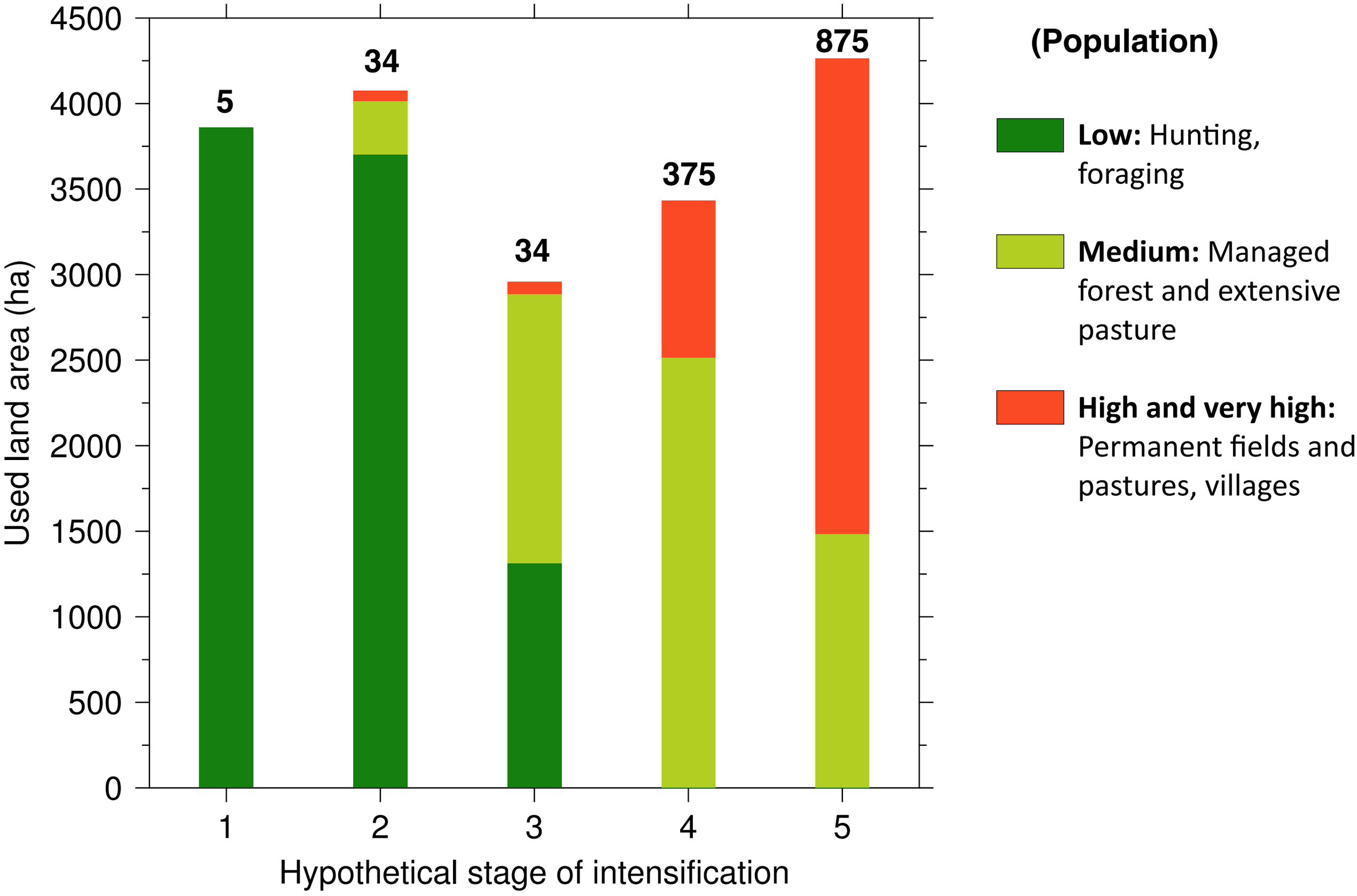
Subsistence livelihood, diet, and land use

Number of individuals: 875

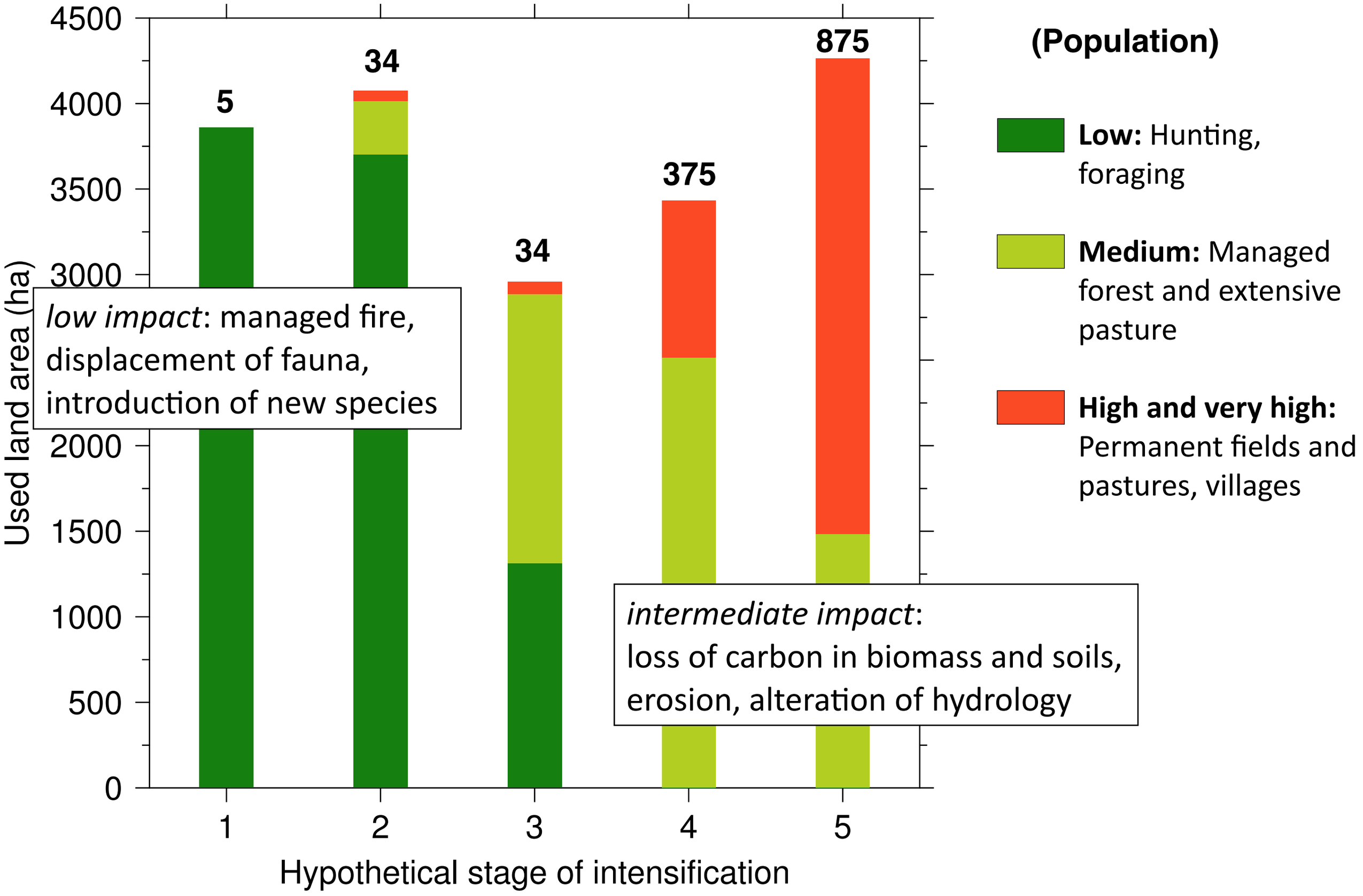
Diet:
69% wheat
22% cow meat/milk
2% goat meat/milk
2% sheep meat/milk
1% pork
4% peas and lentils



Intensification of land use

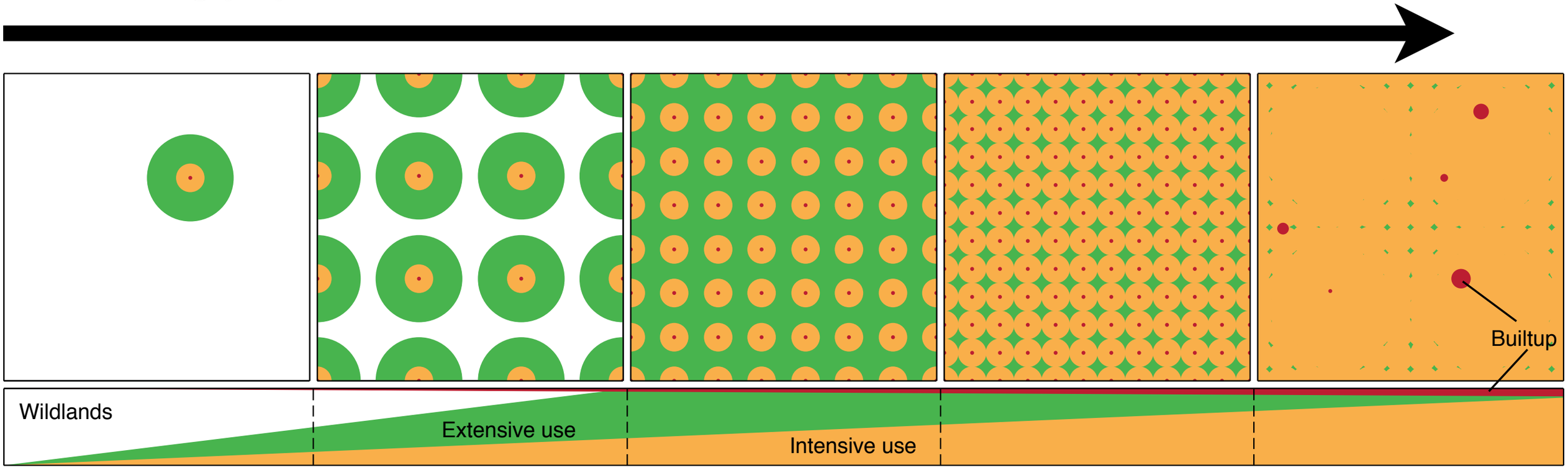


Intensification of land use



Population : Land use relationship

Increasing population



- Increasing populations lead to infilling with high extensive fraction
- Further growth leads to intensification, with reduction in highest intensity land use

An example from Africa

Anthropocene 9 (2015) 14–32

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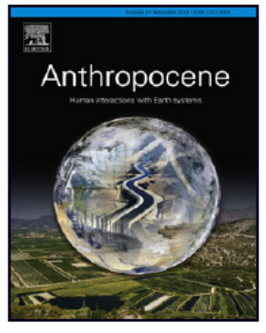

Invited Review

Human subsistence and land use in sub-Saharan Africa, 1000 BC to AD 1500: A review, quantification, and classification

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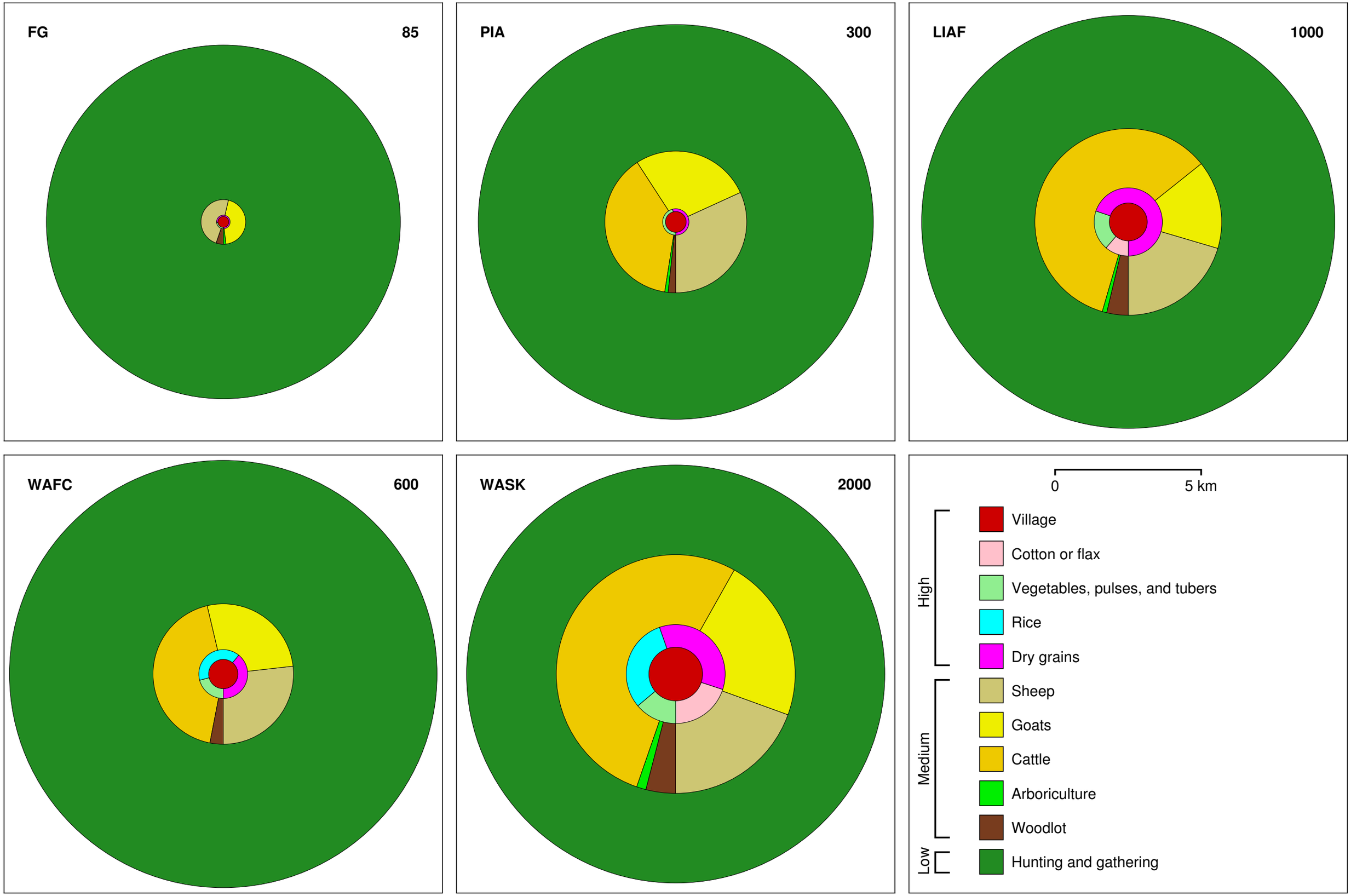
Intensification
Human–environment interactions

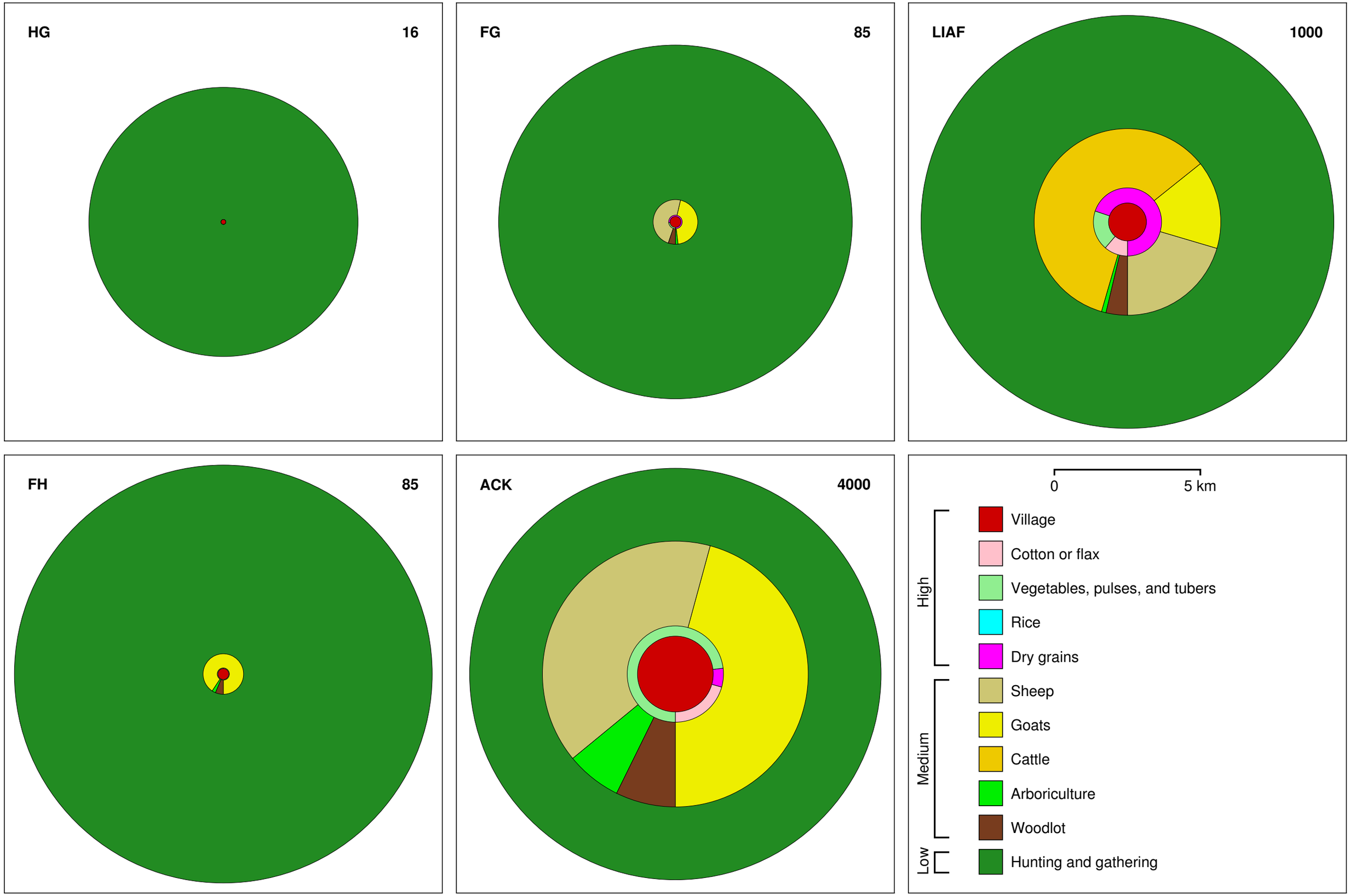
ABSTRACT

The Iron Age transition in sub-Saharan Africa represents a time when the relationship between humans and their environment was fundamentally altered at near-continental scale. This alteration may have had widespread consequences for regional climate, hydrology, biodiversity and ecosystem services that persist to the present. Quantification of these impacts and potential feedbacks is difficult, however, because the archaeological and historical record is highly fragmented in time and space. Here, we present a classification of human subsistence in Iron Age Africa from 1000 BC to AD 1500 that illustrates the various degrees of land use intensity employed by different groups at different times. The classification is based on a broad synthesis of archaeological, archaeobotanical, and ethnographic observations. The primary goal of our classification is to employ it as input to quantitative models of human–environment interactions to test hypotheses on the importance of humans for the development of African environments over the late Holocene.

Regional land use: Sahel c. AD 1100



Regional land use: Forest c. AD 1100



(3) Social organization

- Primary data sources: Chandler (1987), Modelski (2000), Tellier (2009), Satterthwaite (2009), Geonames.org database
- Geolocation of ancient and some modern cities a major problem
- Dataset is incomplete for all time periods

Kaplan et al., unpublished

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Kaplan et al., unpublished

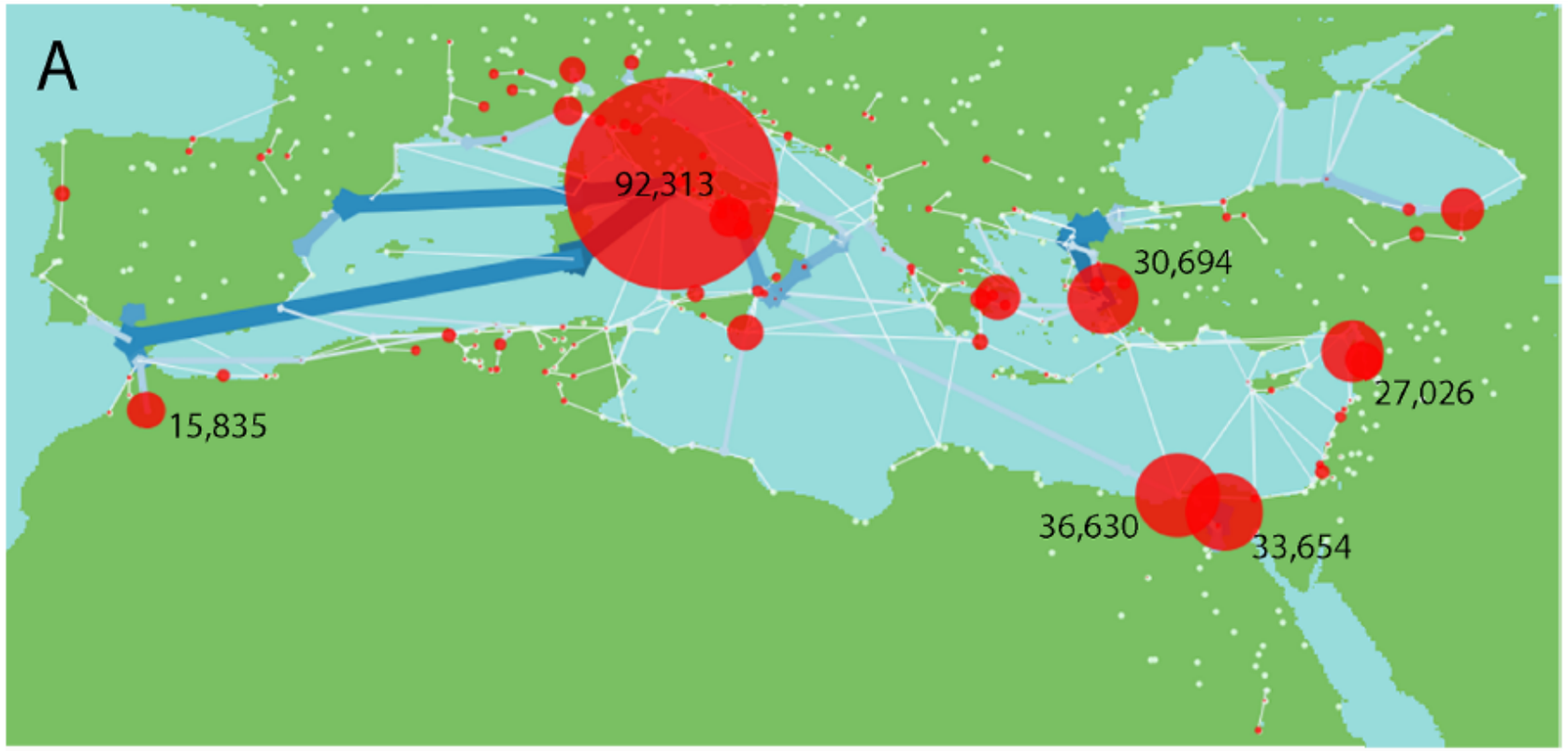
(3) Tribute and Trade

- Large-scale trade in bulk commodities started in the empires of antiquity
- This was already a form of “regionalization” and de-localization of economic activity

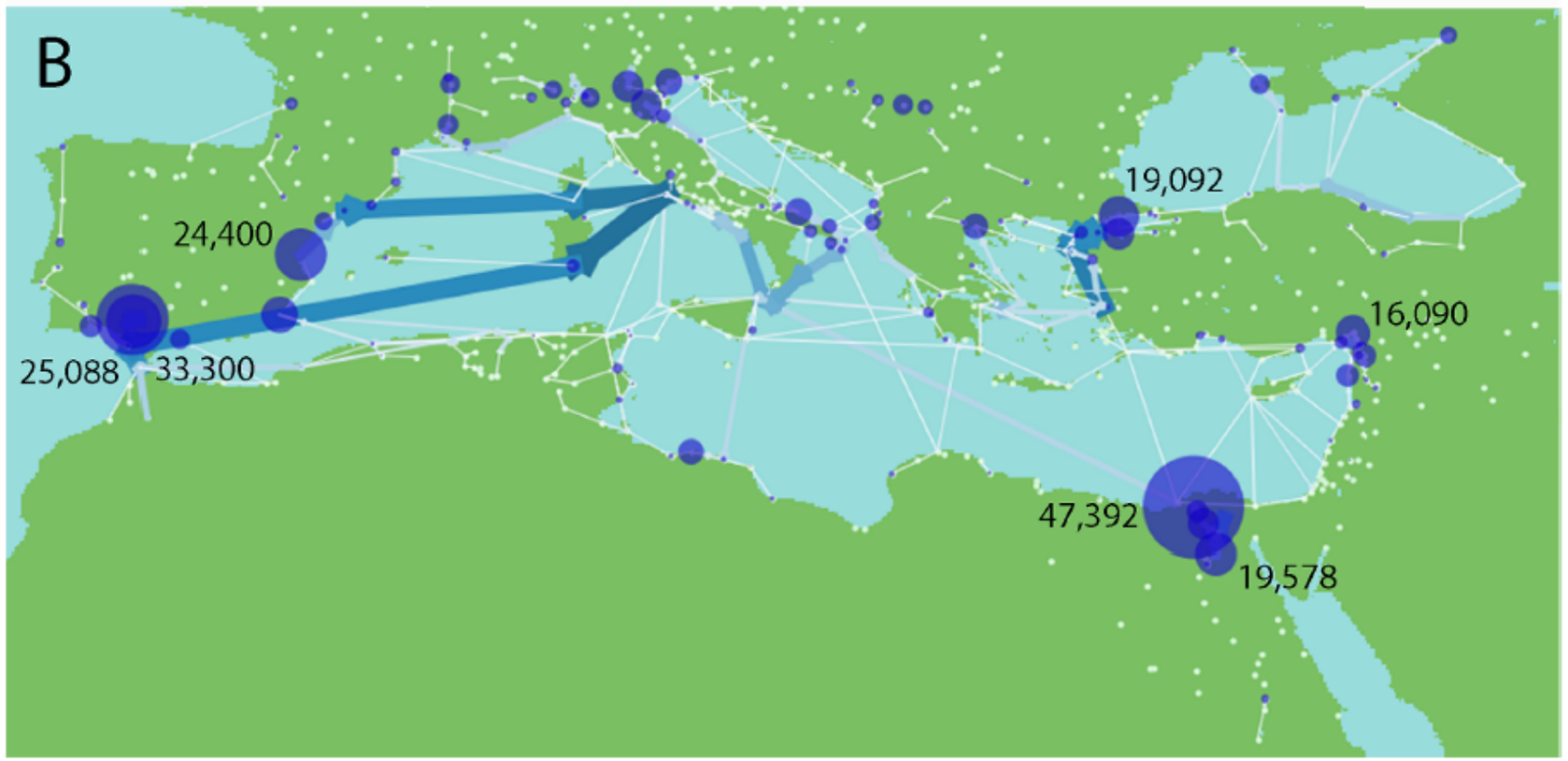
Monte Testaccio, Rome, 53 million amphorae

Virtual water in the Roman world

Imports
(food only)



Exports



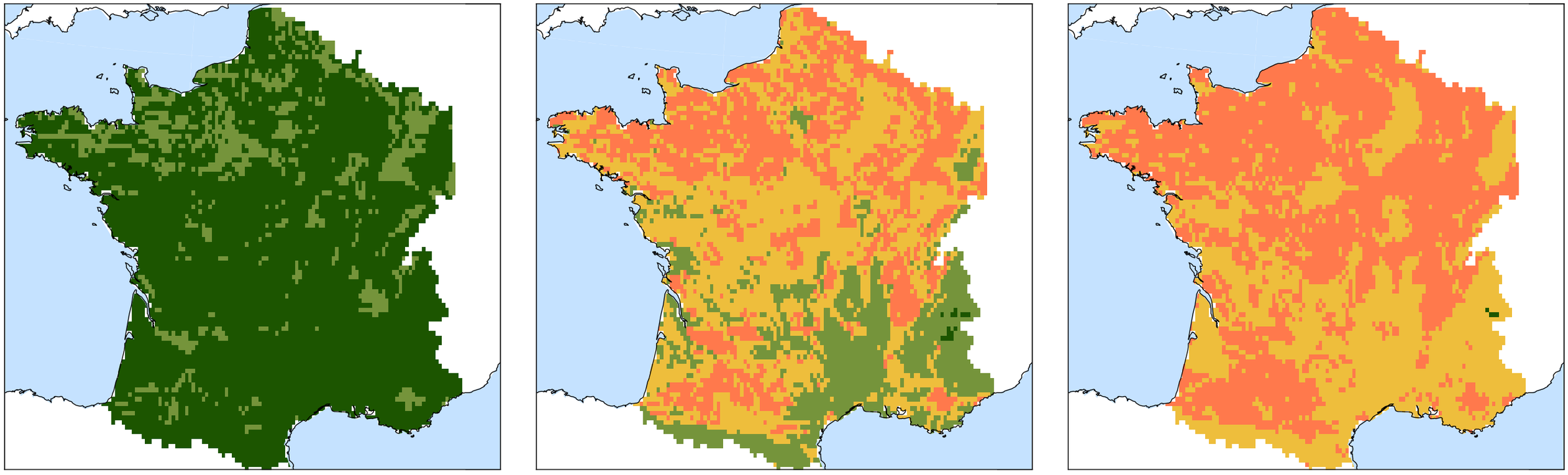
Dermody, et al., *Hydrol. Earth Syst. Sci.*, 2014

Land use classification into “Anthromes”

mid-Holocene
8000 BP / 6051 BC

Early Bronze Age
4000 BP / 2051 BC

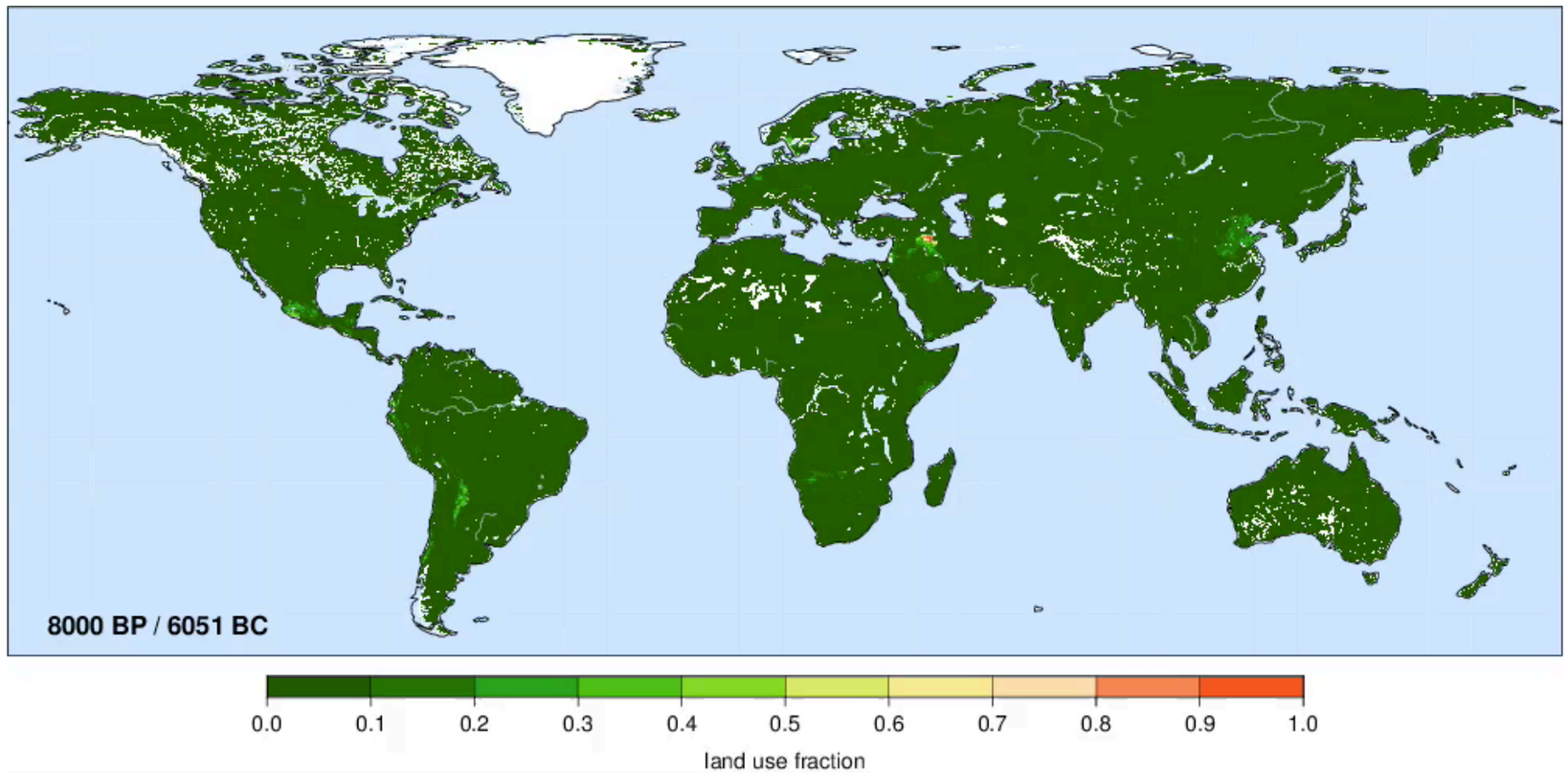
Early Iron Age
3000 BP / 1051 BC



- Dense settlements/intensified cropland
- Large villages/cropland
- Villages/low intensity cropland
- Residential woodlands
- Pastoral villages/rangeland
- Seminatural
- Wildlands

Summary and conclusions

- “land use” is universal - even very low population densities, foragers affect landscapes with fire, displacement of fauna, etc.
- Current and future work concentrates on process modeling and more evaluation in light of historical, paleoecological, archaeological, and genetic archives



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