CLIMATE-SMART Agriculture 2015

Global Science Conference

March 16-18, 2015
Le Corum, Montpellier France

Sustainable intensification and climate change mitigation

[Mercedes Bustamante and
Ch. 11 team - IPCC WGIII AR5]
[University of Brasília]

Montpellier

March 16-18, 2015

Agriculture
Changes through time…

- Agriculture – 12,000 years ago
- Agricultural techniques were developed soon after the Neolithic Revolution.
  - such as irrigation, crop rotation, the application of fertilizers
- <u>But significant advances in the past 200 years.</u>

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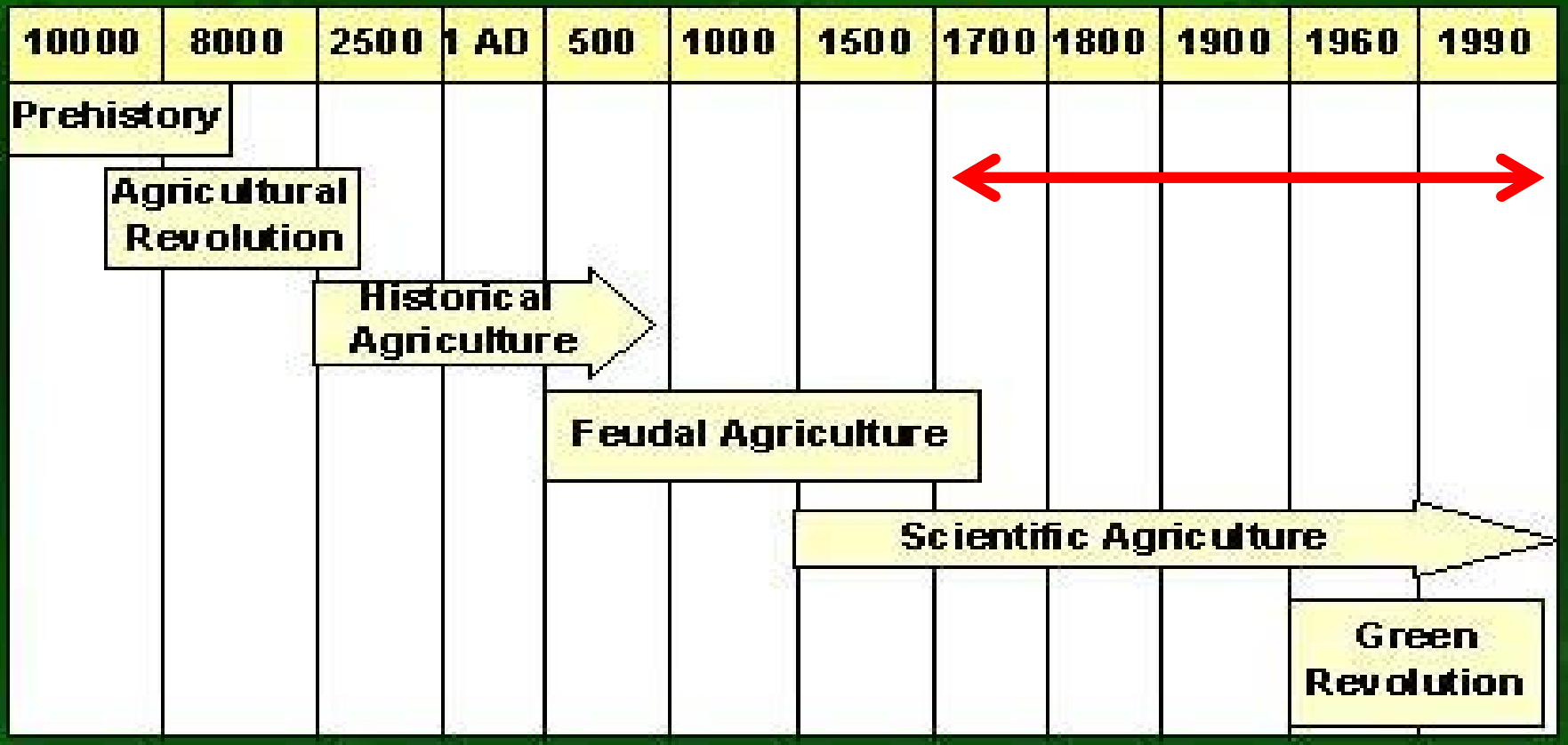
Evolution of Agriculture



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Changes through space…the spread of agriculture

Over the last 300 years =

Intensification and Expansion

- Nearly every area of the world has seen agriculture become more locally dense.
- Since 1850, several episodes of rapid expansion into previously untapped areas

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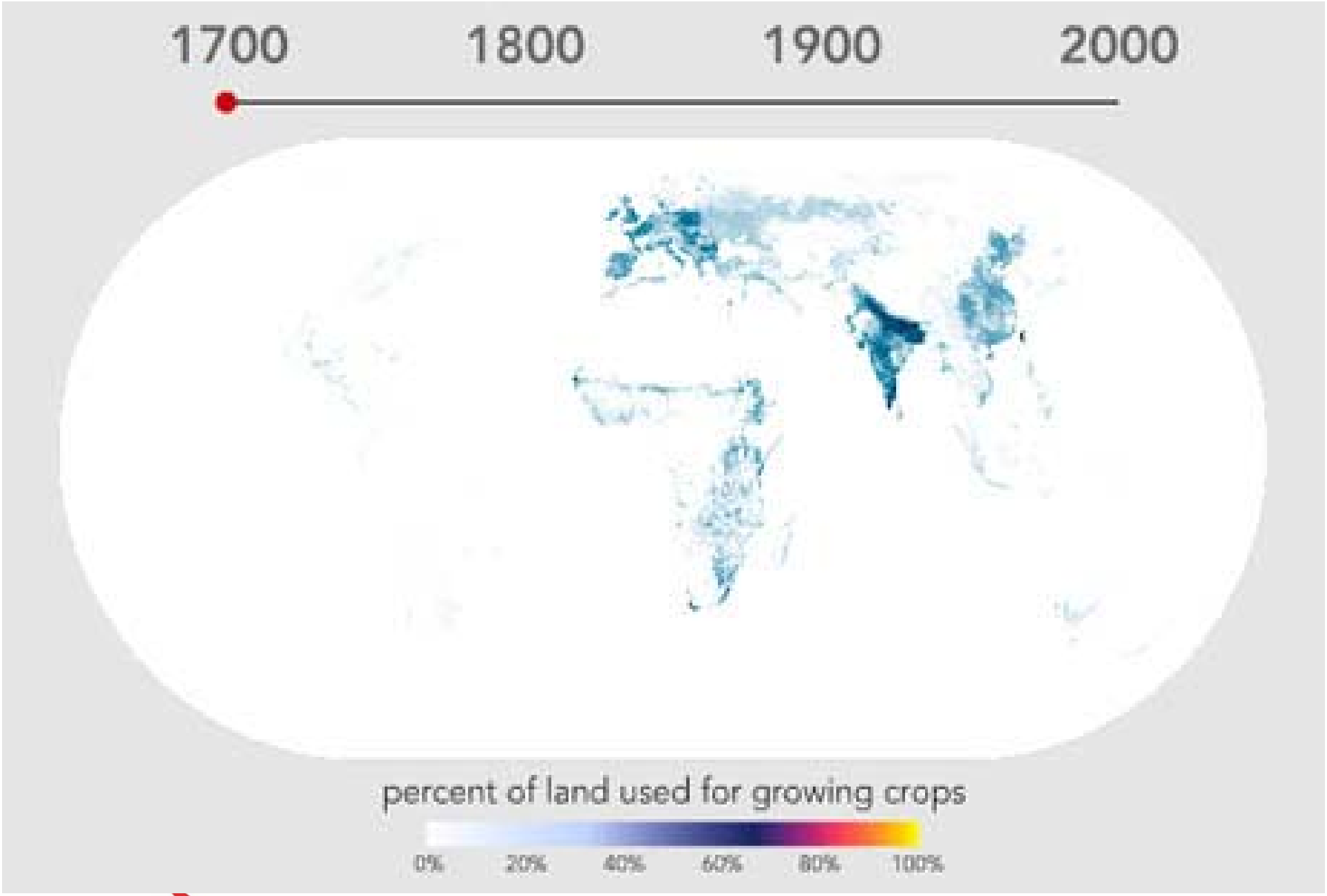

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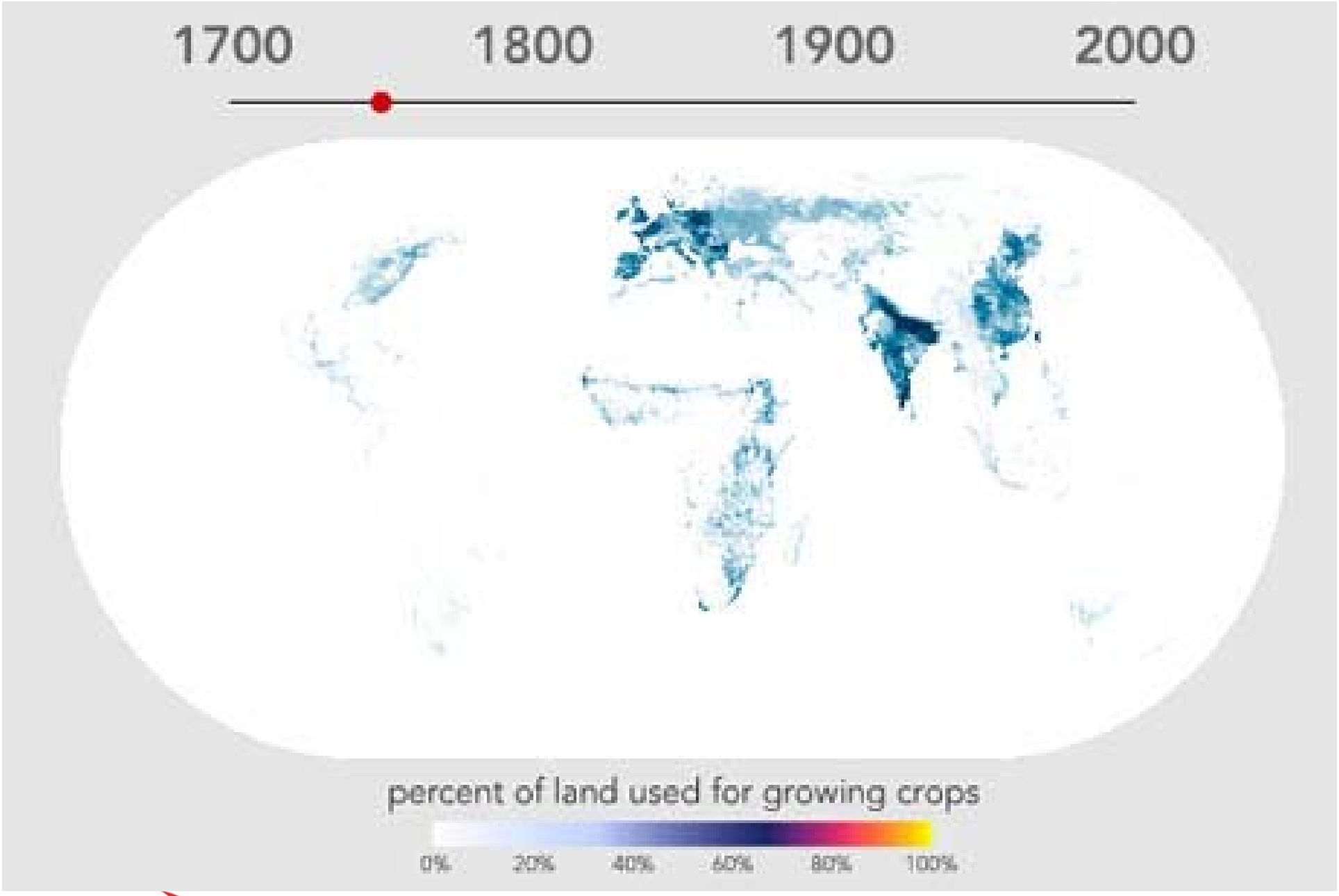

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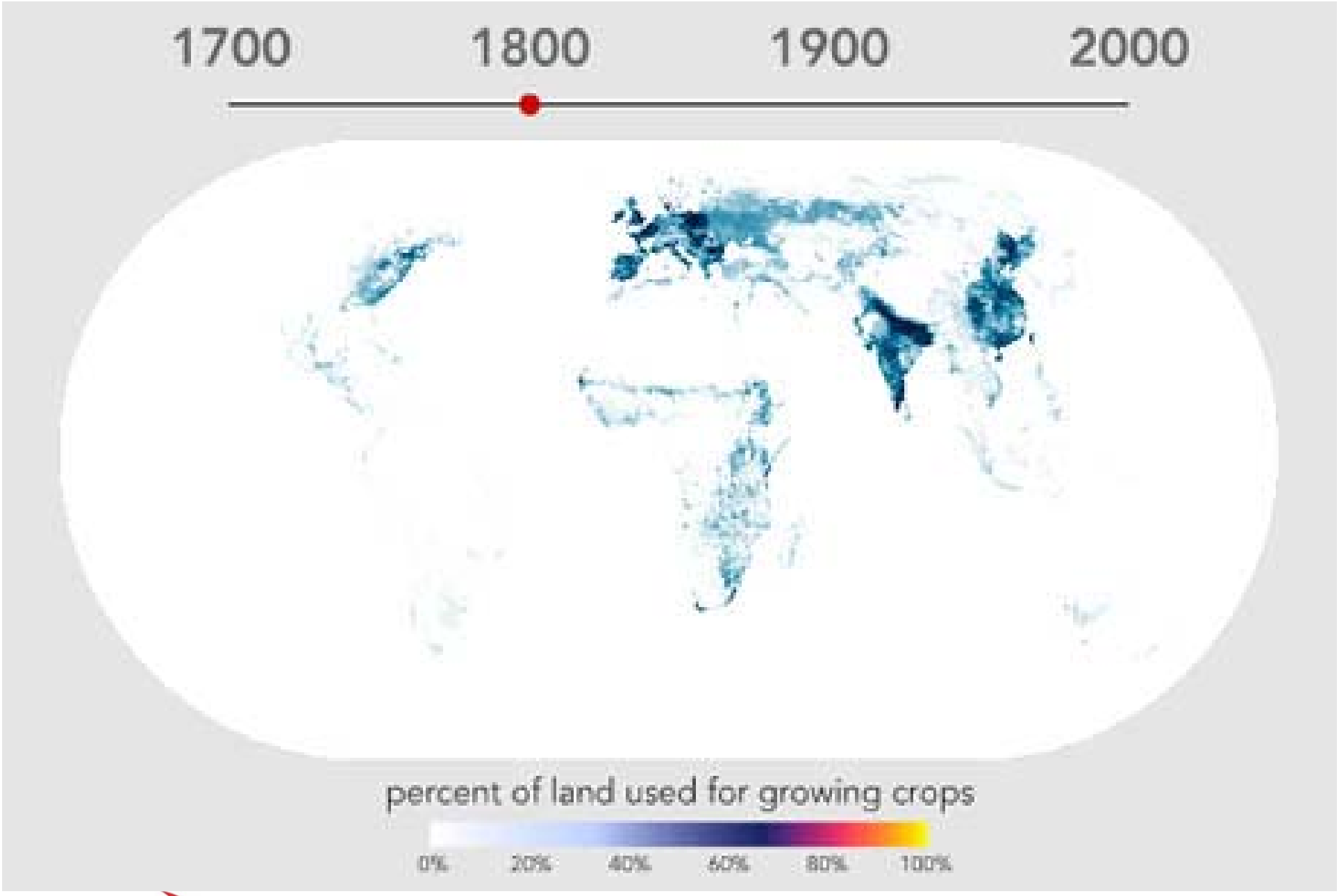

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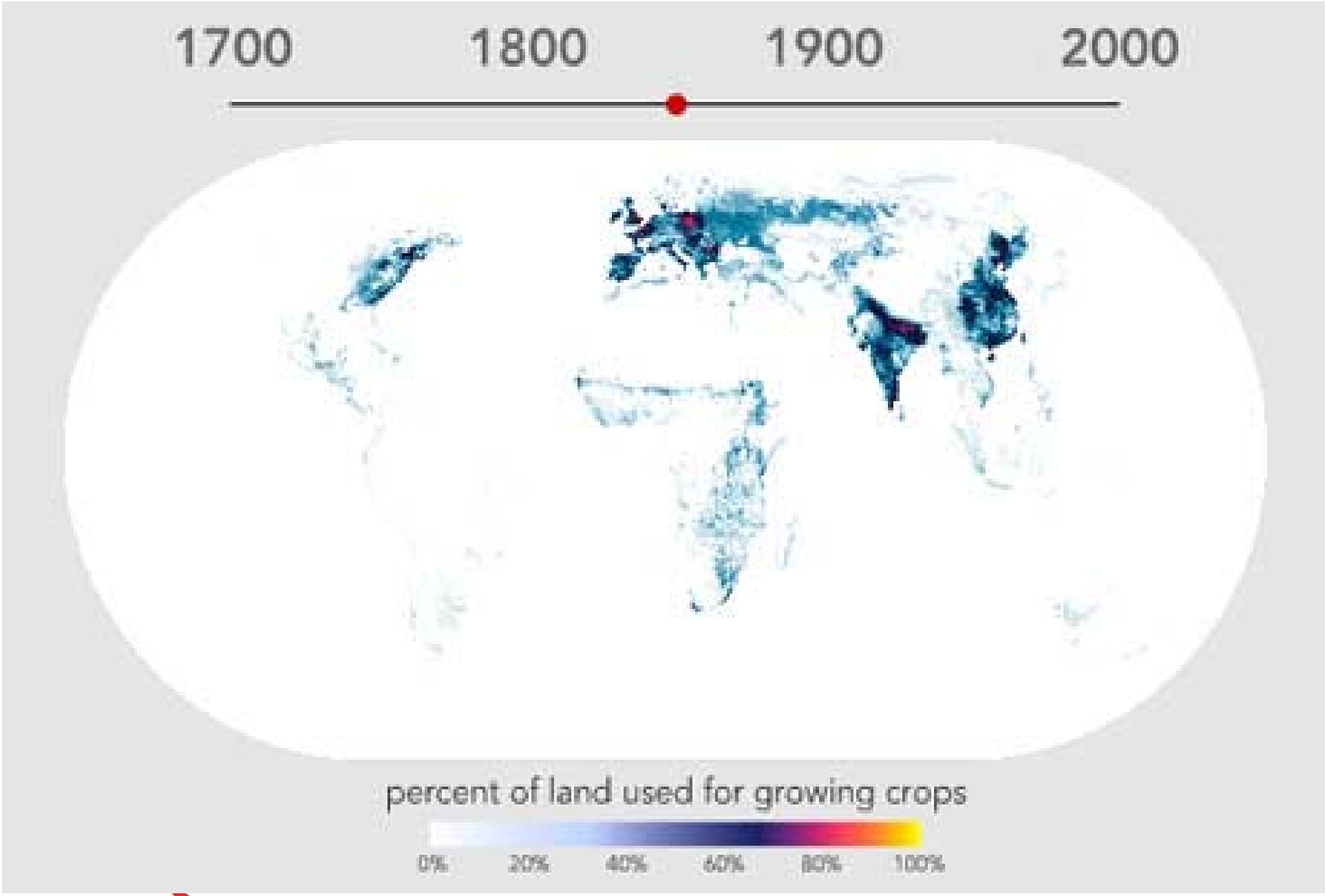

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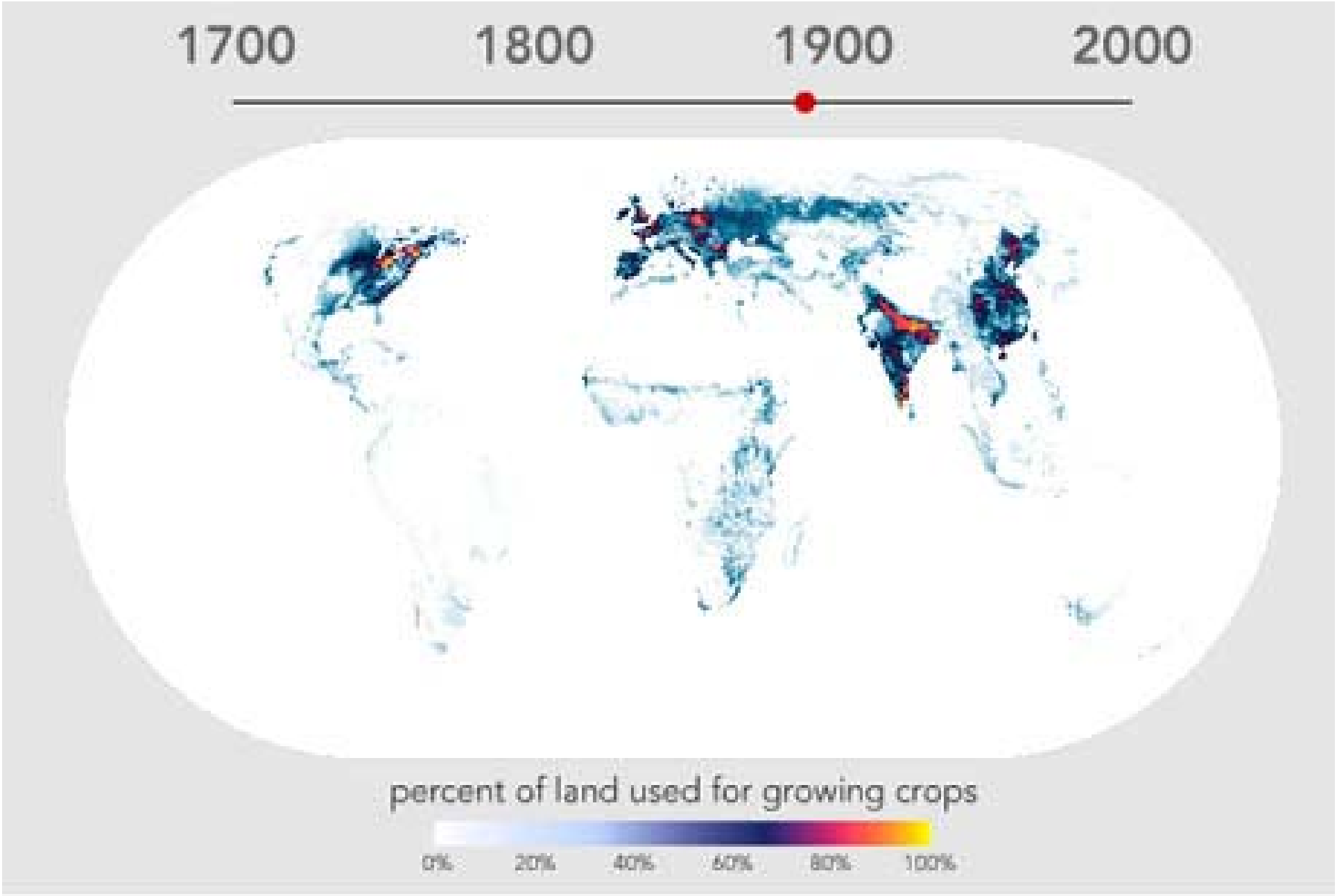

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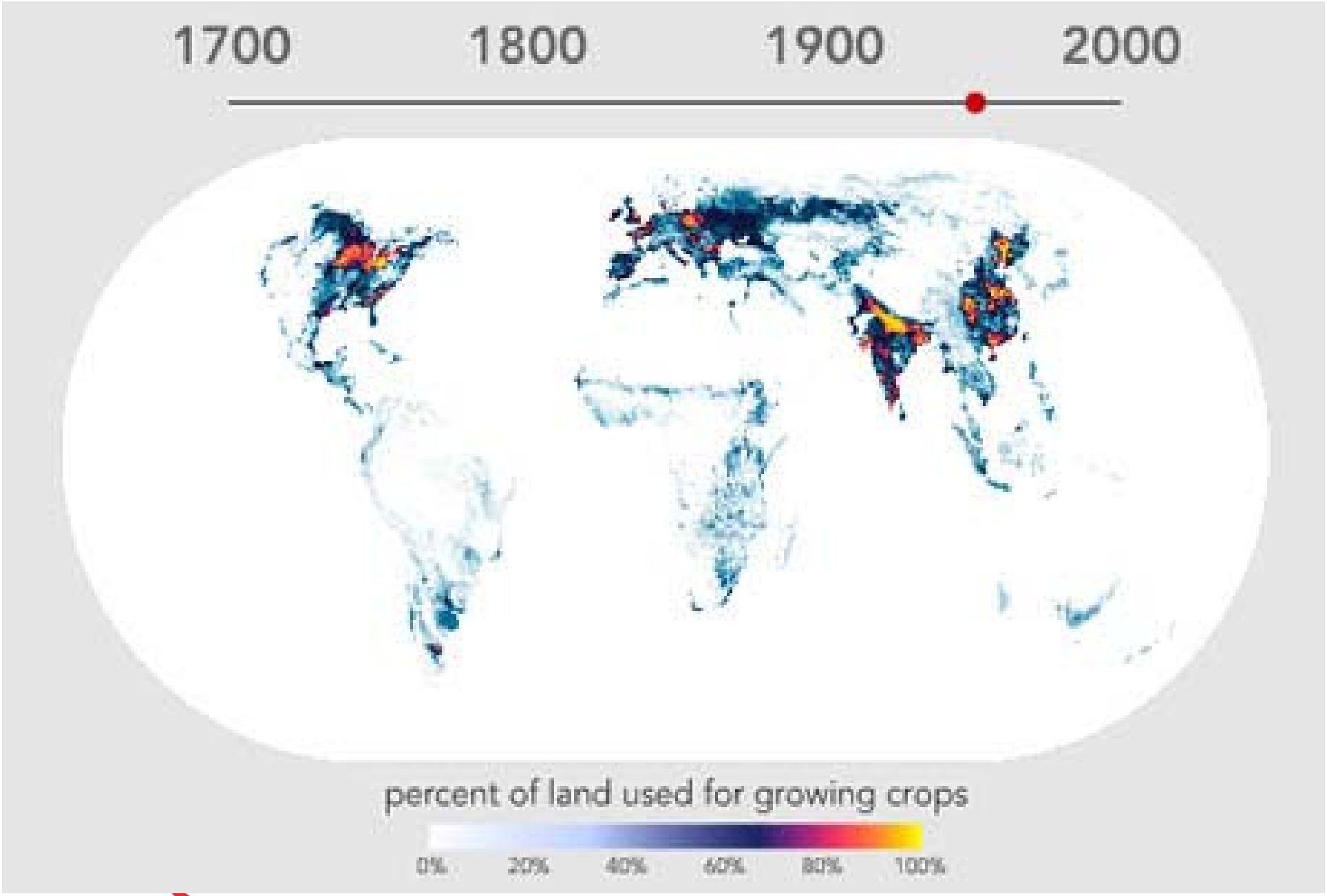

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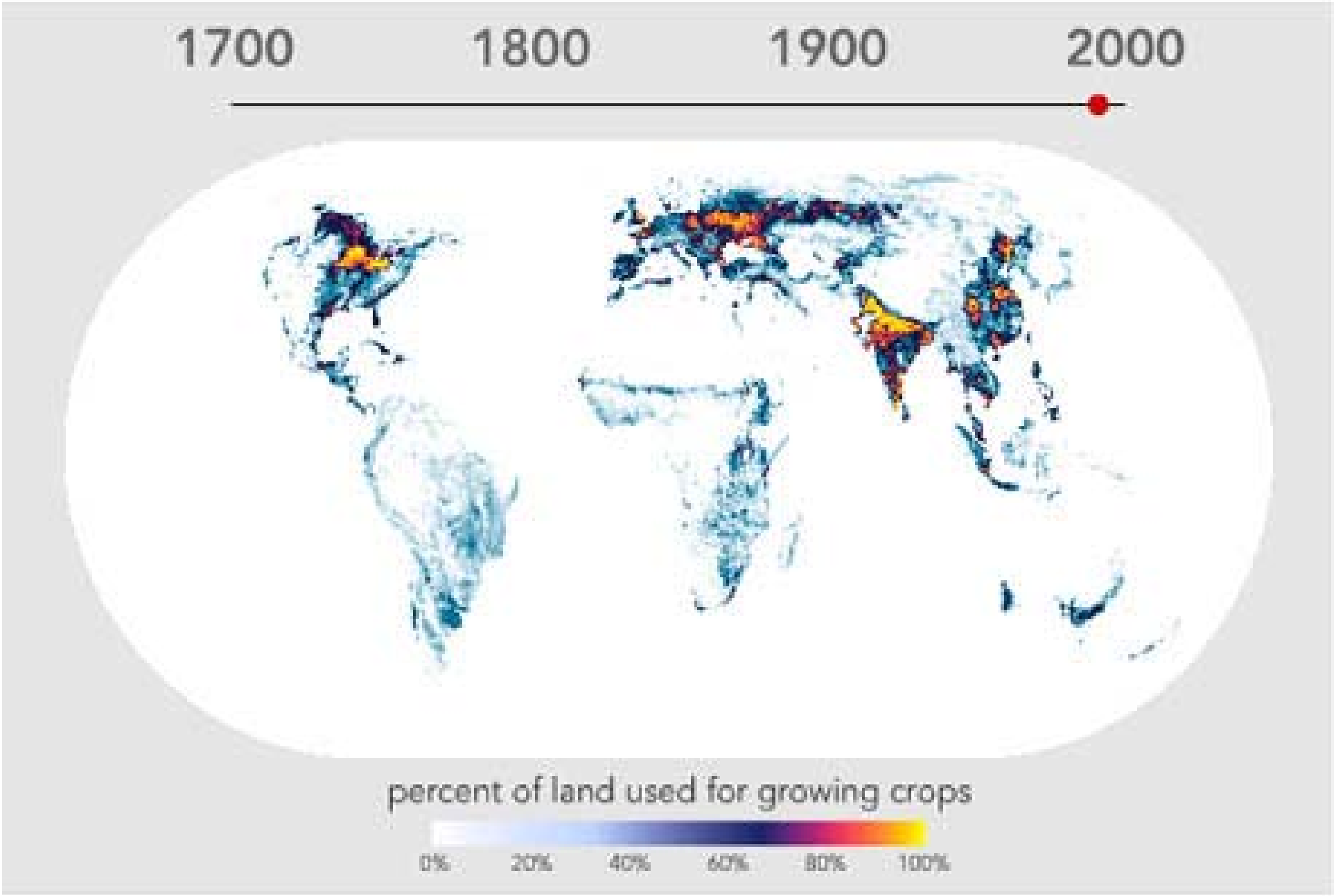

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Intensification – the two-way road…

- Agricultural intensification **has been successful to meet increasing global food demands** by increasing the productivity per unit area.

- **On the downside**…
- significant negative impacts on the environment and biodiversity
- some of which might even have negative feedbacks on sustained crop productivity.

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In parallel…

- **Extensive conversion of land use** over the past decades,
  - with loss of natural habitat elements and
  - simplification of the agricultural landscape.
- **Social consequences** - over the past 50 years :
  - considerable change in the composition of national food supplies,
  - diets around the world have become more similar.

(Khoury et al. 2014)

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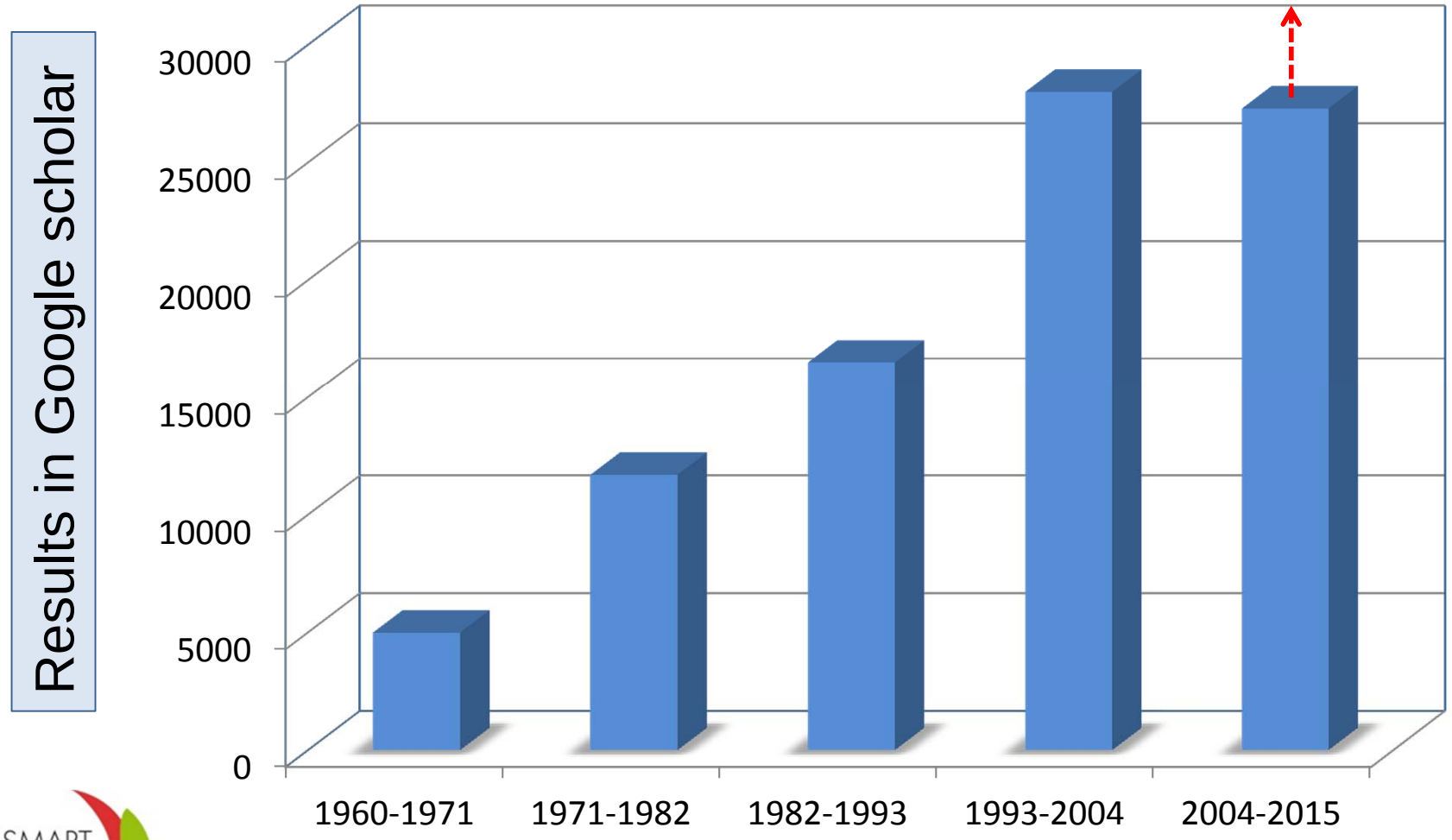
Investigation on Agriculture Intensification 1960 -2015



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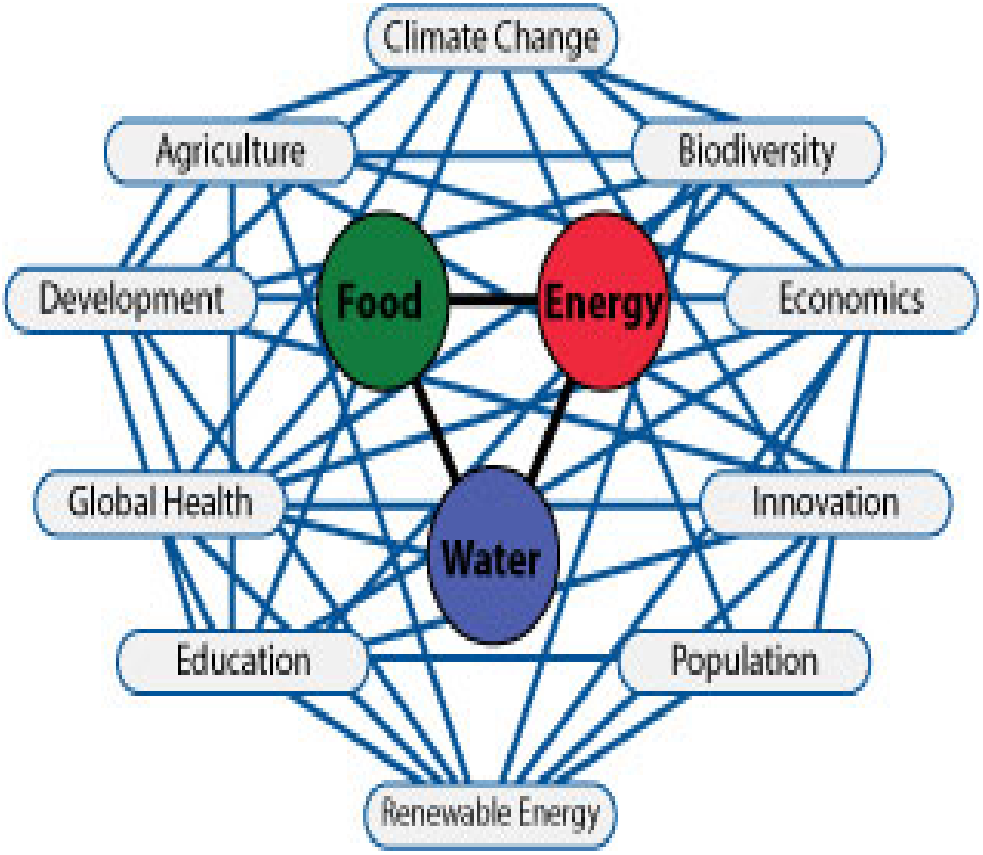
Food, energy, environment (water, climate, biodiversity) nexus

- The recent history of agriculture = closely tied with a range of societal and political issues.
- Analysis of different kinds of intensifications and consequences.



Source: AAAS

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Global food demand and the sustainable intensification of agriculture

David Tilman[a,1], Christian Balzer[b], Jason Hill[c], and Belinda L. Befort[a]

Global Environmental Change

Volume 15, Issue 4, December 2005, Pages 320–337

Global change and the intensification of agriculture in the tropics

Eric Keys[a], William J. McConnell[b]

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Climate Change and Food Systems

Sonja J. Vermeulen,[1,2] Bruce M. Campbell,[2,3] and John S.I. Ingram[4,5]

Greenhouse gas mitigation by agricultural intensification

Jennifer A. Burney[a,b,1], Steven J. Davis[c], and David B. Lobell[a,b]

[a]Program on Food Security and the Environment and [b]Department of Environmental Earth System Science, Stanford University, Stanford, CA 94305 and [c]Department of Global Ecology, Carnegie Institution of Washington, Stanford, CA 94305

Edited by G. Philip Robertson, W. K. Kellogg Biological Station, Hickory Corners, MI, and accepted by the Editorial Board May 4, 2010 (received for review December 9, 2009)

Volume 116, Issues 3–4, September 2006, Pages 189–196

Further evidence of continent-wide impacts of agricultural intensification on European farmland birds, 1990–2000

Paul F. Donald[a], Fiona J. S

Contents lists available at SciVerse ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

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When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture

Pablo Tittonell[a,*], Ken E. Giller[b]

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[b] Plant Production Systems, Wageningen University, P.O. Box 430, 6700AK Wageningen, The Netherlands

Land as a limiting resource

- **Not all of the total land area of the planet** (134 million km^2) **is suitable for food production**, due to climatic, soil and topographic constraints.

- Cropland area may expand by about 1.5–2.0 million km^2 up to 2050 under a business-as-usual scenario, where **most of the increase in food supply will come from intensification** (Fischer et al., 2011).

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Changing context…

- Production gains from the Green Revolution are diminishing
- Population is increasing faster than food production
- Farmland is being lost to land degradation and urbanization
- Climate change effects on future agricultural productivity
- Demand is increasing due to changing eating habits

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Intensification – changing concepts

- *Cassman 1999*
- Term ecological intensification
- Challenge of increasing attainable yield and narrowing yield gaps
- by implementing new insights in precision agriculture, plant and crop physiology, and soil science,
- approaches and strategies should be different for favorable and unfavorable agricultural conditions

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Intensification – changing concepts

- *Meinke et al. 2009*
- ‘adaptation science’ to develop climate-robust agriculture and management of natural resources.
- adaptation science as a solution oriented, scientific effort in the global agenda to facilitate adaptation actions.

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Intensification – changing concepts

- *Keating et al. 2010*
- Options to make agriculture more 'eco-efficient'
- Efficiency refers to output per unit of input,
- 'Eco-efficiency' is the output of food and fibre relative to the input of ecological resources, (land, water, nutrients, energy, and biological diversity).

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Intensification – changing concepts

- *Tittonell and Giller (2013)*
- Re-defined the concept as
- ‘‘a means of increasing agricultural output, while reducing the use and need for external inputs, and capitalizing on ecological processes that support and regulate primary productivity in agro-ecosystems’’

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Land management and Ecosystem services

Food and water

Ecosystem services

Biodiversity

Livelihoods

Land cover
Land use change

Sustainable Development

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Food production and climate change

- Two of the greatest challenges facing humanity:
  - **Feeding 9–10 billion people by 2050**
  - **Preventing dangerous climate change**
- Both challenges must be met while **reducing the impact of land management on ecosystem services** that deliver vital goods and services, and support human health and well-being.

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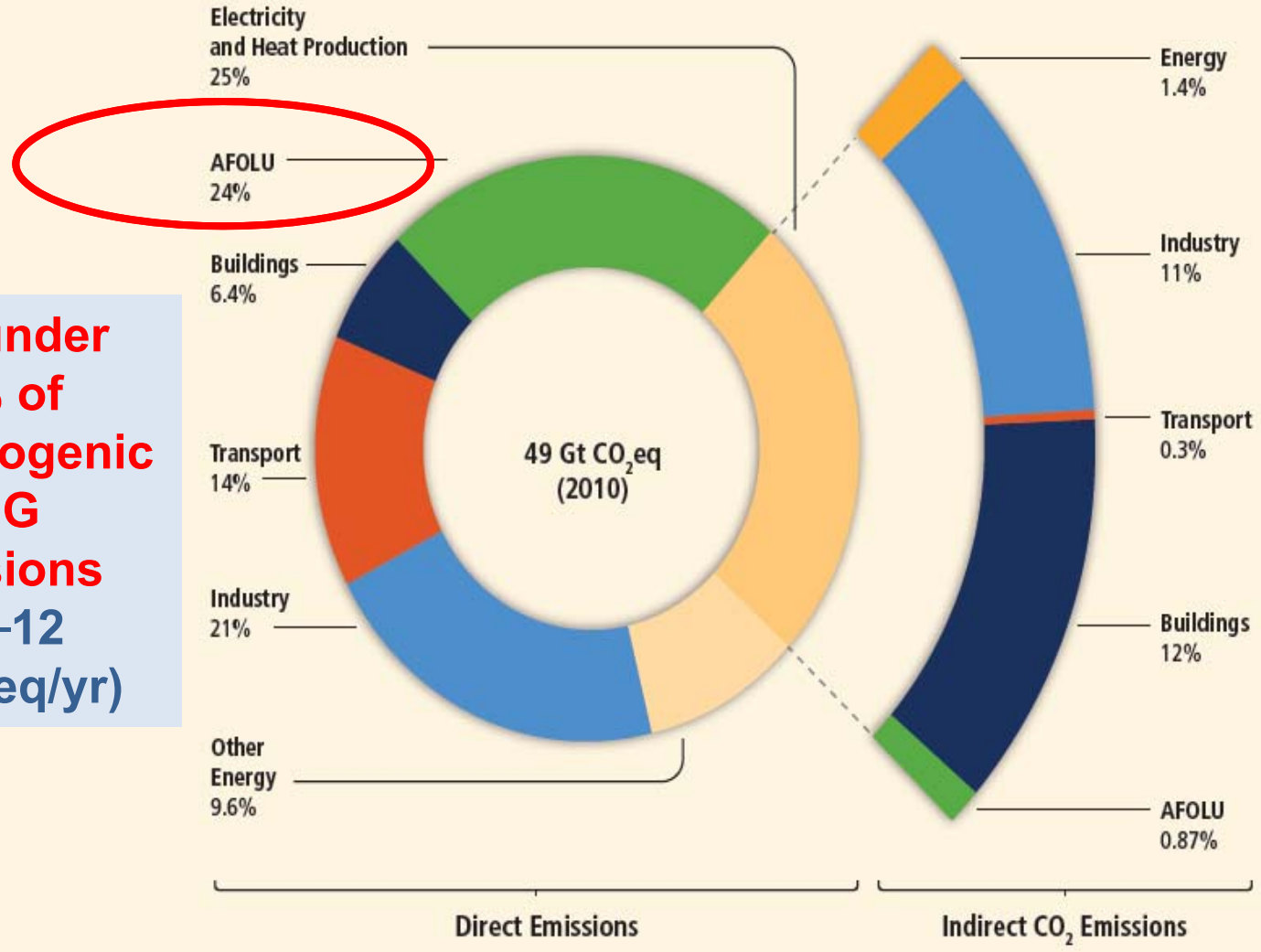
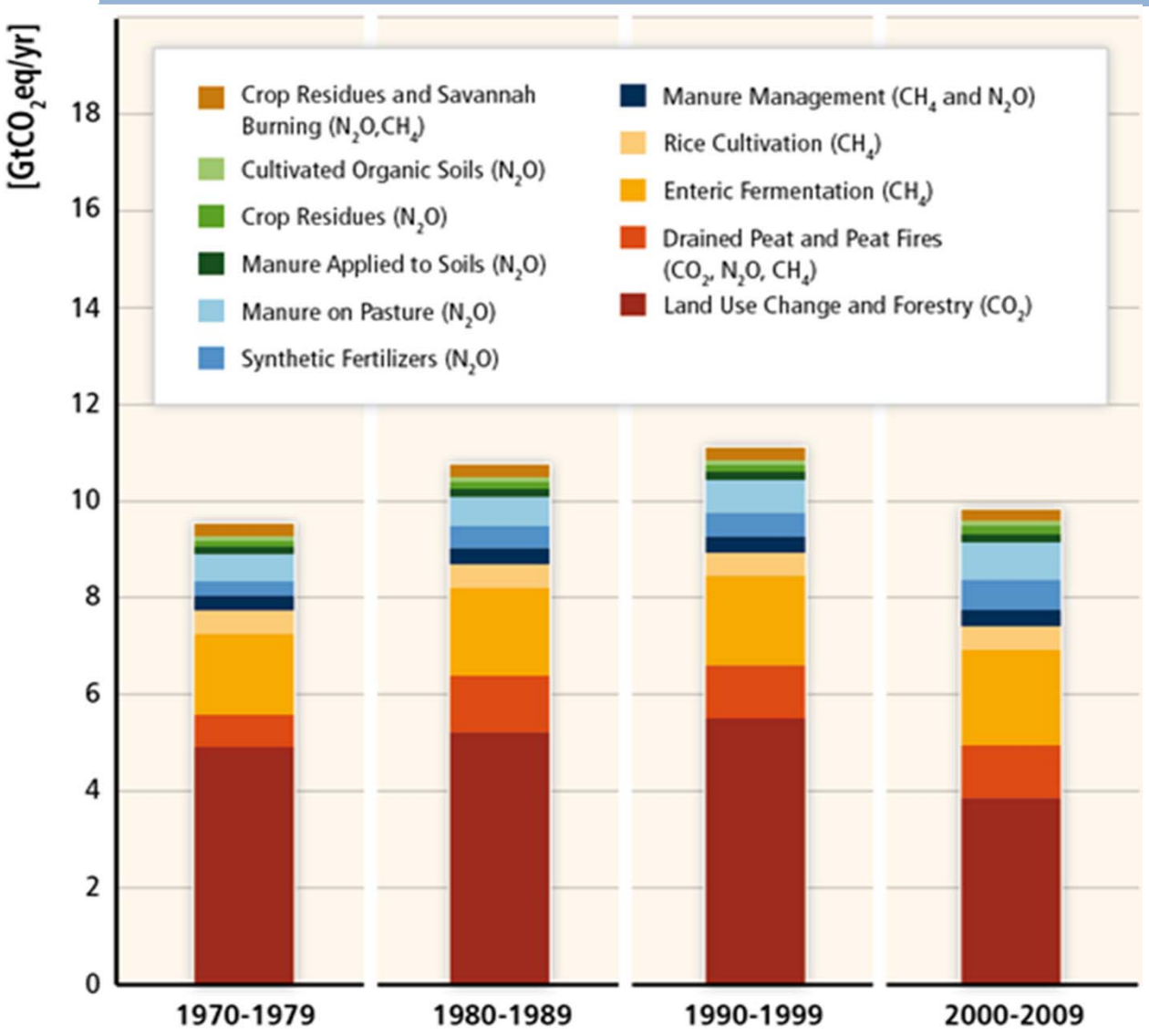
Greenhouse Gas Emissions by Economic Sector



Just under 25% of anthropogenic GHG emissions (~9–12 $GtCO_2eq/yr$)

AFOLU emissions for the last four decades



Current trends

- ↓ Cropland area
- ↑ Irrigated crop area
- ↑ World grain harvest
- ↑ Use of fertilizers
- ↑ Livestock
- ↑ Demand of fish
- ↓ Deforestation

Working Group III contribution to the
IPCC Fifth Assessment Report

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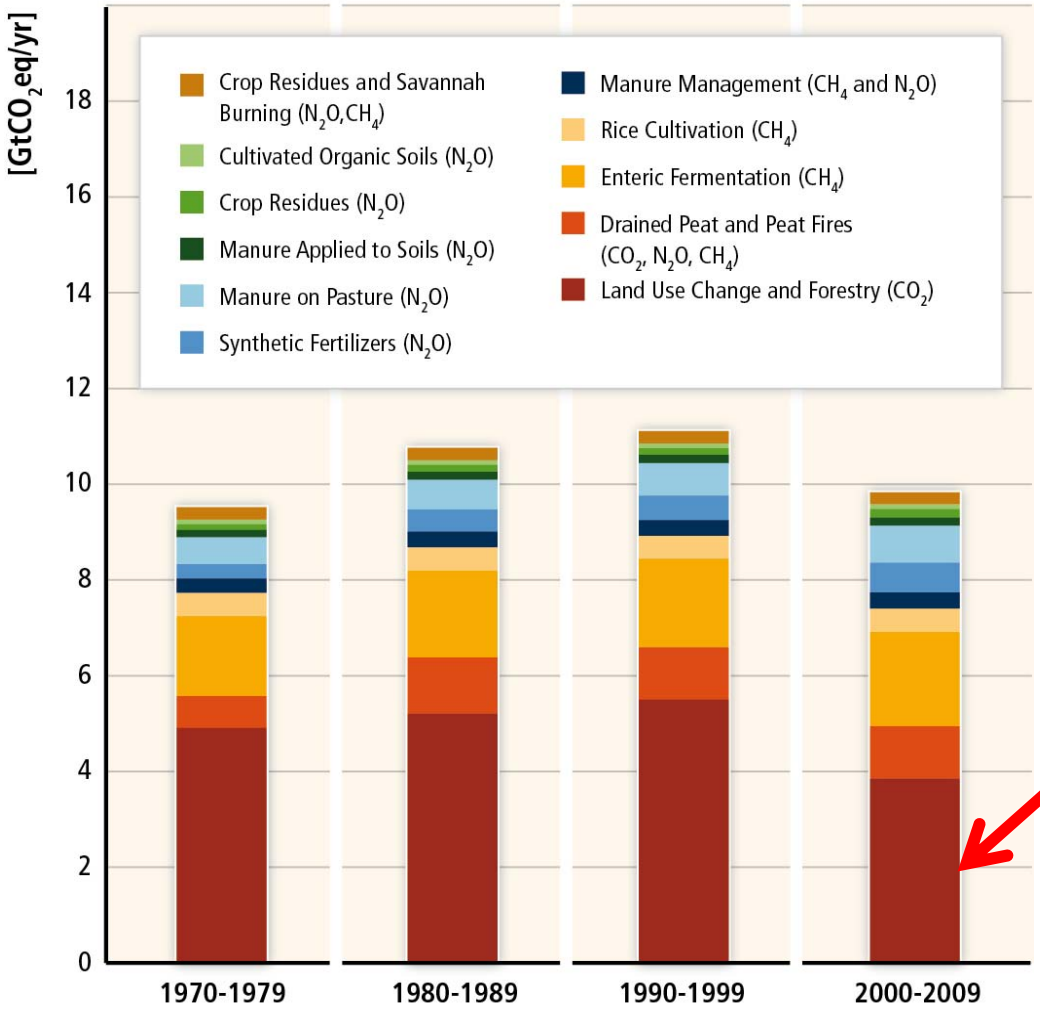
INTERGOVERNMENTAL PANEL ON climate change

WHO UNEP

AFOLU emissions – recent trends



↑ Agricultural emissions

↓ net CO_2 emissions from forest sector

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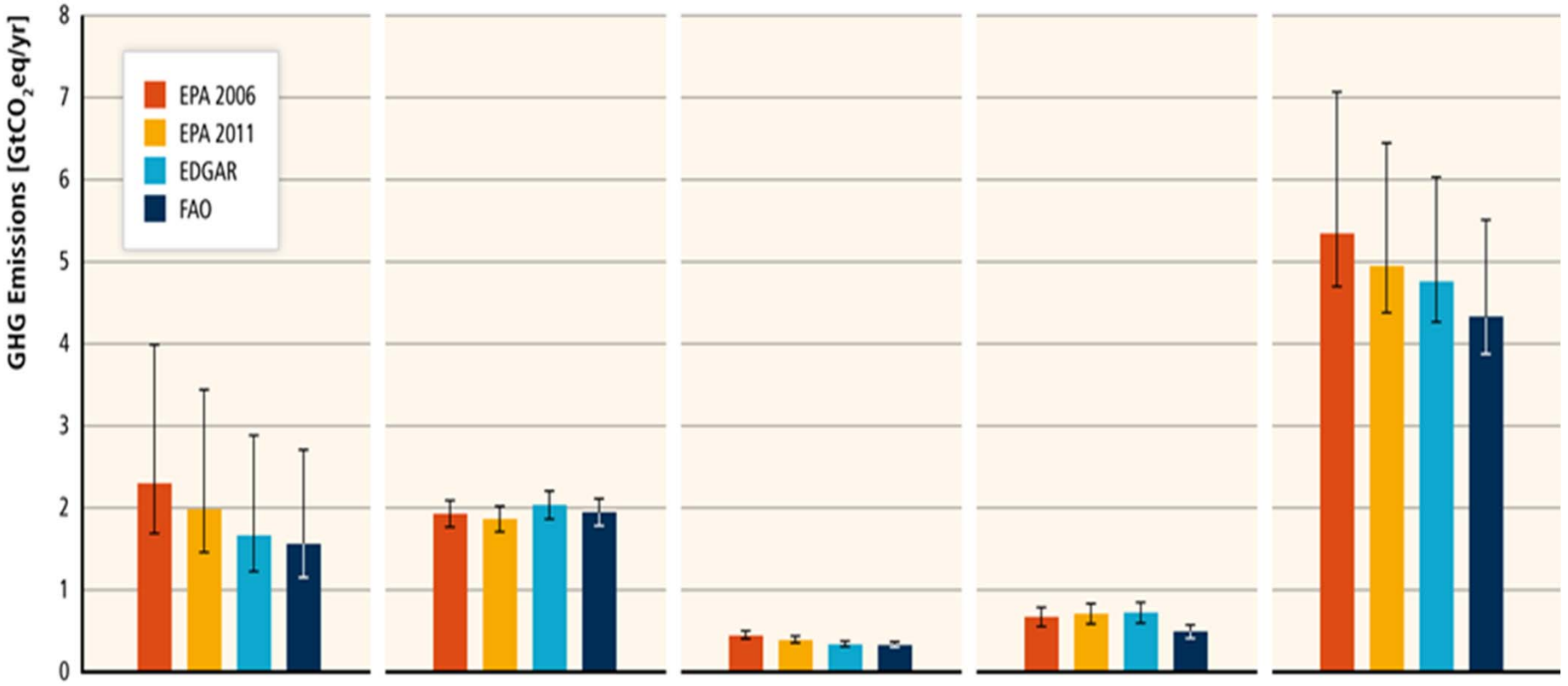
Key agricultural emission categories for 2005



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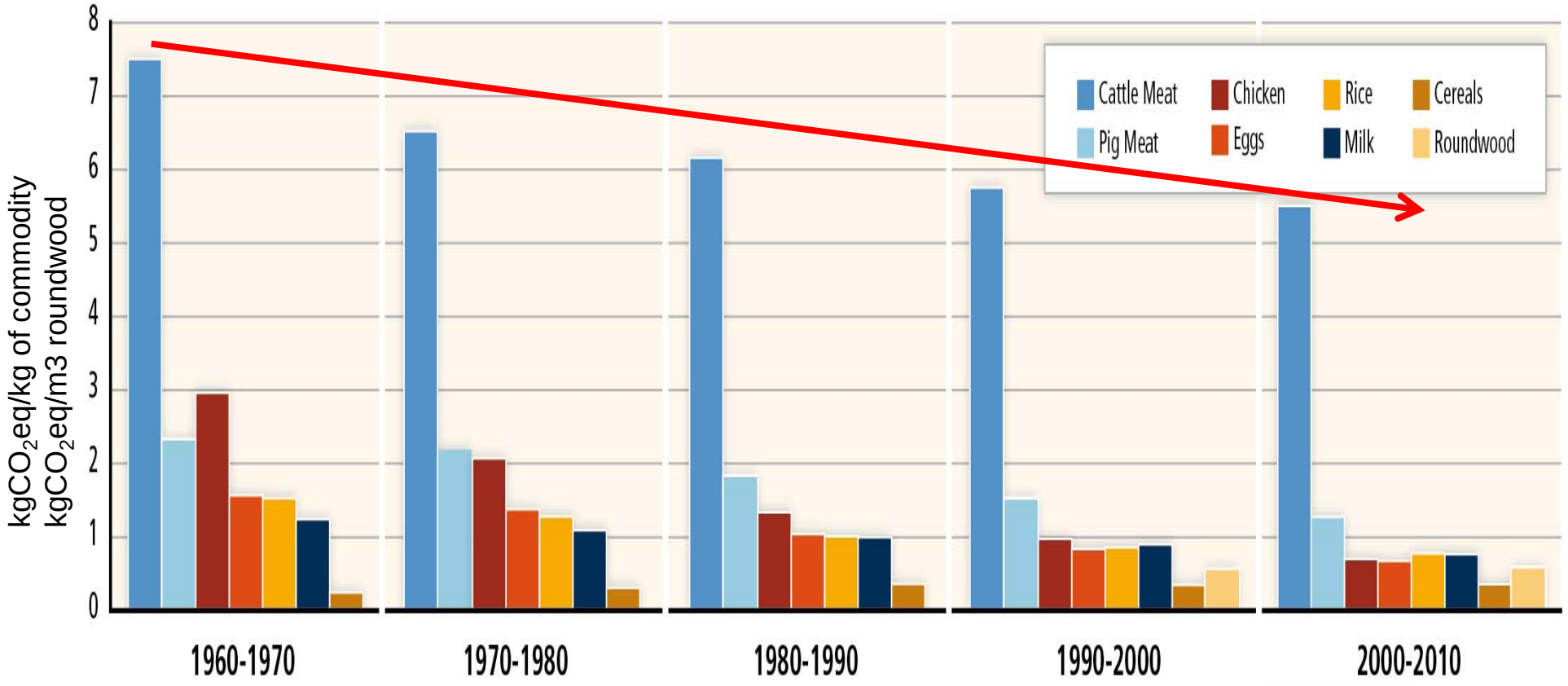
Emission Intensity from products of AFOLU sector is falling due to greater efficiency in agriculture and forestry



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Strategies for sequestering C on land

- **In the short term** - the fastest way to reduce carbon emissions and increase carbon sinks on land is to stop deforestation and expand the area of forests.

- **In the long term** - must be to increase the carbon density of all lands through management.

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AFOLU – mitigation options

- Cost-effective contribution to transformation pathways associated with long-run climate change management.

- The size and regional distribution of future mitigation potential is difficult to estimate accurately.

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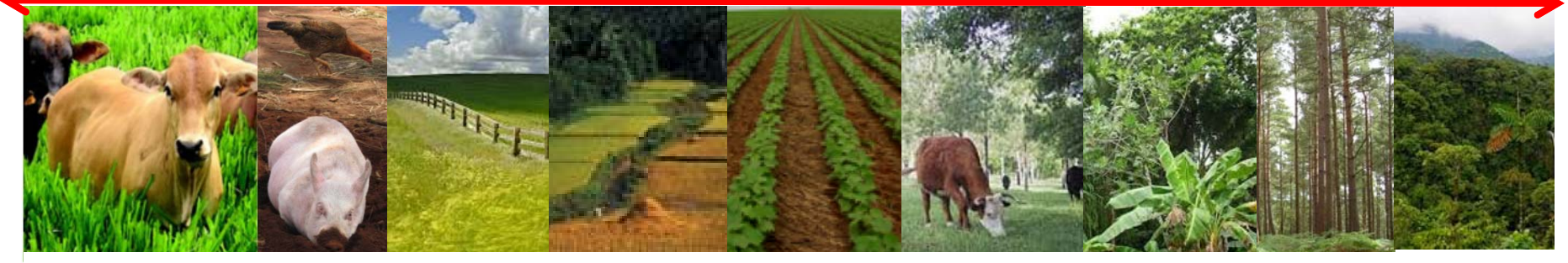
AFOLU mitigation options

SUPPLY SIDE

Livestock mgmt. Cropland mgmt. Int. systems Forestry



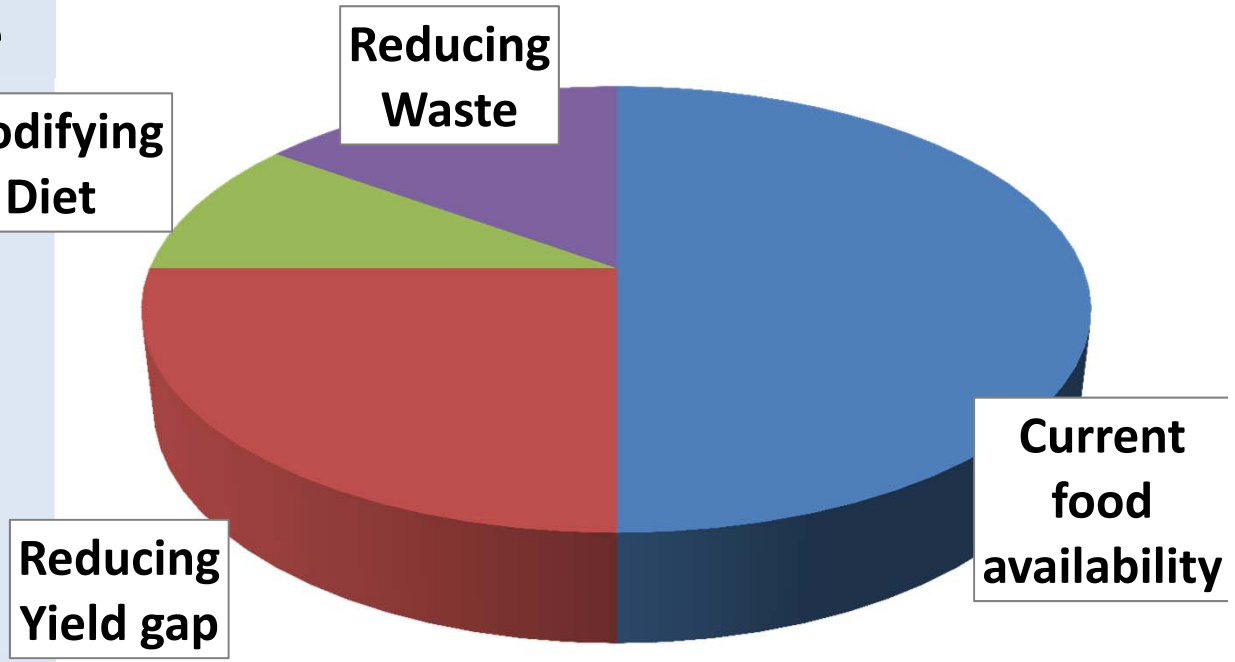
… and bioenergy

DEMAND SIDE

Dietary change
Improvement in the food chain
Use of wood products

Sustainable agriculture, food, society and environment

- *Foley et al. 2011*
- Deployed simultaneously these strategies can increase food availability by 100-180%.
- At the same time - reducing GHG emissions, biodiversity loss, pollution and water use.



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GHG mitigation by agriculture intensification

Net effect on GHG emissions of **historical agricultural intensification** between 1961 and 2005 (*Burney et al. 2010)*

- Emissions from factors such as fertilizer production and application have increased,

but…

1. Net effect of higher yields has avoided emissions of up to 161 GtC (590 $GtCO_2e$) since 1961.
2. Investment in yield improvements compares favorably with other commonly proposed mitigation strategies.

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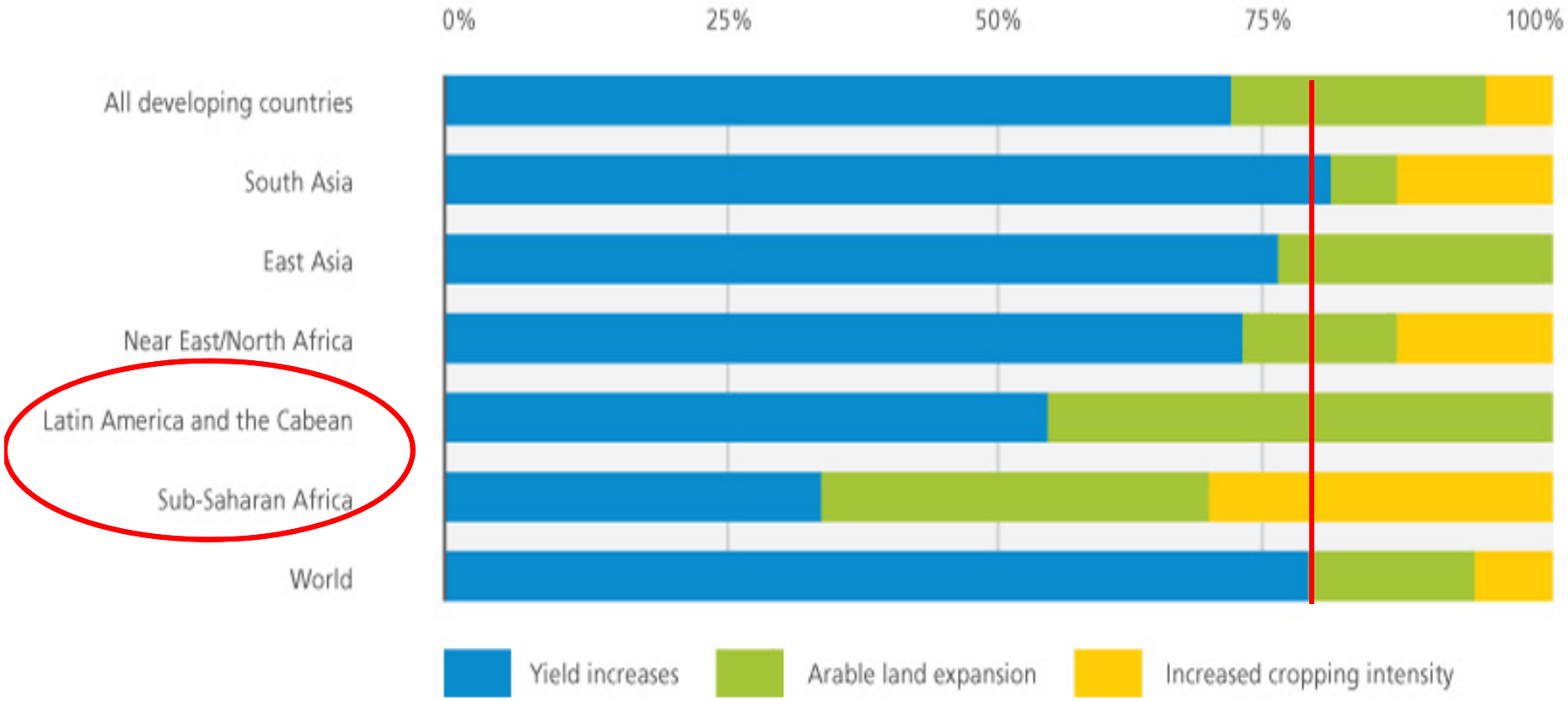
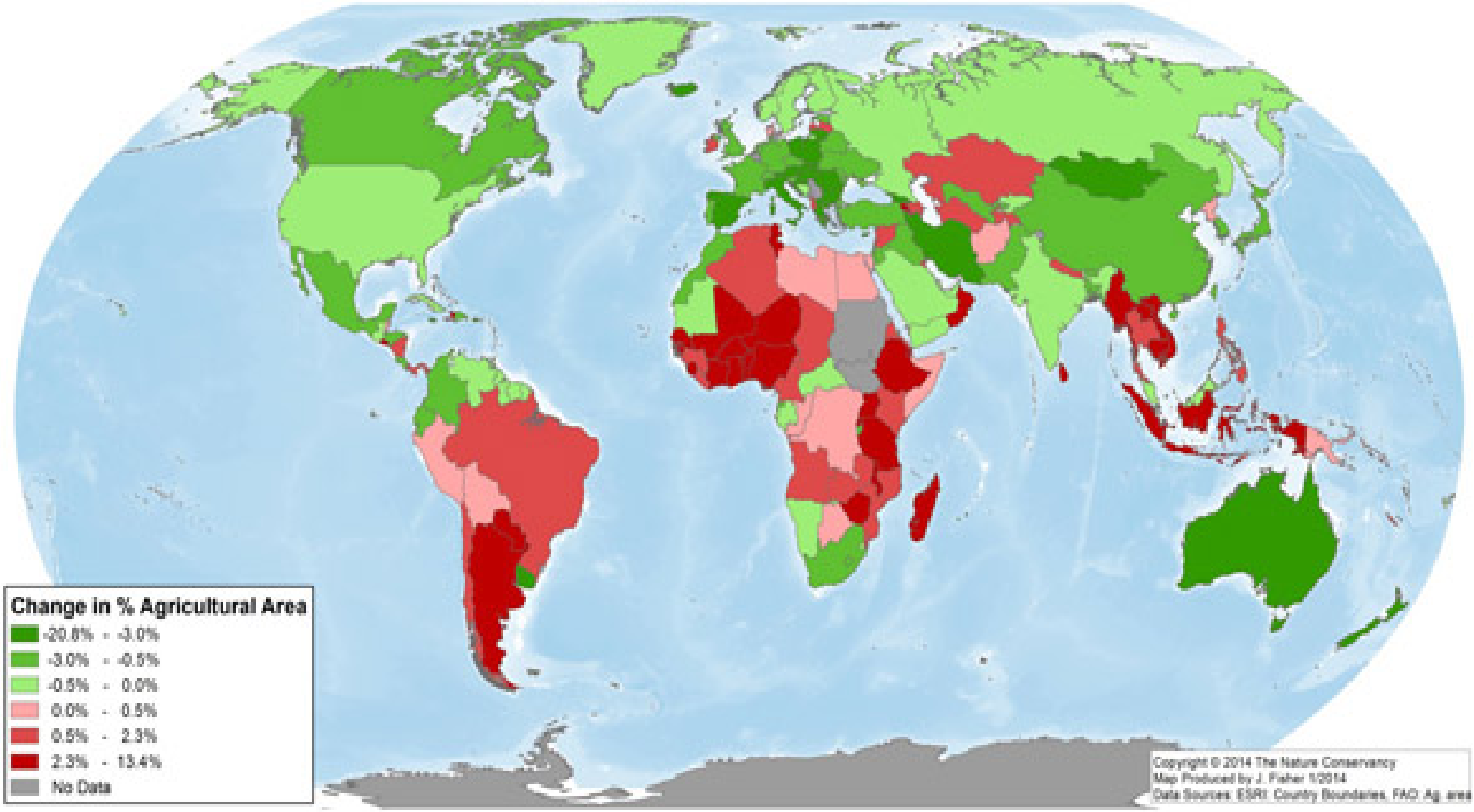


The doubling of world cereal production between 1961 and 1991:
- mainly through increased yield per unit area and greater cropping intensity (85% percent contribution)
- only a small part of the growth coming from increased cropland area (15% contribution).

Change in Agricultural Area 1998-2011 by Country



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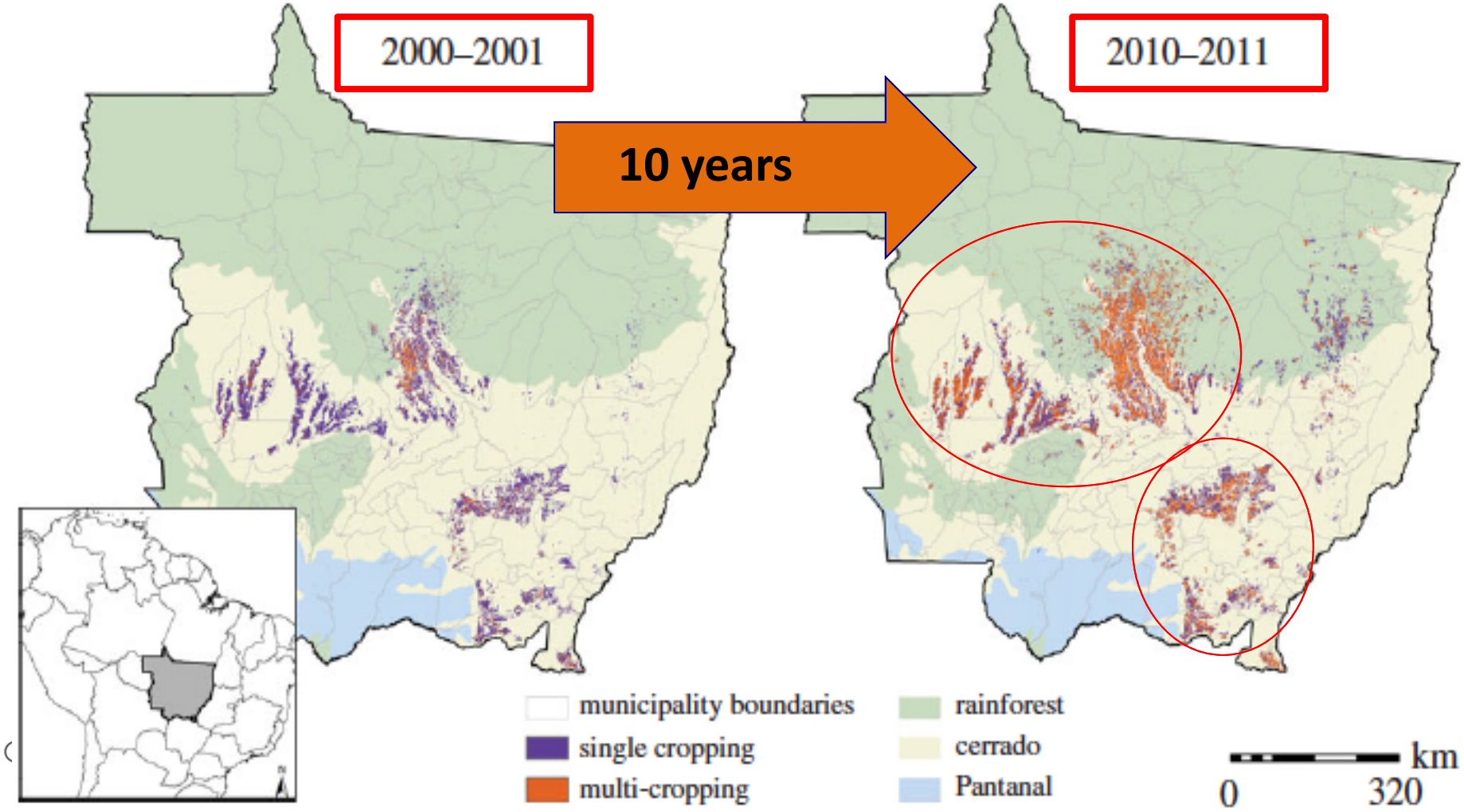
Example: intensification in Mato Grosso, Brazil

Mato Grosso is the main **soybean** producing state
= 30% of national **production**



Van Wey et al. 2013

Yield, efficiency and emissions…

- *Valin et al.(2013)*
- Focus on developing countries.

1. Effects of crop yield and livestock feed efficiency scenarios on GHG emissions from agriculture and land use change
2. Mitigation associated with different productivity pathways (model GLOBIOM).

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Yield, efficiency and emissions…

1. Closing yield gaps by 50% for crops and 25% for livestock by 2050

Decrease agriculture and land use change emissions by **8% overall**, and by **12% per calorie produced**.

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Yield, efficiency and emissions…

2. Outcome is sensitive to the technological path and which factor benefits from productivity gains

sustainable land intensification would increase GHG savings by 1/3 when compared with a fertilizer intensive pathway.

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Crop or livestock sector? Different implications…

Crop yield increase = largest food provision benefits

Livestock productivity gains = greatest reductions in GHG emission

Combining productivity increases in the two sectors = most efficient way to exploit mitigation and food security co-benefits

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Rebound effect

- However, increases in yield may result in feedbacks such as increased consumption.

- Higher yield through total factor productivity = more efficient on the food supply side but…

↓ 50% emissions savings due to a strong rebound effect on the demand side.

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Deforestation, agriculture intensification and nature conservation

- Agricultural expansion is one of the drivers of deforestation (especially in tropical regions)
- Most of the megadiverse countries are found in the tropics
- Combining efficient agricultural land use with biodiversity conservation is a significant concern

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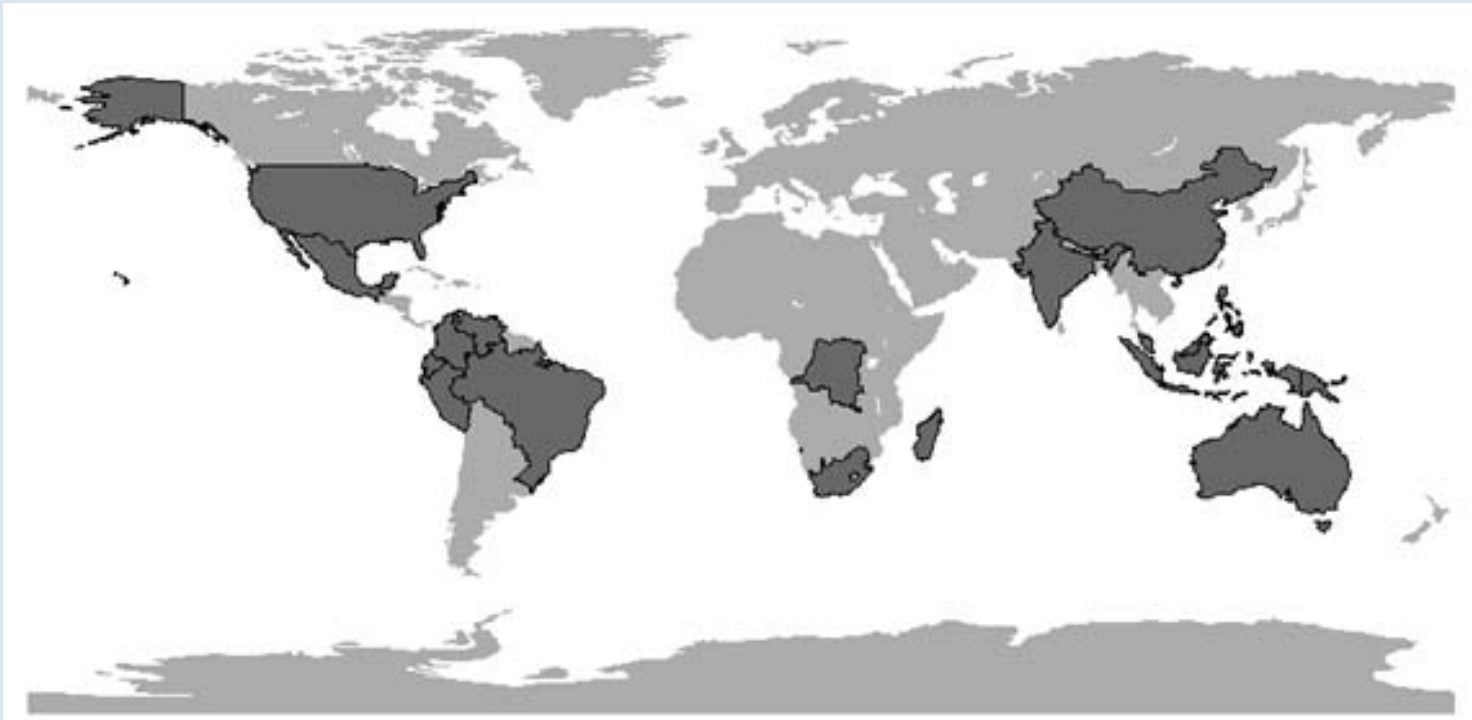
Megadiverse countries

- 17 megadiverse countries = less than 10% of the global surface, but support more than 70% of the biological diversity on Earth



Megadiversity Countries

Mittermeier, R.A., Robles-Gil, P., Mittermeier, C.G. (Eds) 1997. Megadiversity. Earth's Biologically Wealthiest Nations. CEMEX/Agrupaciaon Sierra Madre, Mexico City.

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Biodiversity hotspots with key coffee-growing regions

Today coffee is grown in at least 16 of the 34 hotspots

Agriculture 2015

Land sharing and sparing debate

- Question **whether or at what scale** farming and conservation land management should be:
- Separated - segregating land for nature from land for production = **land sparing**, or
- Integrated - production and conservation on the same land = **land sharing**.

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Land sharing and sparing debate

- Three main problems :

1. Yield and biodiversity are not necessarily negatively correlated where farms are efficiently managed.

2. Increased yield does not necessarily spare land for nature.

3. Conventional intensification tends to disrupt beneficial functions of biodiversity (e.g.,natural pest control and pollination) and degrades environmental quality, threatening sustainability of food production.

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Ecological intensification and ecosystem services: reducing yield gap

- replacement of anthropogenic inputs and/or enhancement of crop productivity,

- by including regulating and supporting ecosystem services management in agricultural practices.

Bommarco et al. 2013

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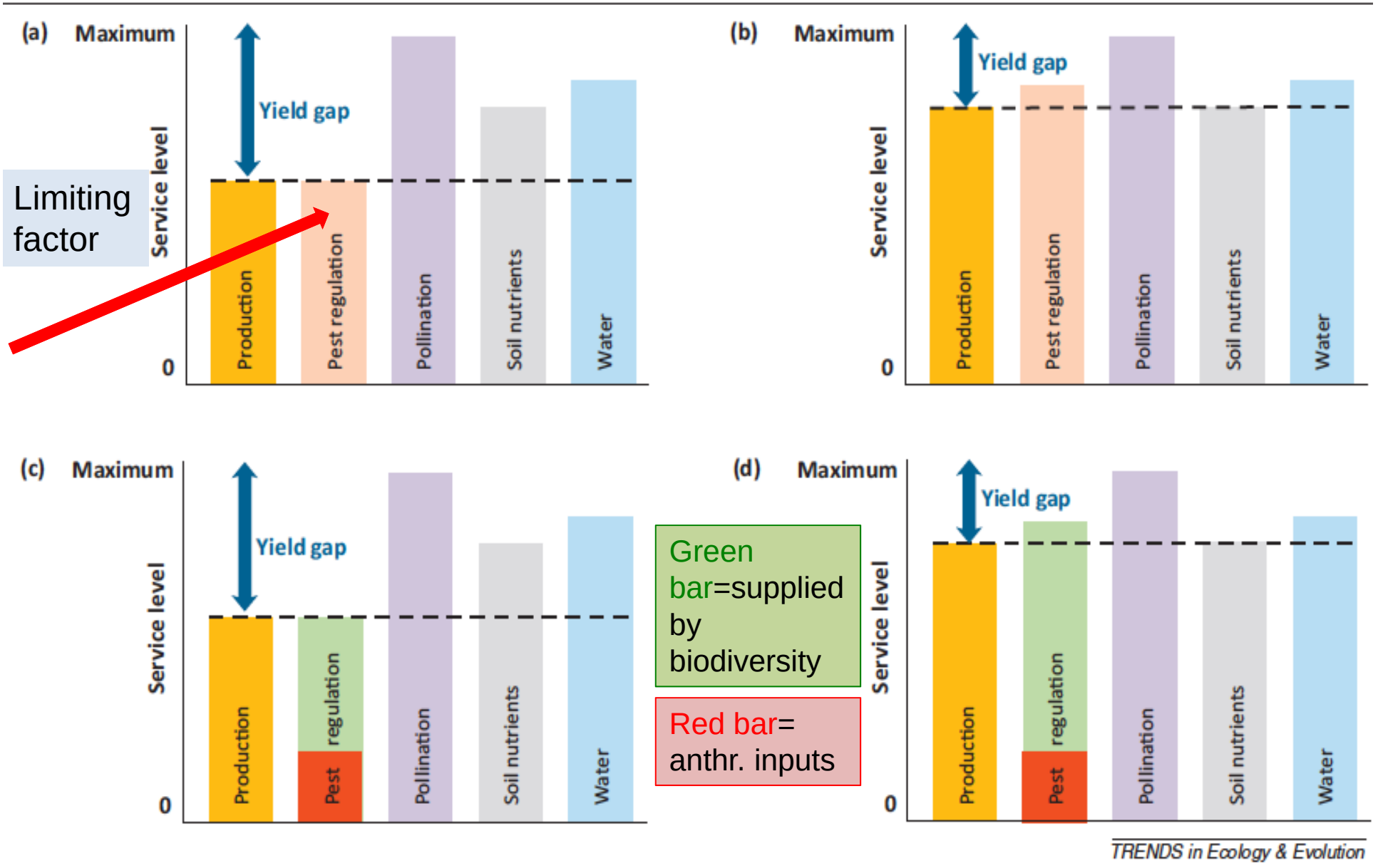

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Bommarco et al. 2013

Yield-biodiversity relationships

- High variability in yield-biodiversity relationships
- High variability of economically viable agricultural practices in both temperate and tropical regions

- **there are promising management options balancing human and ecological needs**

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Bommarco et al. 2013

Agriculture intensification and mitigation

- Can promote innovation
- Many technological supply-side mitigation options also increase agricultural efficiency.
- Need to be assessed, as far as possible, for their potential impact on all other ecosystem services provided by land.

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Local and regional differences

- Large differences in emissions intensity between different regions of the world
- Potential for improving emissions intensities lies especially in developing countries,
- if intensification strategies can be matched to local resources and contexts.

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Local and regional differences

- **Feedbacks with climate change will affect the mitigation potential** with important regional differences and uncertainties.

- Linking agricultural intensification with biodiversity conservation and food production **requires well-informed regional and targeted solutions.**

- Sensitive wildland ecosystems and remaining natural habitats need to be protected

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Synergies of Mitigation and Adaptation - AFOLU

Diversification of production systems

- Crop diversification
- Multi-species plantation forestry
- Regeneration of native species

Integration of production systems

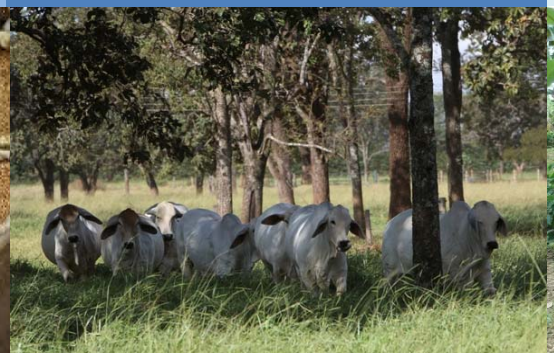
- Crop/livestock
- Agroforestry
- Promotion of legumes in crop rotations
- Adoption of short-rotation commercial species

Management practices and technologies

- Soil, nutrient and water conservation practices
- High quality seeds,
- avoiding burning of crop residues

Ecosystem conservation and restoration

- Forest Conservation
- Protected Area Management
- Afforestation and reforestation
- Control of wildfires

Concluding remark

- **"In the end, the choice is not between forests and agriculture (or energy or fiber) because a habitable Earth and a stable climate require both."**

  Houghton, R. Land Management Options for Mitigation and Adaptation to Climate Change (2014)

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Thank you!

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