2017 All Hands ACME Meeting
Potomac, MD
June 5-7, 2017

Spatiotemporally dynamic drivers of global land use and land cover change (LULCC) in the past century

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Acknowledgements
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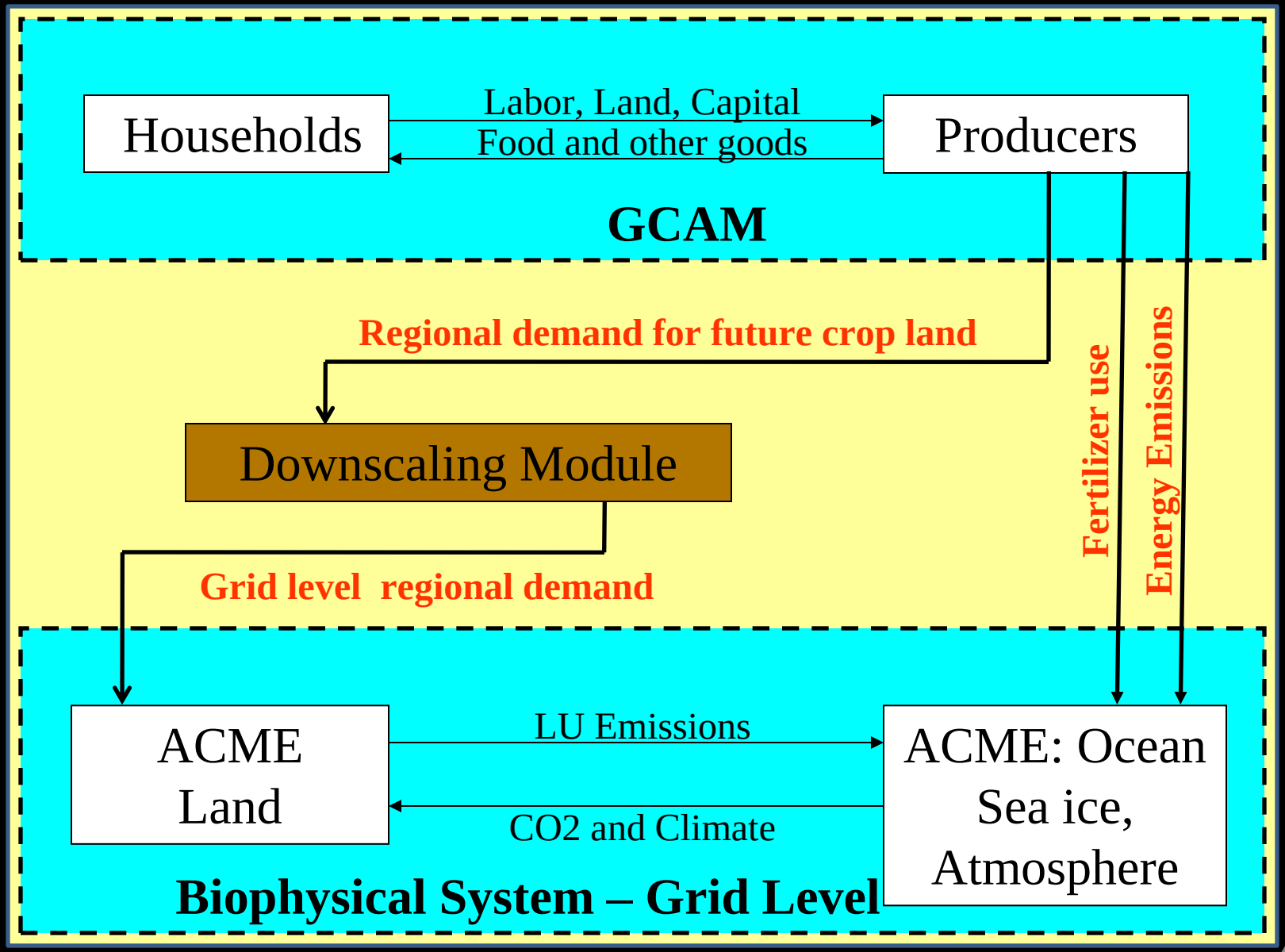
Overall Objective of Our ACME Project

- Advance the treatment of land disturbance, particularly LULCCs and land management practices, within GCAM and couple it with ACME
- Use the coupled systems to fully explore the potential contribution of
  - LULCC and land management practices to future emissions and mitigation opportunities
  - terrestrial carbon sources and sinks, and climate change.

GCAM Makes Future Projections of LULCC at Regional Scale

283 agro-ecological zones (AEZs) within 32 geo-political regions

Linking GCAM and ESM – Current Approach



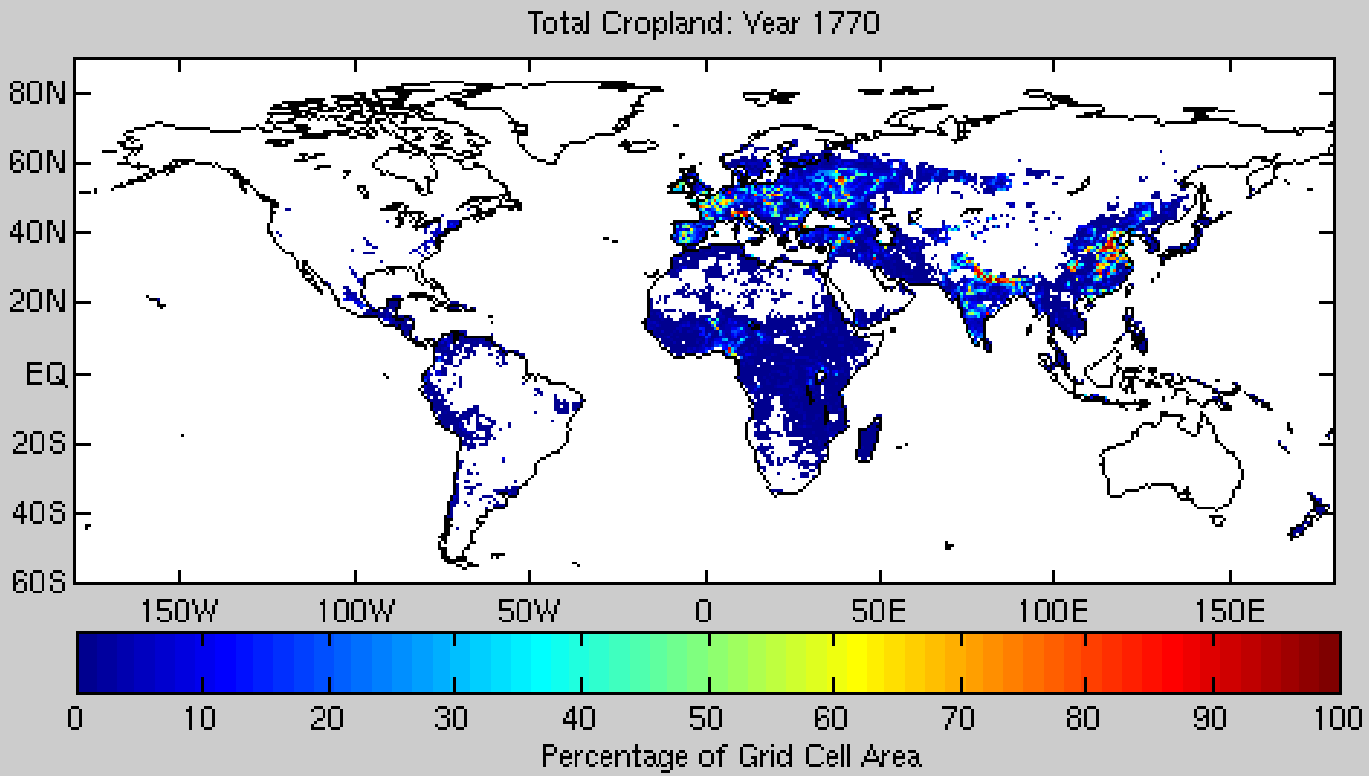
Focus of Today's Talk

Implementation of Global-Scale Spatial Dynamic Allocation Model (SDAM) of Forest (primary and secondary) and Agricultural Land use Changes in GCAM-ACME Coupled Modeling Framework.

Requires understanding of:

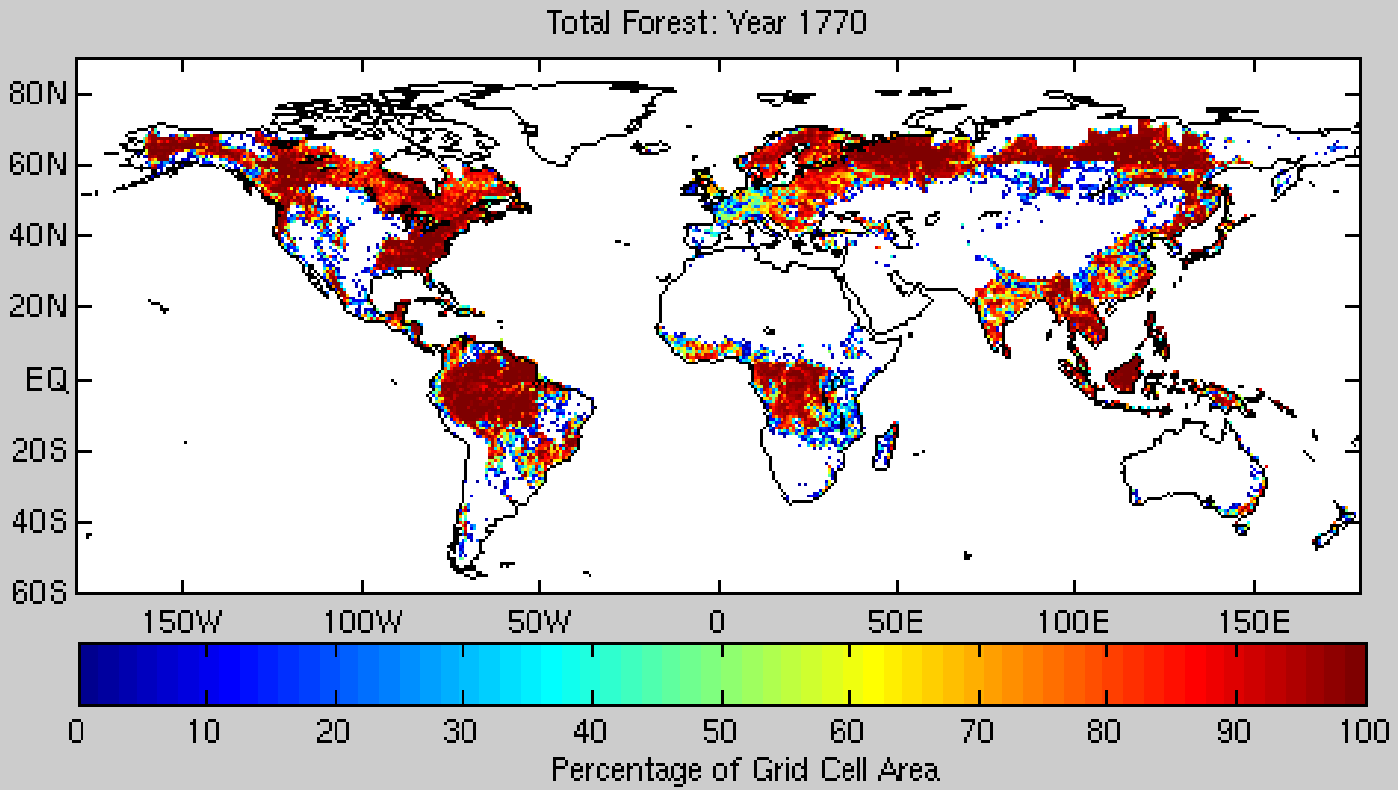
- dynamics of historical LULCC
  - available based of the historical reconstructions
- spatial and temporal heterogeneities of LULCC drivers over the historical time
  - limited information available at global and centenary scales

Changes in Agriculture Land from 1770-2010



Meiyappan and Jain (2012)

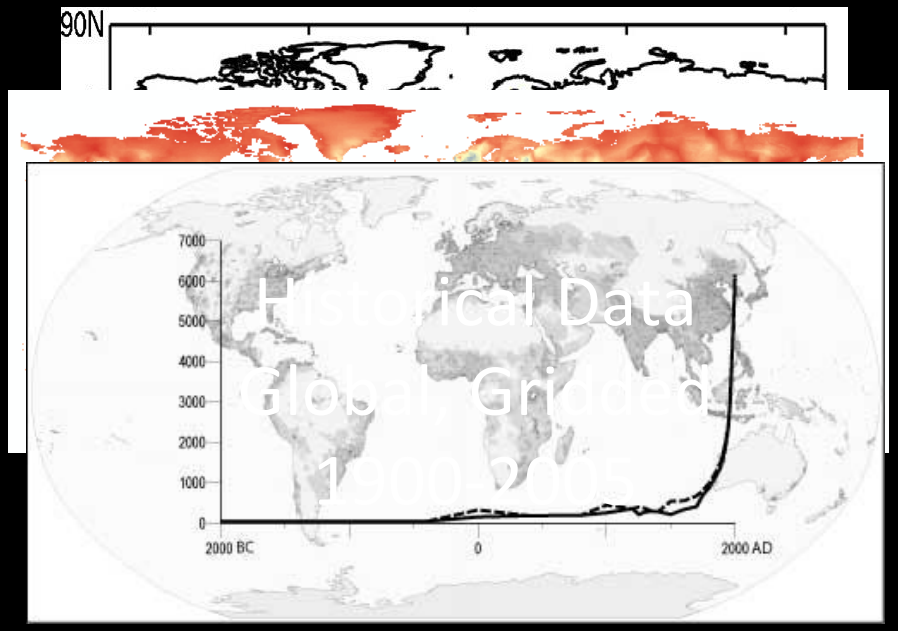
Changes in Forest Land from 1770-2010



Meiyappan and Jain (2012)

LULCC downscaling model (SDAM)

(Meiyappan et al., 2014)



Estimation

Historical land use data (Ramankutty & Foley)

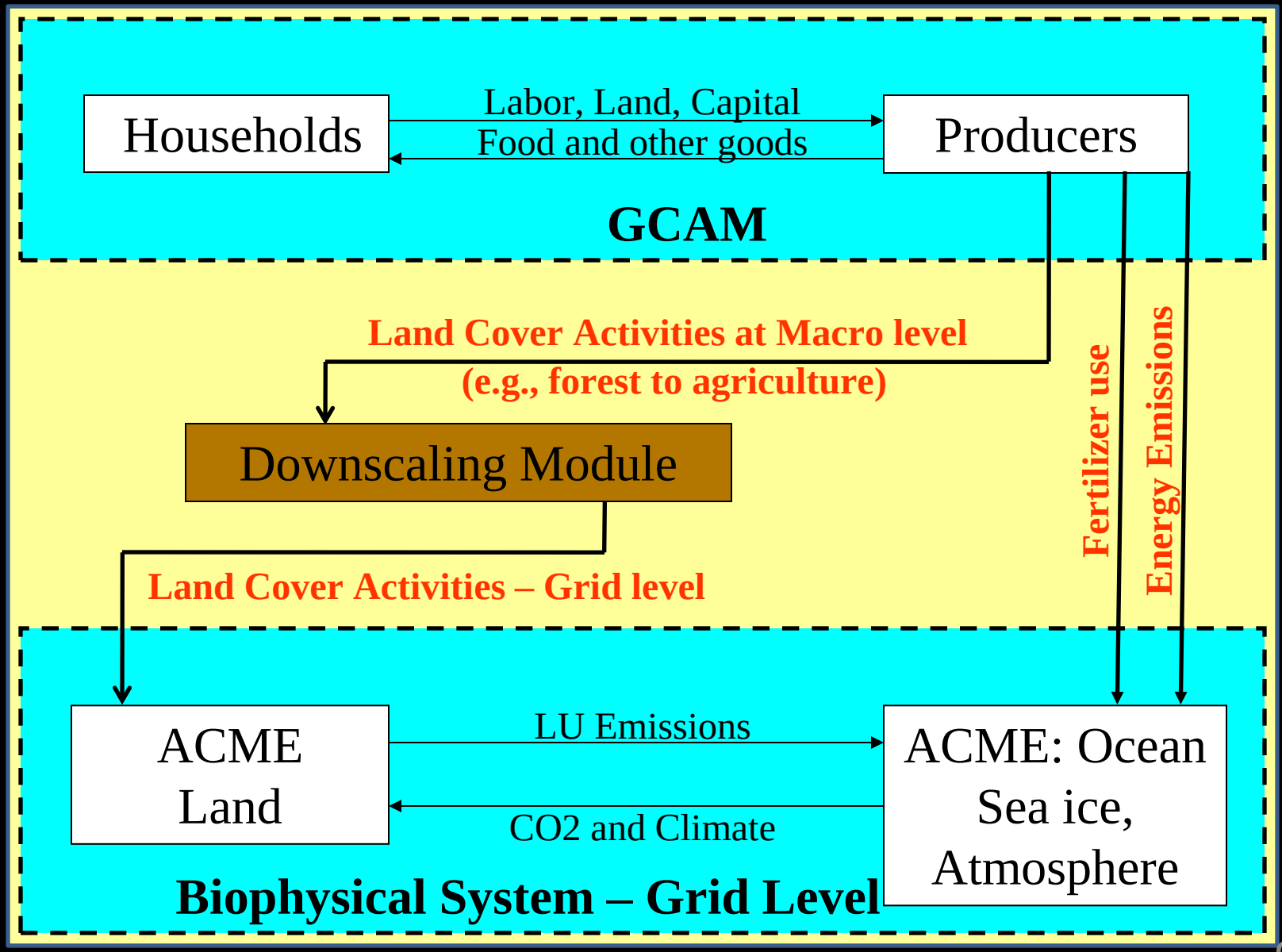
Historical climate data (CRU-TS) (also soil, terrain)

Historical population data (HYDE) (also urban areas, GDP, market access)

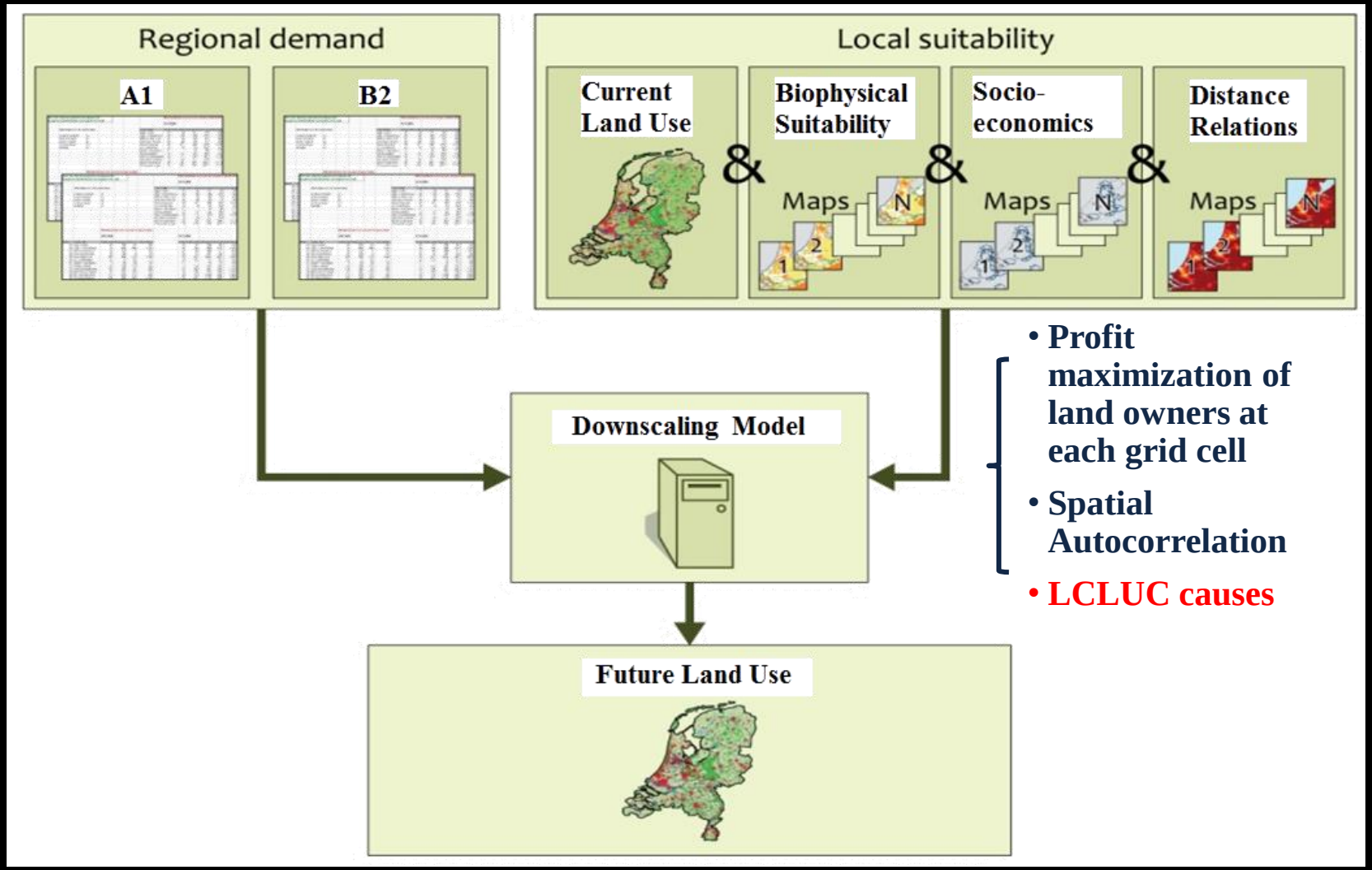
Evaluate Spatial & temporal land use downscaling model

SDAM parameters

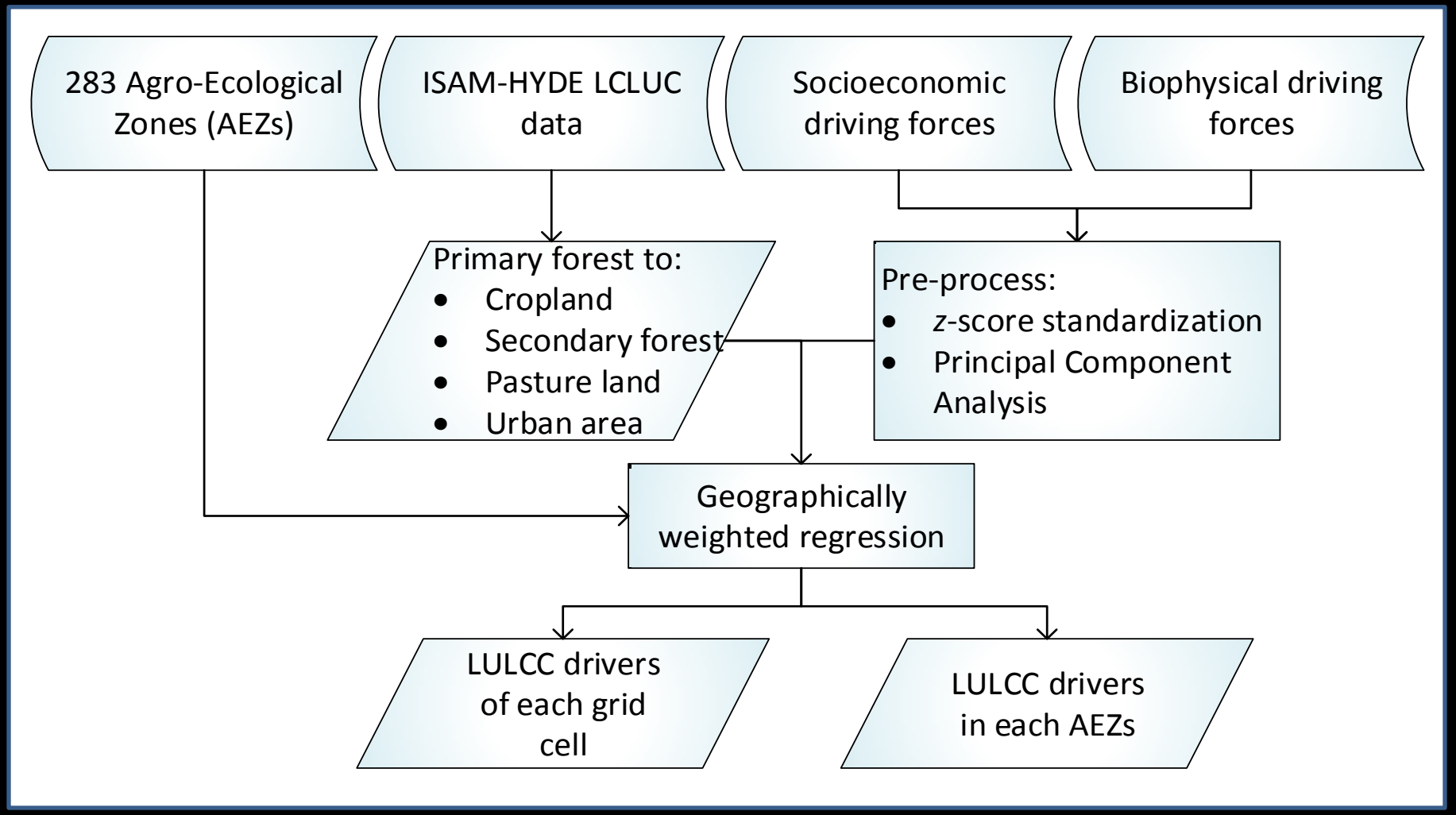
Linking IAM and ESM – Modified Approach



SDAM - Downscaling



SDAM – Causes of LULCC



ISAM - HYDE LCLUC Data

Estimated Forest Area (1990s) - Comparison with Previous Studies

(Unit million km^2)

Regions	Hurtt et al. (2006)	LUH2 (Hurtt et al. 2017)	ISAM-HYDE (Consistent with IGBP Classification)	Test Case	
				FAO[2]	ISAM-HYDE (UMD Classification)
North America	9.3	8.1	5.8-6.0	5.1	4.1-4.5
Latin America	9.0	8.2	7.4-8.3	10.2	9.8-10.1
Europe	1.6	1.3	1.3-1.4	1.7	1.5
North Africa and Middle East	<0.1	<0.1	<0.1	0.1	0.4
Tropical Africa	4.4	3.4	2.8-3.15	6.9	7.0-9.8
Former USSR	9.7	8.8	5.9-6.0	8.1	6.3- 6.5
China	2.5	2.1	1.2-1.35	1.7	1.8- 2.0
South & South East Asia	3.3	3.2	3.1-3.2	3.6	3.3- 3.4
Pacific Developed Region	1.1	1.0	1.1	2.2	2.4- 3.7
World	40.9	36.2	29.0-30.1	39.6	37.2-41.3

Driver Data – Biophysical and Socioeconomic Data sets

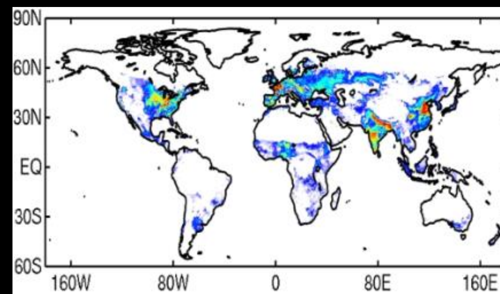
Category	Data Variable	Description/Units	Spatial Characteristics	Period of Availability	Source
Terrain (1)	Elevation, Slope and Inclination Combined	Categorical Data classified into 9 gradient classes	5 minutes^ (lat/lon)	Constant with time	FAO/IIASA, 2010. Global Agro-ecological Zones (GAEZ v3.0). FAO, Rome, Italy and IIASA, Laxenburg, Austria. http://www.fao.org/nr/gaez/en/
Soil characters (5)	Soil fertility	Categorical Data classified into 7 gradient classes of land suitability for agriculture			
	Soil drainage				
	Chemical composition				
	Soil depth				
	Soil texture				
Temperature (6)	Temperature (T_a)	°C	0.5 degrees (lat/lon)	1901-2009 (monthly)	Climatic Research Unit (CRU) TS 3.1 (updated estimates based on Mitchell and Jones, 2005)
	Daily Average Maximum Temperature (T_{max})				
Seasonal PET (4)	Potential Evapotranspiration	Millimeters			
Precipitation (7)	Precipitation				CRU TS 3.10.01#
Seasonal PDSI (4)	Palmer Drought Severity Index (PDSI)	No units	2.5 degrees@	1870-2010	Dai et al. (2011a,b)
Seasonal THI (4)	Temperature humidity index (THI)	°C			
Socioeconomic Factors (7)	Urban/built-up land	% of grid-cell area	5 minutes^ (lat/lon)	10,000 BC – 2005 AD (decadal)%	Goldewijk et al. (2010)
	Urban Population	Inhabitants/km^2			
	Rural Population				
	Gross Domestic Product (GDP) per capita	Constant 1990 international (Geary-Khamis) dollars/person	National level	1 AD-2010	Bolt and Van Zanden (2013)
				(annually between 1800-2010)$	(The Maddison Project - http://www.ggdc.net/maddison/maddison-project/home.htm)
	Market Accessibility	No units	1 km^ (lat/lon)	~2005	Verburg et al. (2011)

LULCC Activities Studied

- Following activities
  - Primary forest to cropland
  - Primary forest to secondary forest
  - Primary forest to pasture land
  - Primary forest to urban area
- Over the time period 1900-2005

SDAM downscaling results - Cropland

Base map (1900)



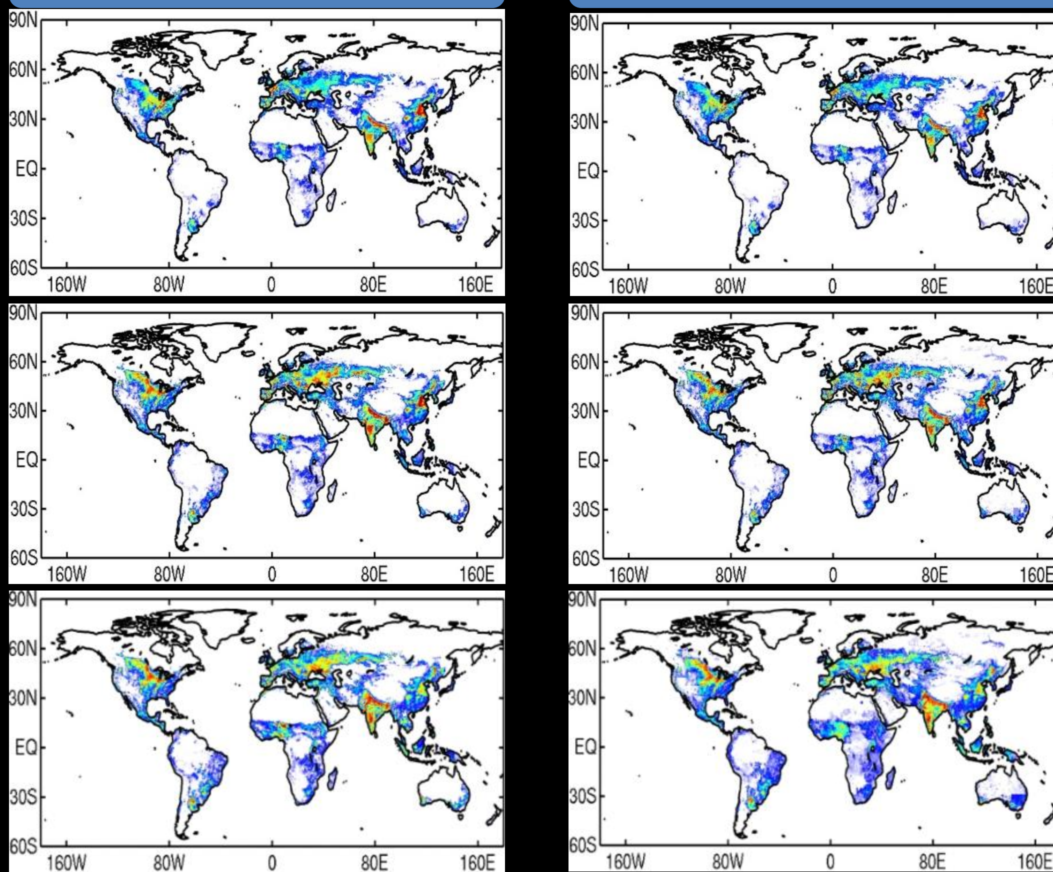
Reference map -HYDE

Modeled map - SDAM

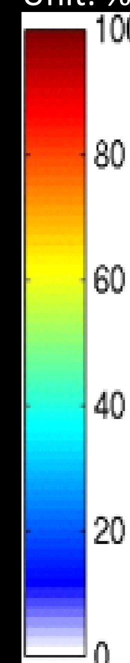
1920

1960

2005

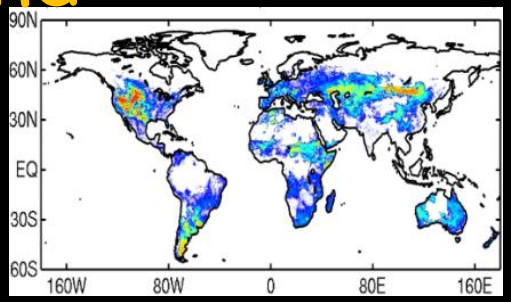


Unit: %



SDAM downscaling results: Pastureland

Base map (1900)



Reference map -HYDE

Modeled map - SDAM

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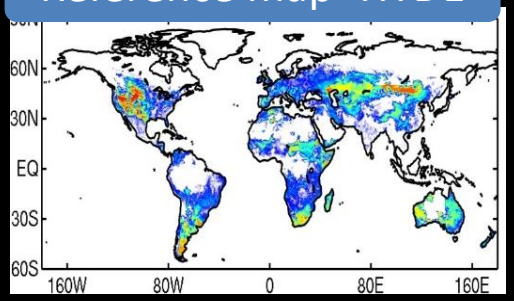
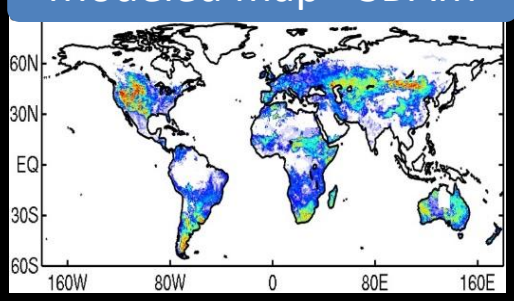
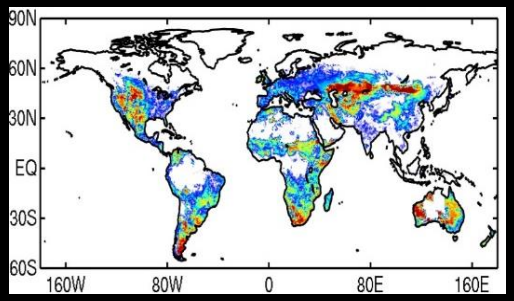
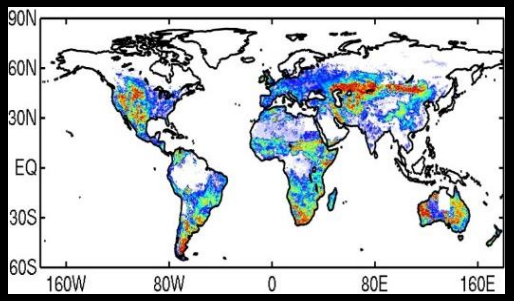
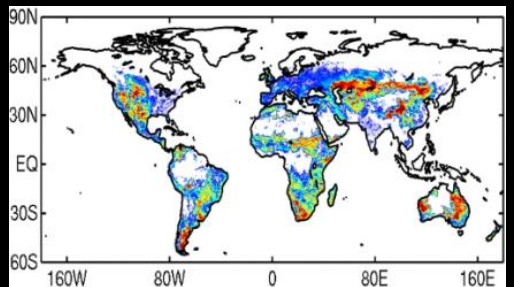
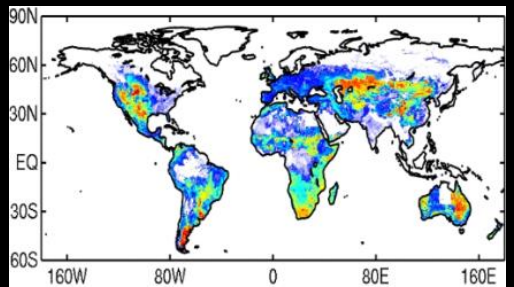


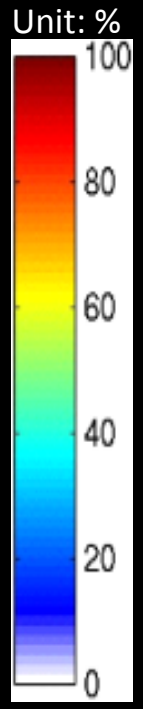






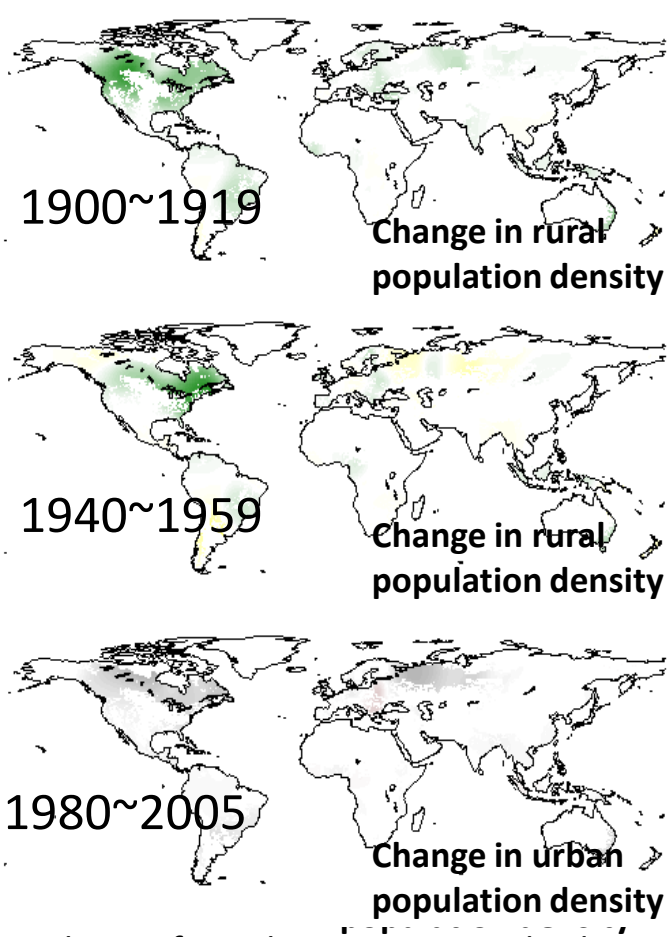


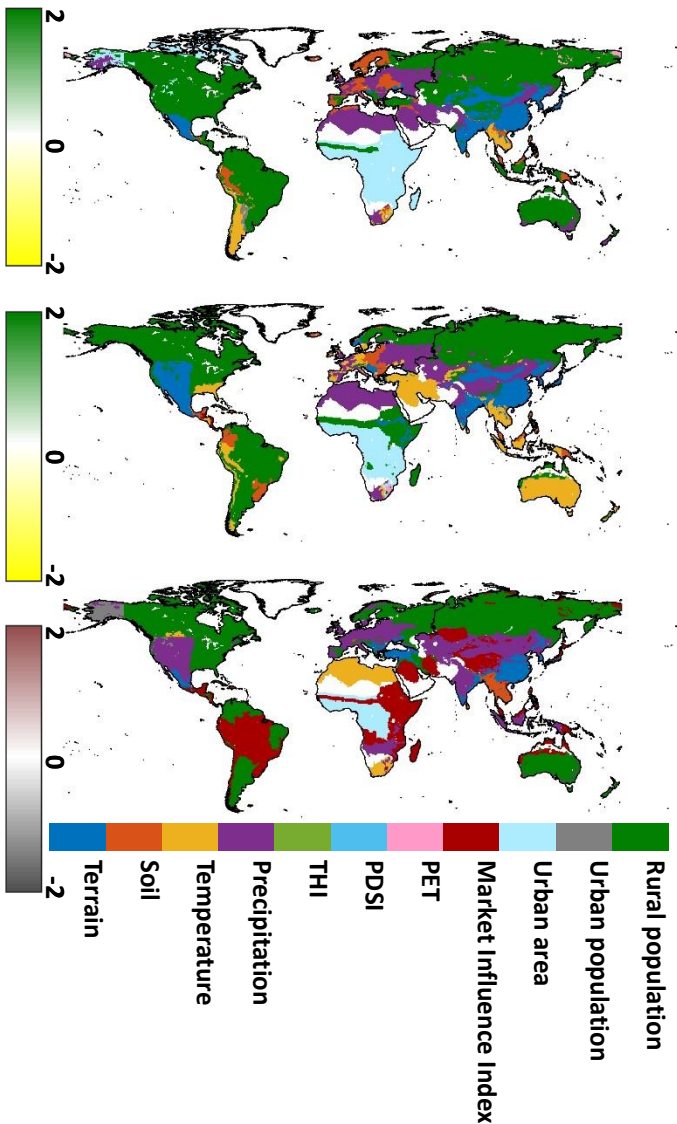


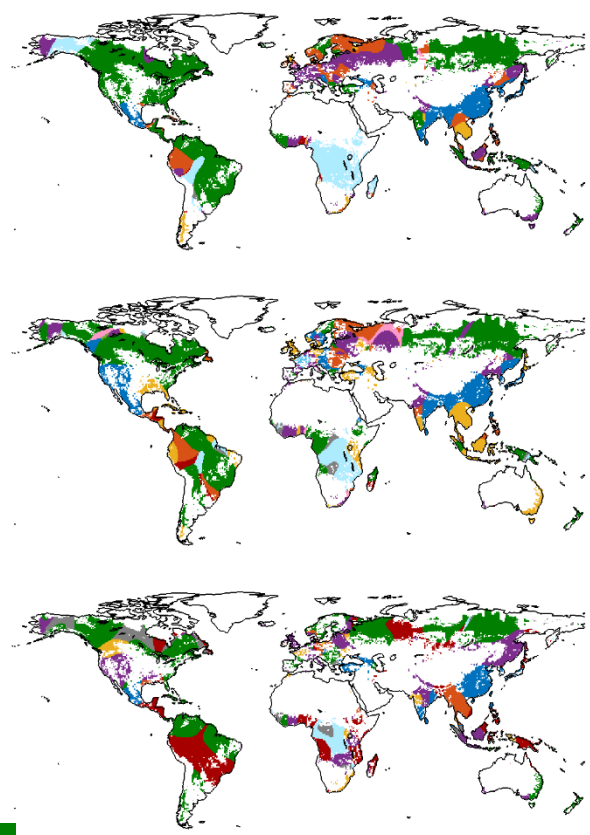


Results: Primary forest to cropland

Overall dominant driver	Dominant driver by AEZ	Dominant driver in each grid





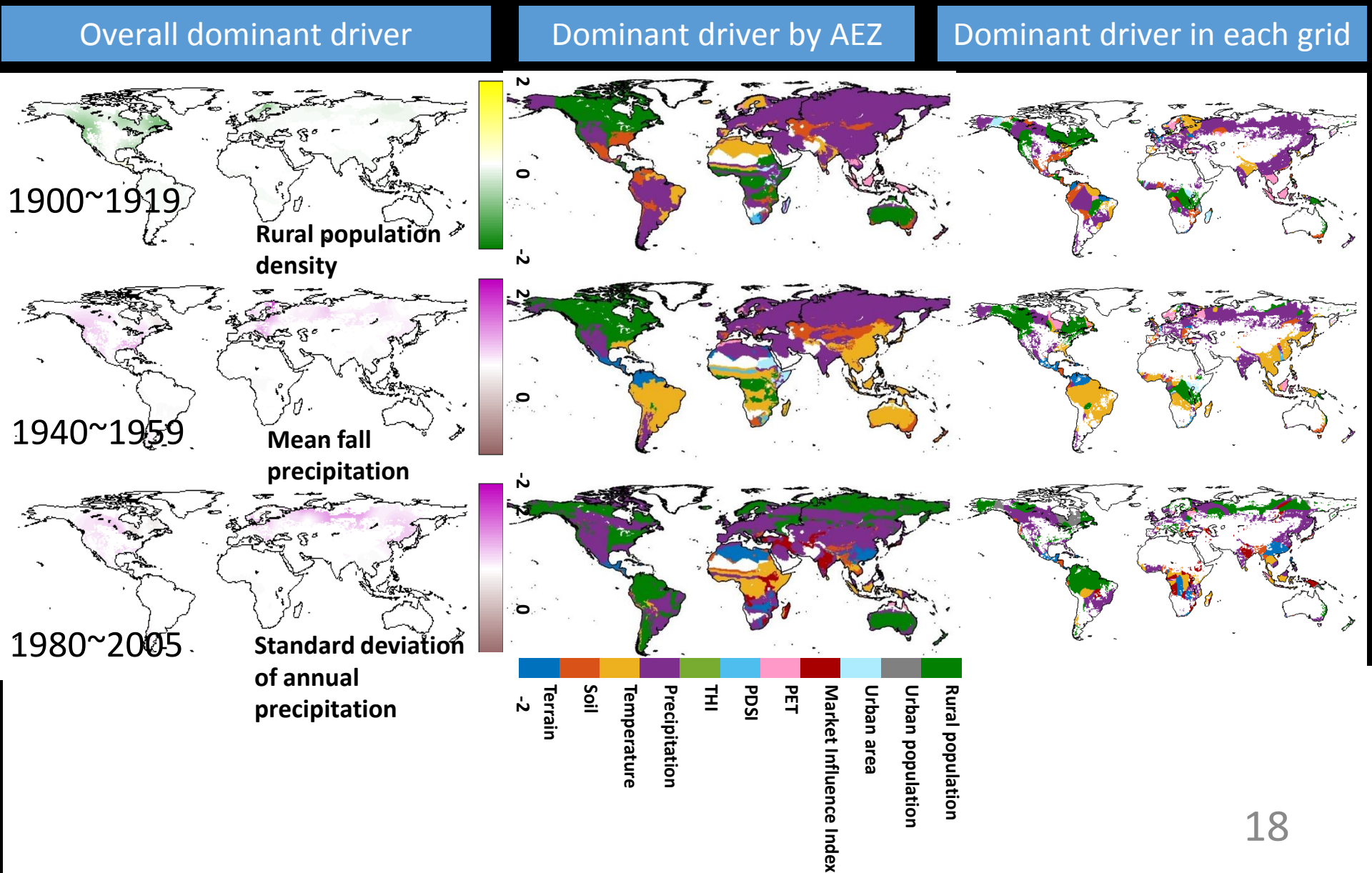


Values refer to how many standard deviations the LULCC areas will change, per standard deviation increase in the drivers

Market influence index:

- *downscaled GDP per capita by market accessibility*

Results: Primary forest to secondary forest



Take Home Message

- Spatial land use modeling and other tools necessary to bridge scales between human and ESMs
- Both biophysical and socioeconomic drivers will strongly modulate climate change implications for agriculture, forest and other land use
- Understanding the drivers and dynamics of LULCC over the historical time can help to improve IAM-based projections of LULCC on a longer time scales

Near Term Research Plan

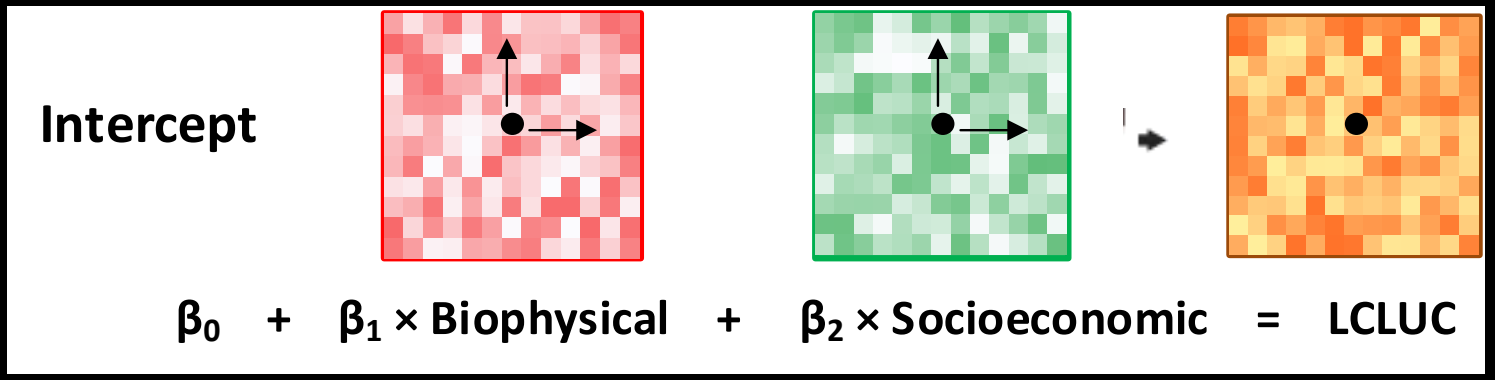
- Analyze the drivers of more LCLUC types
- Synthesize case studies at different scales to evaluate the LCLUC drivers
- Implement SDAM into GCAM

The End

SDAM

- Two objectives
  - downscale agricultural, forest and other land use and changes from large world regions to the grid cell level
  - determine the causes of these changes
- The SDAM estimated land use changes within each grid cell are driven by nonlinear interactions between
  - socioeconomic conditions (e.g. population, technology, and economy),
  - biophysical characteristics of the land (e.g. soil, topography, and climate), and
  - land use history

Geographically Weighted Regression (GWR)



- GWR constructs a distinct relationship between each LULCC grid cell and driving variables by incorporating grid cells falling within a certain bandwidth of the target pixel

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