Deep Roots of the Anthropocene
Archaeological Mapping of Global Land Use
10,000 BP to 1850 CE

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Snowmass, Colorado
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Geoglyphs >0.7 ka
Rondonia, Brazil
Earth System

Anthropocene

"Human Systems"

Climate Systems

Anthroposphere

Biosphere

Atmosphere

Hydrosphere

Lithosphere

anthroecology.org
Anthropocene: Recent

Fires and Deforestation on the Amazon Frontier, Rondonia, Brazil
May 28, 2009

**Period of first Significant Use**

- >8000 years BP
- 5000 – 8000
- 3000 – 5000
- 2000 – 3000
- 1000 – 2000
- 500 – 1000
- 250 – 500
- 100 – 250
- < 100

**Recovery** (% from peak use)

- 1 – 5%
- 5 – 10%
- 10 – 20%
- 20 – 50%
- >50%

**Dense Settlements**

- AD 2000

Ellis et al. 2013 *PNAS*
The Ruddiman Hypothesis: Early farmers deforested the Earth

Early Land Use: **Global Climate Change**

He et al 2013 GRL
Conserving Biodiversity in an **Anthropogenic Biosphere**

**Anthropogenic Changes in Plant Assemblages**

- **Species Richness Increases**
- **Species loss and gain are related**

**ASI + ASL: Vascular Plants**

![Image](image_url)
Anthropogenic Environmental Change
Evolution of Sociocultural Niche Construction

Social Scales
- Kinship
  - Small Bands
- Tribes
- Villages
- Chiefdoms
- Kingdoms
- States
- Empires
- Federated states
- Beyond states?

Niche Construction Intensity
- Wildlands
- Seminatural Lands
- Croplands
- Rangelands
- Dense Settlements

Energy Use
- Cooking
- Burning
- Smelting
- Animal Traction
- Biomass
- Fossil
- Abiotic

Palaeolithic
- Lower
- Upper
Mesolithic
Early Neolithic
Later Neolithic & Chalcolithic
Bronze Age
Iron Age
Industrial Age
Emerging Futures

GJ person\(^{-1}\)

km\(^2\) anthromes person\(^{-1}\)

Cooking
Burning
Smelting
Animal Traction
Biomass
Fossil
Abiotic

Efforts by an AI to understand the anthropogenic environmental change and sociocultural niche construction, illustrated through various social scales, niche construction intensity, and energy use. This information is sourced from the work of Ellis, EC 2015, Ecology in an Anthropogenic Biosphere, Ecological Monographs 85(3):287–331.
The Anthropocene is **Diachronous**

**THE DEEP ROOTS OF THE ANTHROPOCENE**

Human societies began altering Earth long ago. Human social and cultural capacities to alter its environmental processes have accumulated, scaled up and reinforced each other in complex and historically contingent ways. Defining an Anthropocene epoch should involve examining these transformative social-environmental changes, rather than solely focusing on globally instantaneous environmental transitions. ‘Golden spikes’ mark stratigraphic boundaries of geological time periods; ‘?’ highlight recent boundary proposals.

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**Sociocultural Change drives Environmental Change**

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**GEOLOGICAL TIMELINE**

- Suggested ages:
  - Miocene
  - Pliocene
  - Pleistocene
  - Holocene (?)

- Golden spikes:
  - 5.33 million years ago (Myr)
  - 2.58 Myr

- Key events:
  - 50,000 years ago (Yr): Megafauna extinction starts
  - 8,000 Yr: CO₂ emissions due to farming
  - 1500 AD: Columbian exchange begins
  - 1800: Industrial revolution
  - 1945: Atomic bomb
  - 1950s: AWG view

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**HISTORICAL TIMELINE**

- Greenhouse-gas emissions (CH₄ and CO₂)
- Deforestation
- Species introductions & invasions
- Extinctions
- Megafauna extinction
- Island extinctions
- 1610 (?): Orbis spike
- 1964 (?): Radiocarbon peak from above-ground nuclear test

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**Environmental impacts**

- Mass extinction

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**Cultural changes**

- Information age
- Fossil fuels
- Intensive trade networks
- Cities
- Agriculture
- Cities

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**Human cultures**

- Homo spp.
- Homo sapiens

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**Stone tools**

- Fire
Domesticated Crops

Cultivation

Possible Cultivation

West Africa
(Pearl millet)

Levant
Near East
(Wheat & Barley)

India Savanna
(Millets)

India Ganges
(Rice)

North China
(Millets)

South China
Yangtze
(Rice)

Domestication Pathways

Dorian Fuller & Chris Stevens (2017)
A Tale of Two Planets: Two different models of global land use history

Period of first Significant Use
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Recovery (% from peak use)
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- >50%

Dense Settlements
- AD 2000

HYDE 3.1 - Intensification

KK10 + Intensification

Ellis et al. 2013 PNAS
Used Planet: A Global History
doi:10.1073/pnas.1217241110
Anthropocene Transition

Land use = $f(\text{population})$

**HYDE** constant

**KK10** empirical

Ellis (2011)
Carbon Release from Agricultural Land Use

(6000 BP - )

**with Intensification**
(decreasing land/person)

**No Intensification**
(constant land/person)

Kaplan et al. (2010)
Amazonia 1492: Pristine Forest or Cultural Parkland?

Michael J. Heckenberger, Afukaka Kuikuro, Urissapá Tabata Kuikuro, J. Christian Russell, Morgan Schmidt, Carlos Fausto, Bruna Franchetto

Mann, C 2008 Science 321:1148

Squared off. The Fazenda Atlântica geoglyph in Acre is 250 meters on a side.
Can the Anthropocene be Dated Empirically?

By Jed Kaplan

Ellis et al. 2013. *Elementa*
Overcoming Geographic Bias in Site Selection
The Challenge:
Can biased sampling yield statistically robust global knowledge?

What is the Global Context of Local Sites?

Are there Sampling Biases?
How to correct them?
A Global Assessment of Archaeological Land Use Knowledge

“Massively Collaborative” Global Assessment of Regional Land Use for 10 Time Slices

10 Time Slices, 10,000 BP to 1850
146 Global Analytical Units
255 Contributing Archaeologists
Contributions solicited May to June 2018
120 Authors

Lucas Stephens,
Dorian Fuller,
Torben Rick,
Nicole Boivin,
Nick Gauthier
Andrea Kay
Ben Marwick.... many more
Erle Ellis

http://globe.umbc.edu/archaeoglobe/
A Global Assessment of Archaeological Land Use Knowledge
An Online Regional Land Use Survey for 10 Time Slices

Select Region

Time Slices

- 10,000 BP
- 8000 BP
- **6000 BP**
- 4000 BP
- 3000 BP
- 2000 BP
- 1000 BP
- 1500 CE
- 1750 CE
- 1850 CE

Land Use Categories

- No Evidence
- Extensive/Minimal
- Foraging/Hunting/Gathering/Fishing
- Extensive Agriculture
- Intensive Agriculture
- Pastoralism
- Widespread
- Common
- Minimal
- None

Level of Prevalence

Stephens et al. (2019)

http://globe.umbc.edu/archaeoglobe/
The ArchaeoGLOBE Project assessed archaeological knowledge on human land use across the globe over the past 10,000 years through the expert knowledge contributions of more than 200 archaeologists provided through a questionnaire between May 18 and June 30, 2018. Regional land use across 146 regions was assessed at 10 distinct time points (10,000 bp, 8,000 bp, 6,000 bp, 4,000 bp, 3,000 bp, 2,000 bp, 1,000 bp, 1500 CE, 1750 CE, 1850 CE). Data were obtained for four land use categories: Foraging/hunting/gathering/fishing, Extensive agriculture, Intensive agriculture, and Pastoralism.
Fig. 1 Archaeological knowledge contributions.

A

B

Contributors

Regions

Stephens et al. Science 2019;365:897-902
Fig. 2 Archaeological expertise, data quality & published excavations.

A. Expertise

B. Data Quality

C. Published Excavations

Stephens et al. Science 2019;365:897-902
Fig. 3 Summary of global land-use trends.

A

Extensive Agriculture

Intensive Agriculture

Widespread

None

Pastoralism

Foraging

Land-use extent

None

Widespread

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0

Thousand years BP

B

Percent of all regions

Urban Centers Split
Extensive Agriculture Common
Intensive Agriculture Common
Pastoralism Common
Foraging Common

Urban Centers Present
Extensive Agriculture Widespread
Intensive Agriculture Widespread
Pastoralism Widespread
Foraging Widespread

Thousand years BP

Stephens et al. Science 2019;365:897-902
Fig. 4 Regional onsets of land-use categories and decline of foraging.

A

Extensive agriculture

Intensive agriculture

Pastoralism

Urbanism

B

Foraging

Decline

Stephens et al. Science 2019;365:897-902
Fig. 5 Comparisons of agricultural onset in ArchaeoGLOBE vs HYDE.

69 of 130 ArchaeoGLOBE onsets were earlier, in regions encompassing 54% of global crop area at 2000 CE.
Intensive Agriculture
10000 years ago
Archaeological assessment reveals Earth’s early transformation through land use

Stephens et al. 2019
Science 365:897-902

Foraging/Hunting/Gathering
10000 years ago

Animation by Nicolas Gauthier

Prevalence

- None
- Minimal (<1%)
- Common (1-20%)
- Widespread (>20%)
Archaeologists confirm early global onset of intensely transformative land use.

What’s Next?

A Global Assessment of Fire Management Regimes?

Seek Funding to build a Collaborative Global Land Use Mapping Cyberinfrastructure?
A Global Archaeology of the **Anthropocene**

**Collaborative Cyberinfrastructure for Anthropocene Dating**

**Figure 2**
Conceptual design of online Anthropocene collaborative geo-cyberinfrastructure for dating human transformation of the terrestrial biosphere.

Site data are utilized to estimate human populations and ecosystem transformation across local observing units (e.g., hexagonal global map tiles) and these are integrated globally to assess human transformation of the terrestrial biosphere using a global ge-temporal computation engine facilitating collaborations across social networks of experts.

doi: 10.12952/journal.elementa.000018.f002

Ellis, Fuller, Kaplan & Lutters. 2013. *Elementa*
Earth Stewardship

What kind of biosphere do “we” want in 2050?

Anthrome Change Scenarios

What kind of biosphere do “we” want in 2050?
Sharing Earth’s Land: Nature Only vs. Shared Landscapes

Nature only landscapes
Giving whole landscapes to nature leads to the most losses

Shared landscapes
Sharing landscapes with nature leads to the least losses

Global
Giving back half of a borderless earth is at minimal cost

Ecoregion
Giving back half of each habitat type comes with the highest cost

Protected
Yes
No
Calorie loss
More
Less

Current Opinion in Environmental Sustainability 38:22-30
Three Global Conditions for biodiversity conservation & sustainable use

A spatial overview of the global importance of Indigenous lands for conservation


Fig. 1 | Global map of lands managed and/or controlled by Indigenous Peoples (percentage of each degree square mapped as Indigenous in at least one of 127 source documents; Supplementary Information section 2).
Global Safety Net
Computationally Optimized Conservation Reserve Design

Land Use Intensification by Hunter-Gatherers

Adaptive technologies to sustain growing populations on limited land

Pre-Agricultural

Dietary Broadening

Proto-Agricultural

Burning for Hunting/Foraging

Propagating Favored Species

Food Processing

Domestication

Ellis et al. 2013 PNAS
Land Use Intensification

Increasing population density drives intensification of land use

Ester Boserup (1965)

Foraging → Long Fallow → Short Fallow → Annual cropping → Multicropping

ha/person
2 - 6
1 - 2
0.3 – 0.6
0.05 - 0.3

Cropping cycle
1:20 - 1:7
1:7 - 1:3
1:2 - 1:1
2:1 - 5:1

Population density
<15
5 – 65
65 - 250
>250

Robert Netting (1993) Smallholders, Householders
In the Anthropocene, ecological change is social change, and social change is cultural change.
Ecology in an Anthropogenic Biosphere

Social Change > Ecological Change

A

Hunter Gatherer

Horticultural

Agrarian

Industrial

Centrality

Suitability

B

Map Legend

Topography

Mobile bands

Water

Land Cover

Trees

Open

Cultivated

Built

10 km

Anthromes (levels)

Wildlands

Seminatural

Rangelands

Croplands

Densely Settled

B

Hunter Gatherer

Horticultural

Agrarian

Industrial

C

Population Density

Land Use

Hunting

Foraging

Pasture

Crops

Irrigated

Forested

Built

Land Cover

Trees

Open

Cultivated