



Understanding and reconciling land use/land cover datasets

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Introduction

What is the purpose of the combined IAM/ESM activities?

1. Reducing the uncertainty and improving confidence in projecting how the Earth's climate at regional to global scales may change in the future in response to natural and/or human forcing
2. Understanding and predicting the sensitivity and adaptability of managed and natural ecosystems to climate change



Incorporating human activities into ESMs

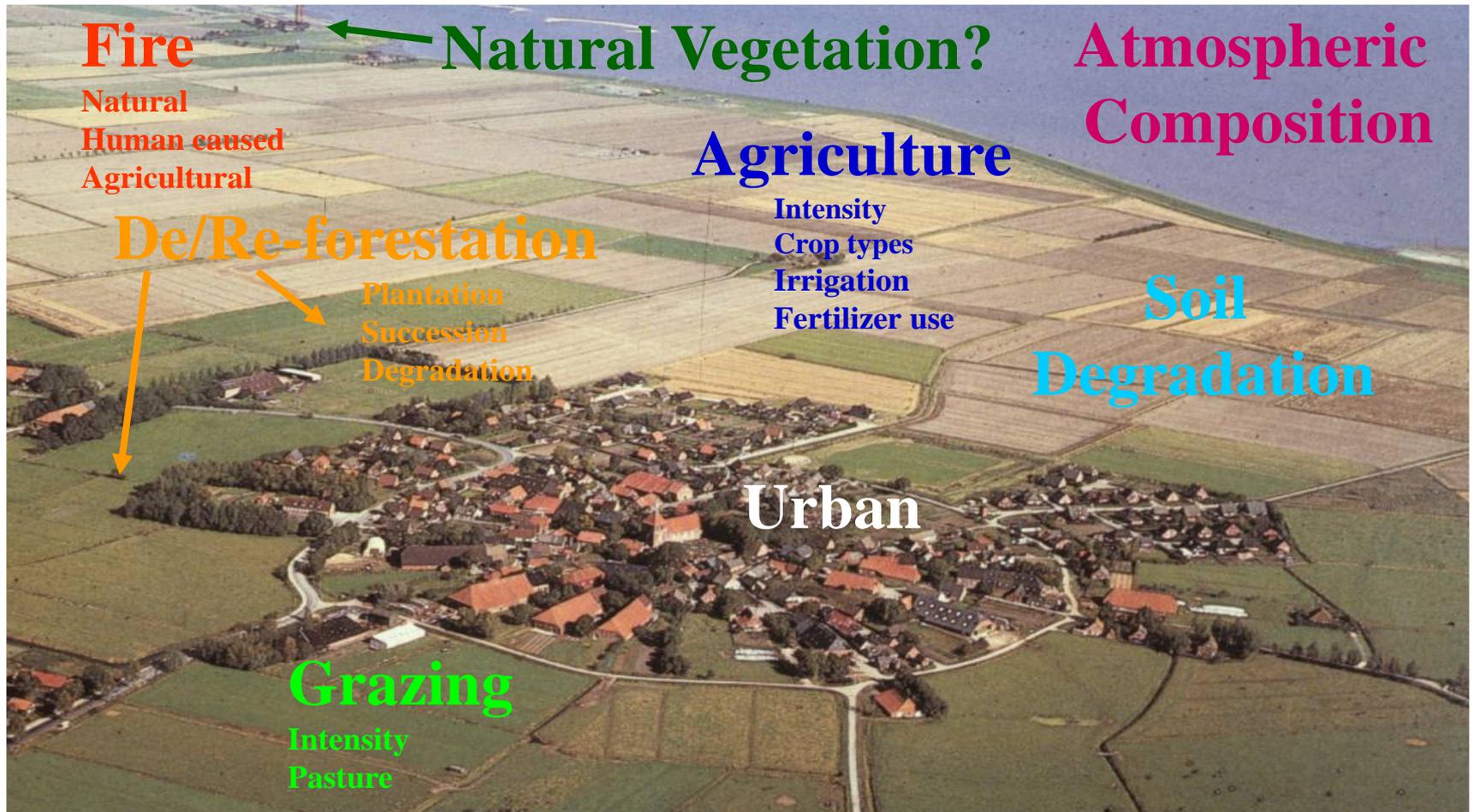
Considerations in developing human activity models:

- What processes are actually important to simulate?
- Which ones can we simulate?
- How should these processes be simulated?
- How should human decision making be included?
- How can these models improve impact assessment?
- How do we gather the historical, present and future information needed to drive human systems?
- What spatial scale do we need to work at?



Background: Human Climate Interactions

What exactly do we want to simulate?





Human Activities v.s. Human Decisions

- For an ESM the focus should be on simulating human activities.
i.e. physical models that simulate human activities in a Earth System framework – many are already in progress
- The parallel IAM effort should focus on human decision making processes.
i.e. These models would control the settings and actual activities that take place.
- These should ultimately be coupled



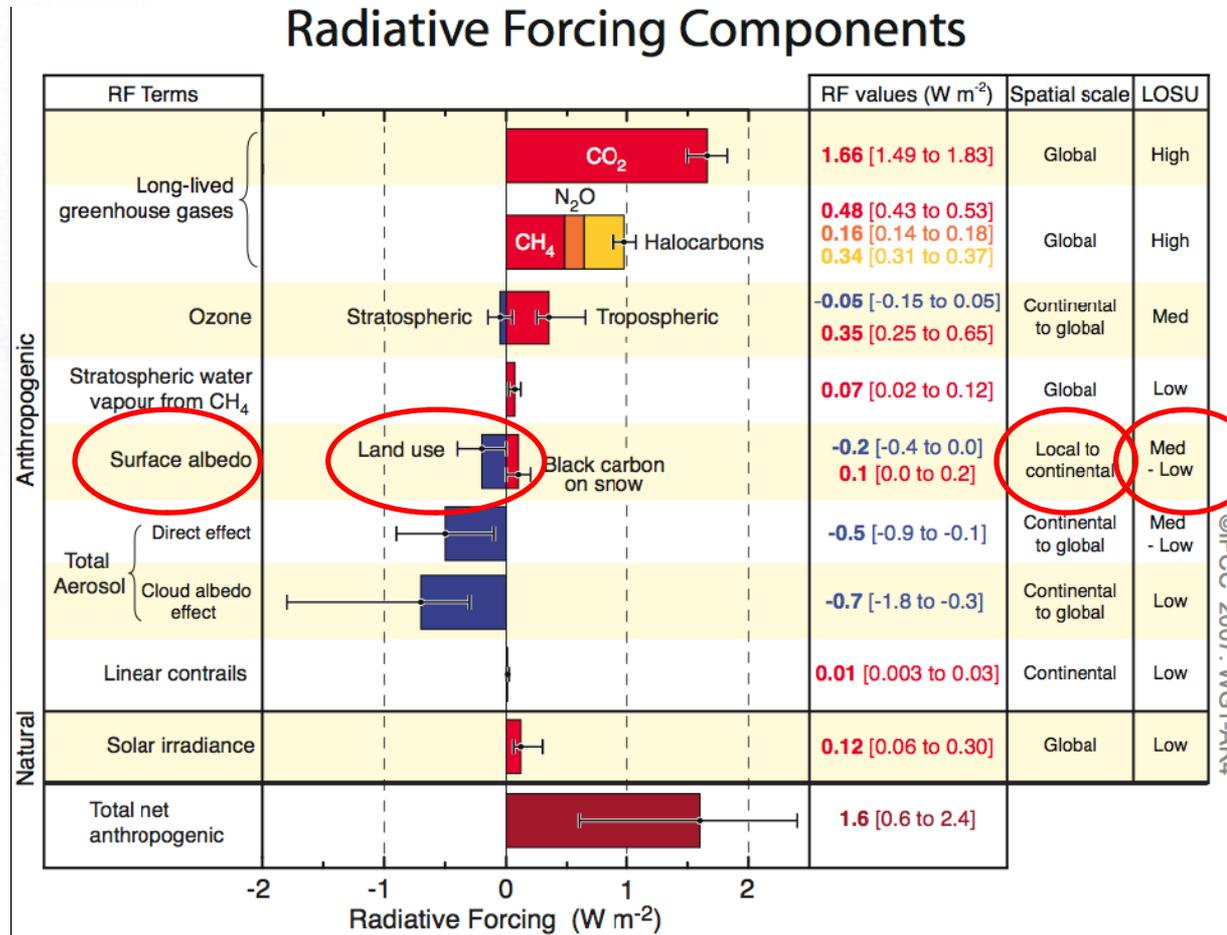
Simulating Human Activities in an ESM

Each human activity sub-models should have the following properties:

- They should be able to be turned on or off for major regions of the world
e.g. the regions used in Integrated Assessment Models should be able to act independently
- They should be able to have a setting to indicate different intensities of each activity.
e.g. you could have intensive agriculture with max resource inputs (fertilizers) in one region, but it could be intensive with lower resources inputs in another region, and extensive agriculture with no resources in a third region
- They should have some possibility for recognizing threshold values that change human activities
e.g. River systems that automatically affect irrigation systems i.e. there is some implied management of the system
- They should be linked together so human impacts cascade through the system
e.g., a well integrated model would be able to simulate intensive cropping that leads to increased soil erosion and nutrient usage, from there the model should simulate the resultant increase in sediment and nutrient transport to a coastal ecosystems model



Status of human land cover change impacts?



How well do we simulate the human impacts?

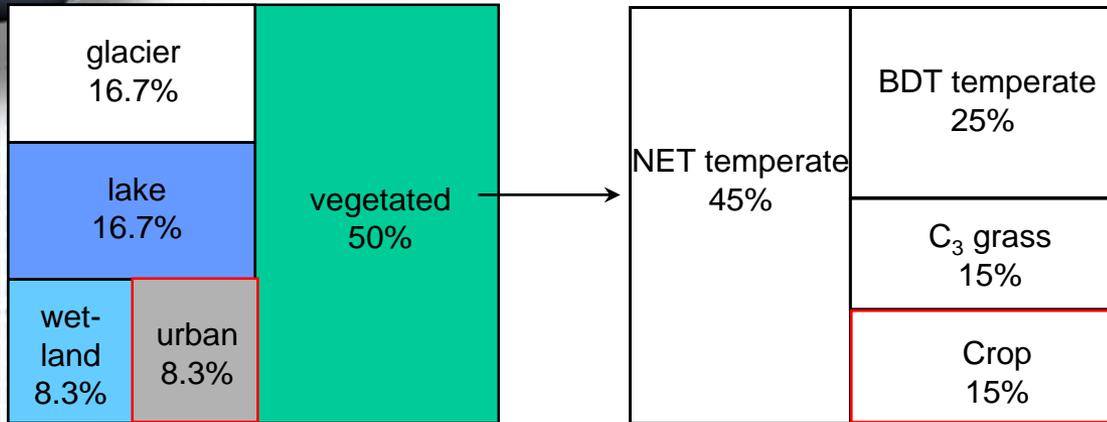
Questions:

What processes do the models actually simulate?

How well?



How do we represent Human impacts?



Each patch has unique:

- PFT composition
- PFT abundance
- leaf area
- height
- biomass

19 Plant Functional Types

Needleleaf evergreen tree
temperate

boreal

Needleleaf deciduous tree

Broadleaf evergreen tree

tropical

temperate

Broadleaf deciduous tree

tropical

temperate

boreal

Shrub

broadleaf evergreen, temperate

broadleaf deciduous, temperate

broadleaf deciduous, boreal

Grass

C₃, arctic

C₃

C₄

Crop

Wheat

Winter wheat

Maize

Soy

+ Bare Ground

Additional grid-cell data:

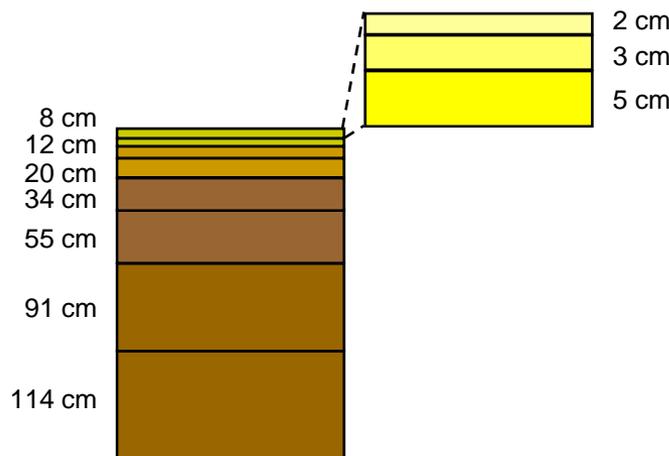
- land fraction
- soil color
- soil texture (% sand, % clay, mineral composition)

Additional data:

- 1/2⁰ river network

Soil Profile

- total depth - 343 cm
- 10 layers
- texture varies with depth





Information about the Natural System

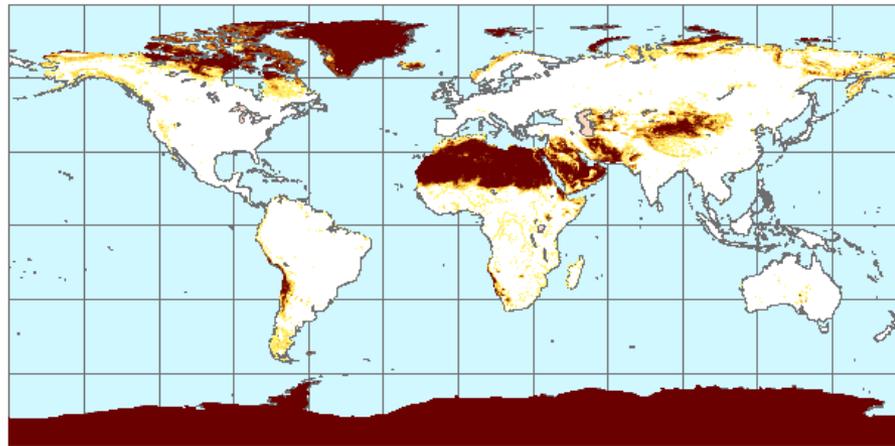
- Use satellite information to acquire information about present day land cover
- Use ground truth and socio-economic statistics to validate – in a few spots we have access to.
- Use socio-economic and population statistics to extrapolate back in time
- Use the IAM projections forward in time



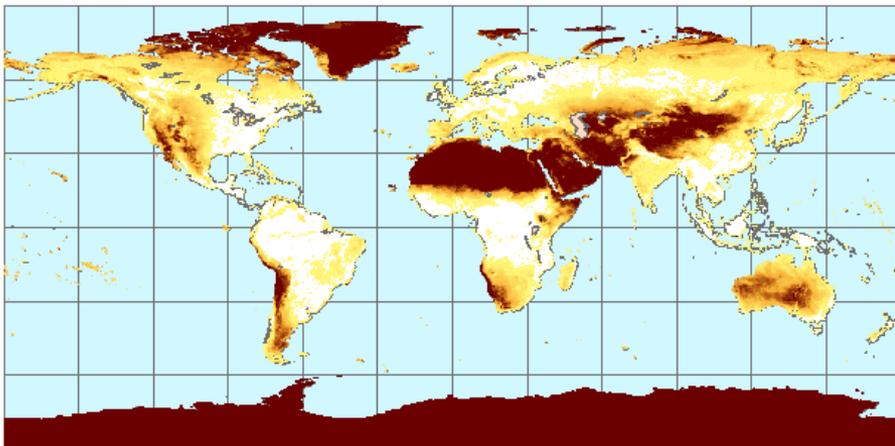
How good is our information about land cover?

Comparison of Discover and MODIS Bare Ground Fraction

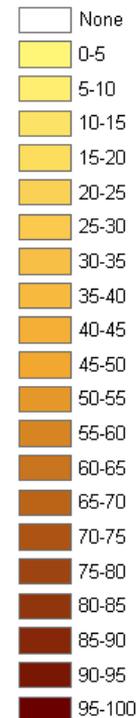
Discover - CLM 3.0



MODIS



Percent Bare



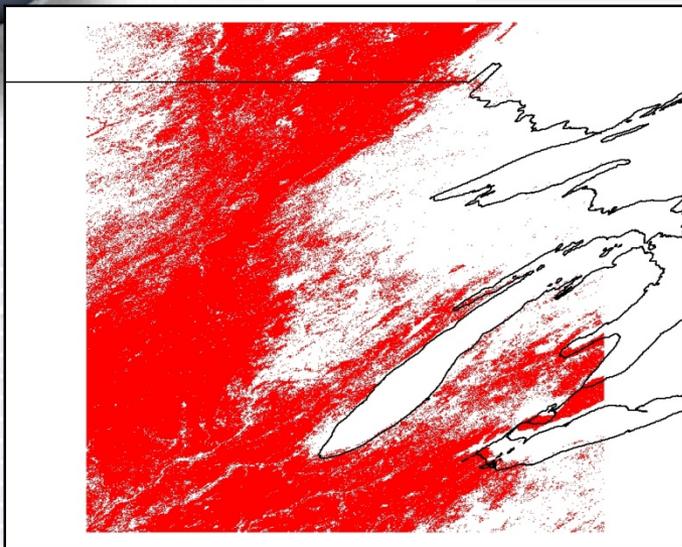
Challenge:

Improve access to
and reliability of
Earth Observations

Comparison of Agriculture land classes from 3 satellite products 10 degree tile over northern Midwest US

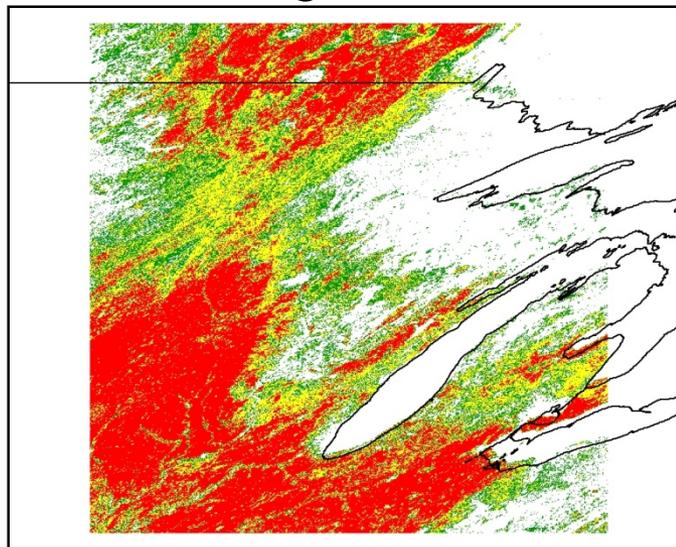
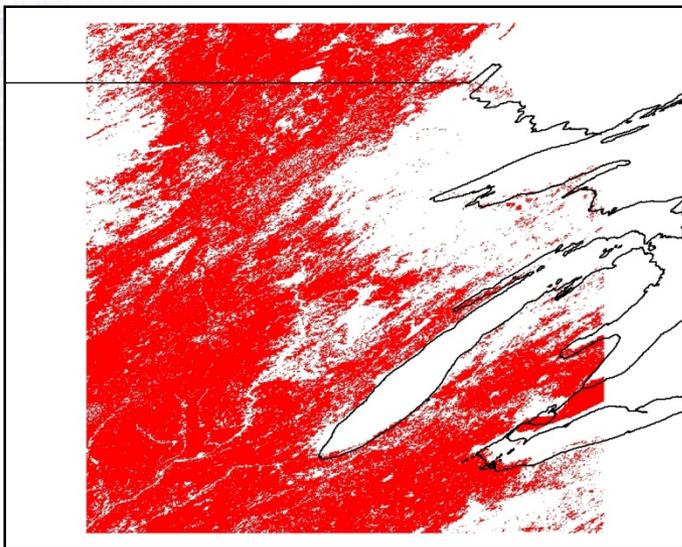
MODIS

IGBP



GLC2000

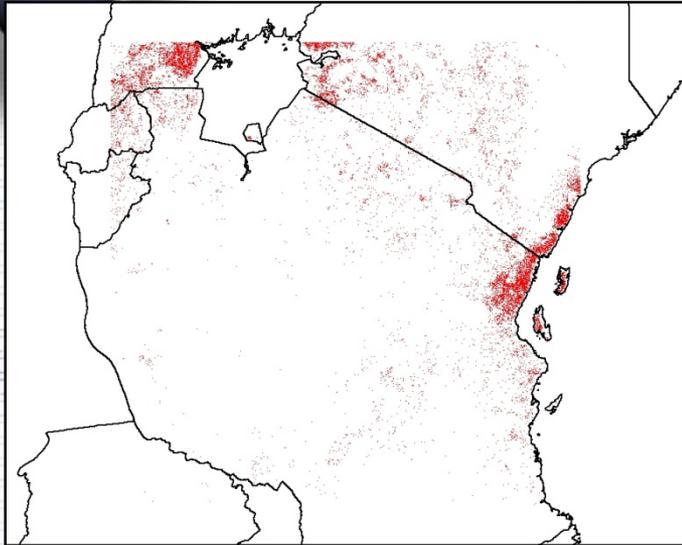
Agreement



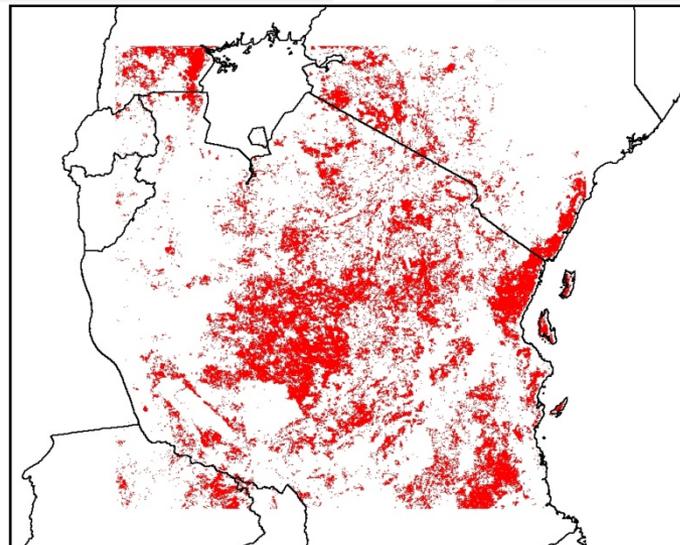
- No Ag
- 1 product
- 2 products
- All products

Comparison of Agriculture land classes from 3 satellite products 10 degree tile over East Africa

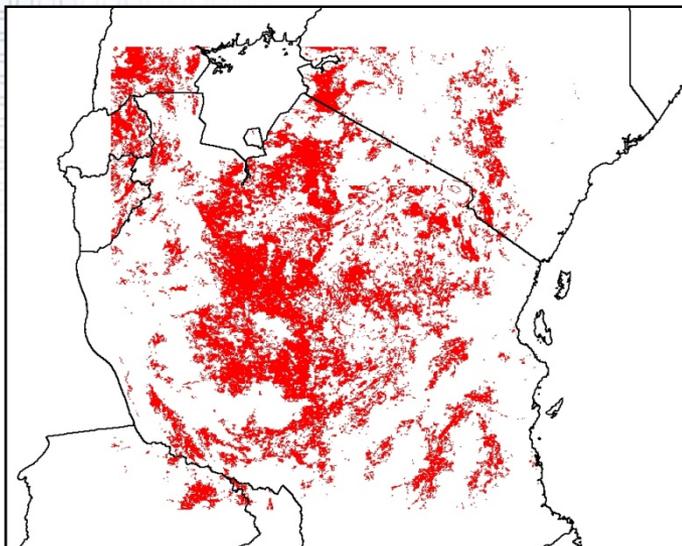
MODIS V003



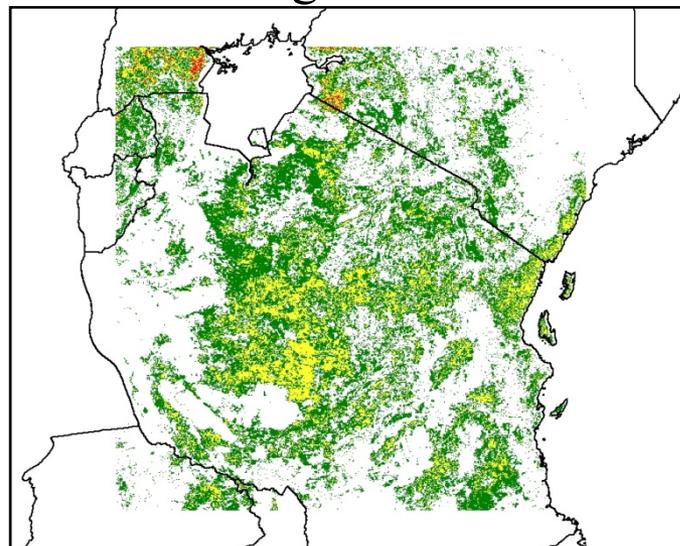
IGBP



GLC2000



Agreement



Challenge:

Improve access and reliability of Earth Observations

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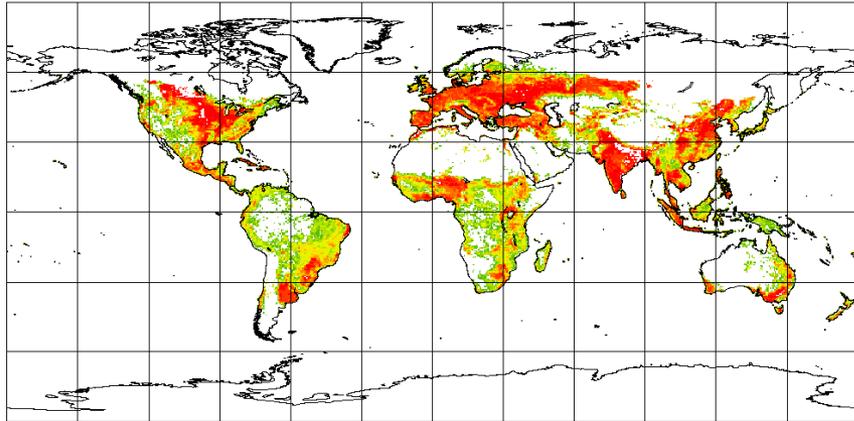


**Agriculture?
Shrub?
What is this
anyway?**

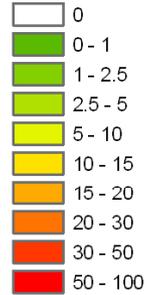


Present Day Options: Croplands

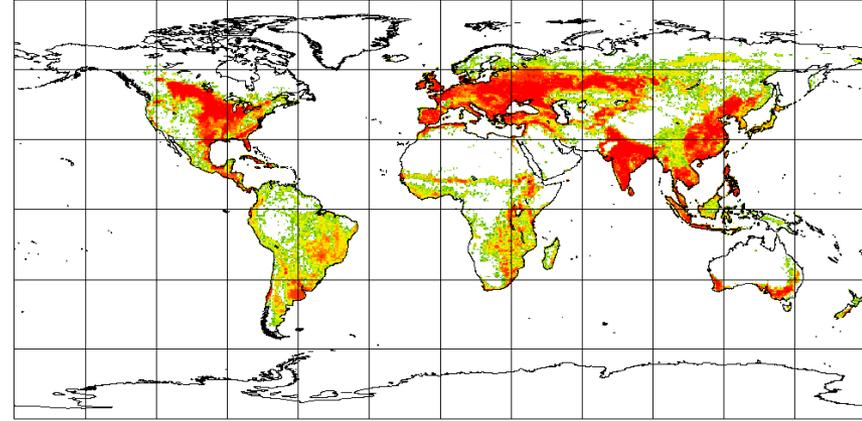
HYDE 3.0



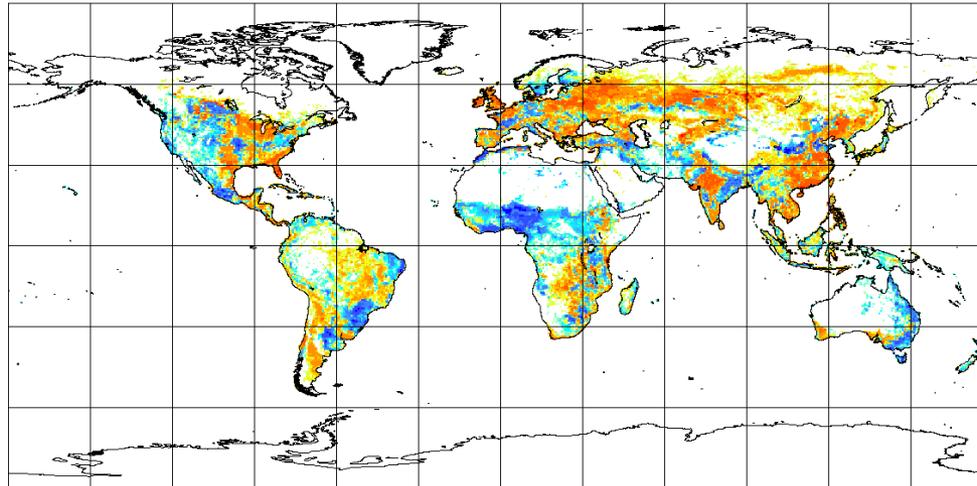
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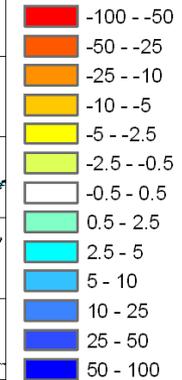
Sage 1992



Difference

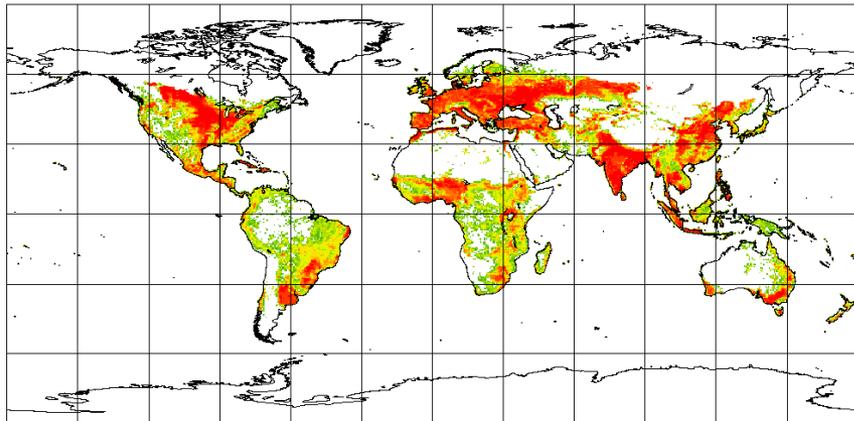


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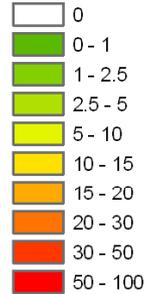


Present Day Options: Agriculture

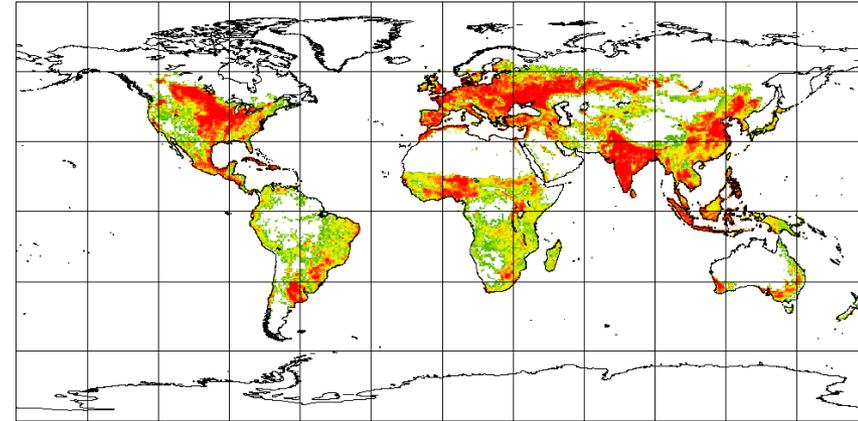
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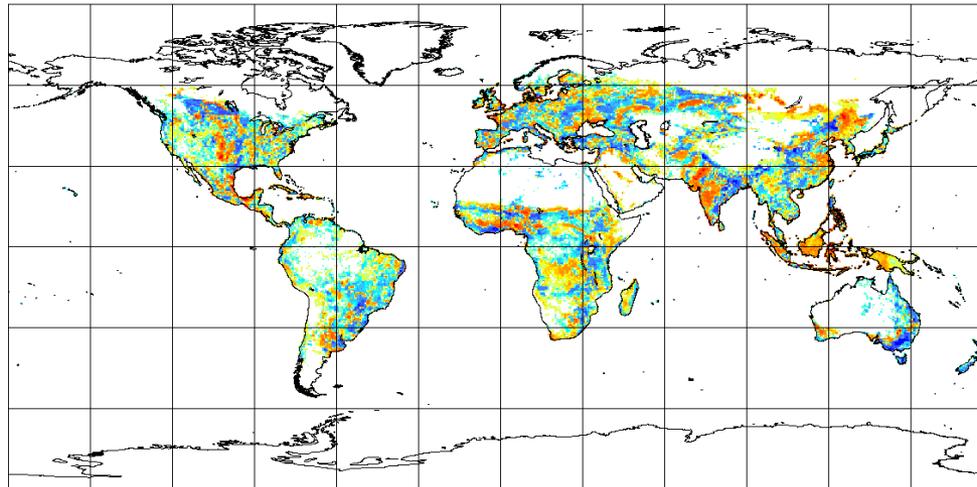
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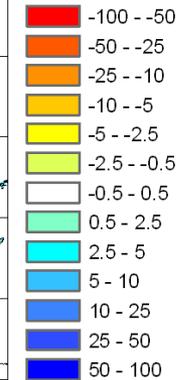
Ramankutty 2000



Difference

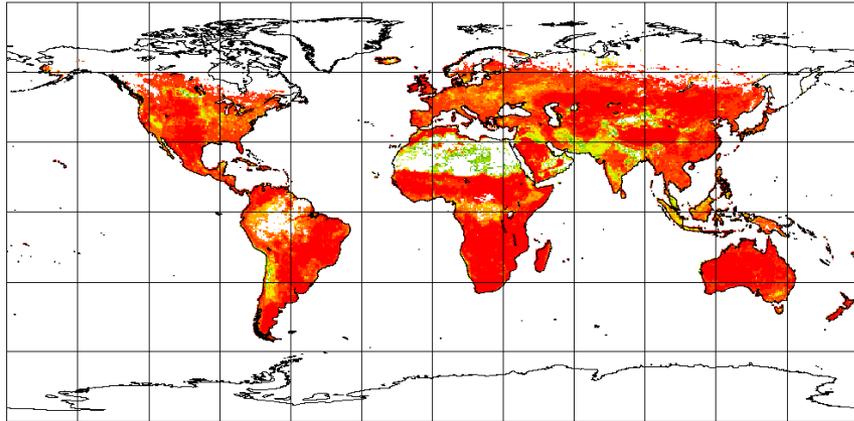


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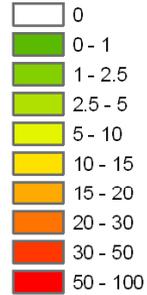


Present Day Options: Grasses

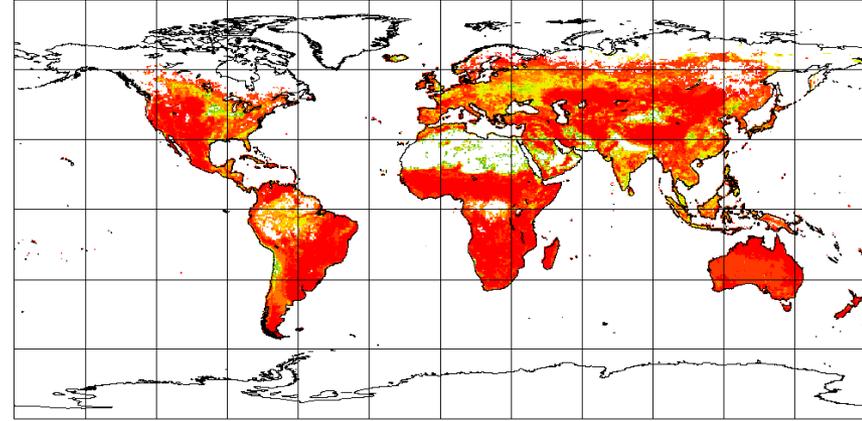
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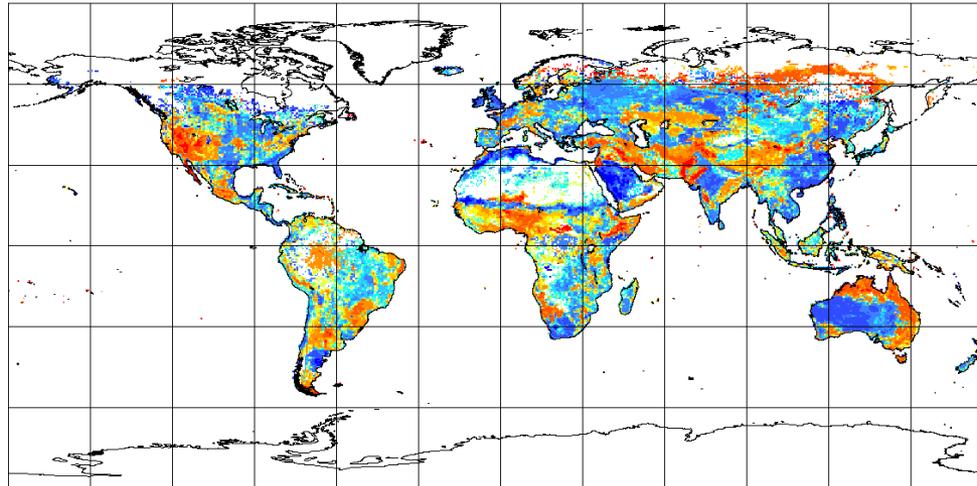
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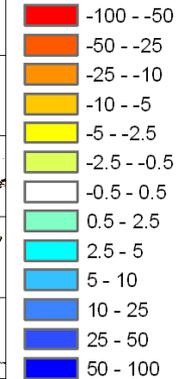
SAGE 1992



Difference

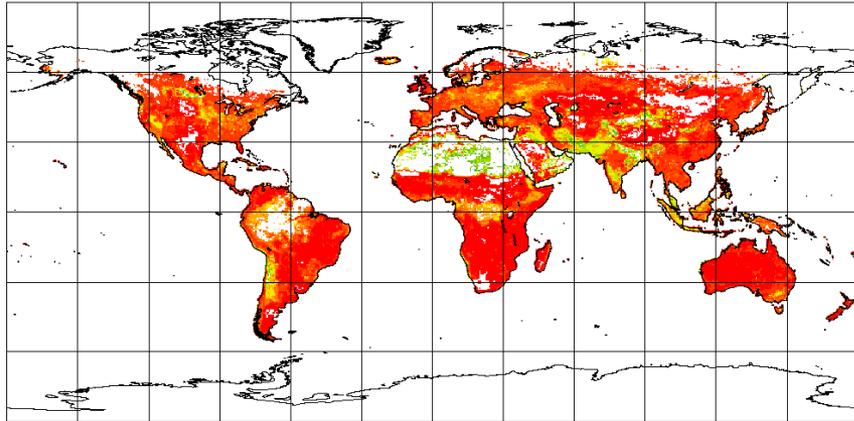


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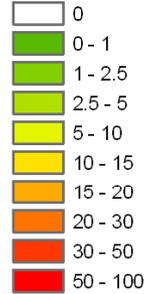


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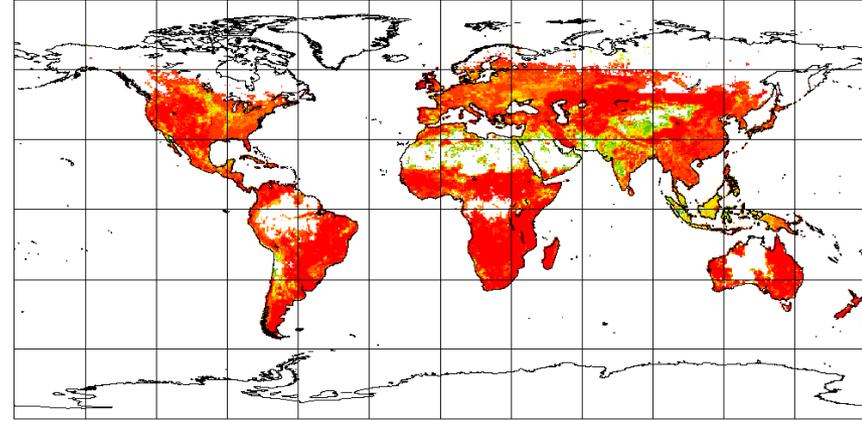
HYDE 3.0



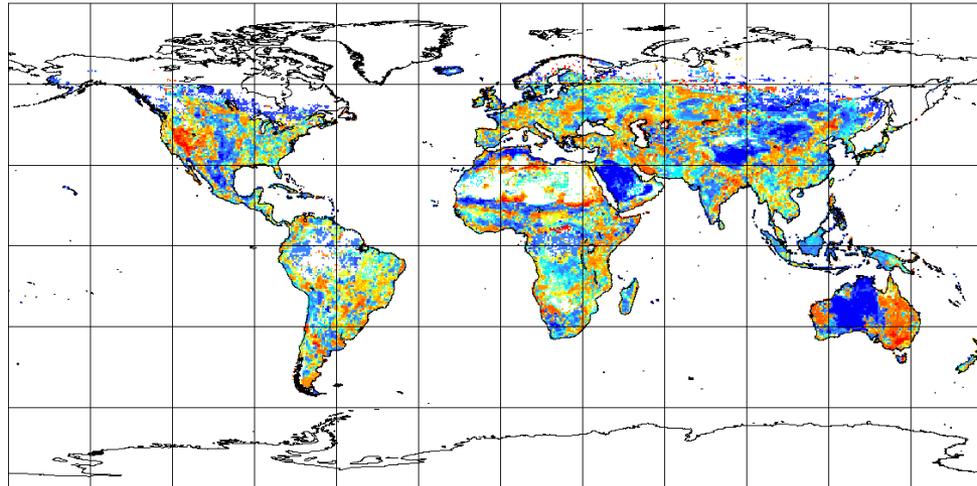
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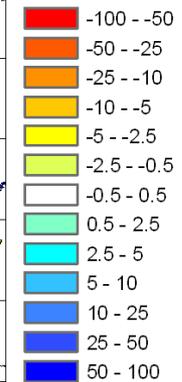
Ramankutty 2000



Difference



% Difference



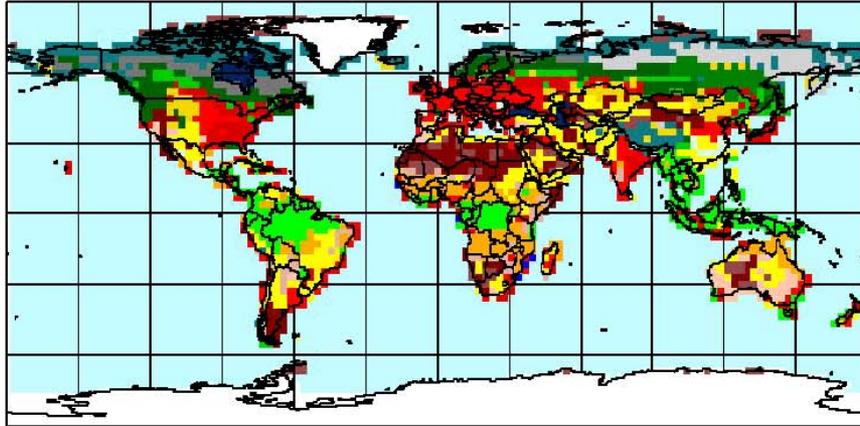


Question

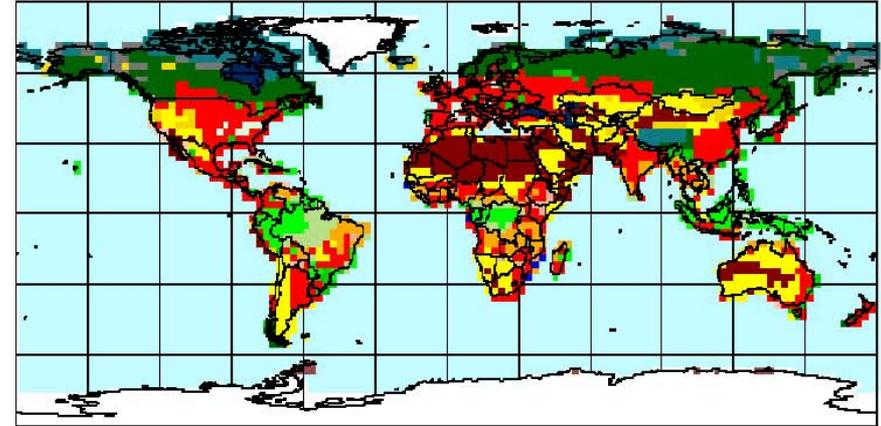
- How important is it to get this right and coordinated?

How important is the choice of present day land cover?

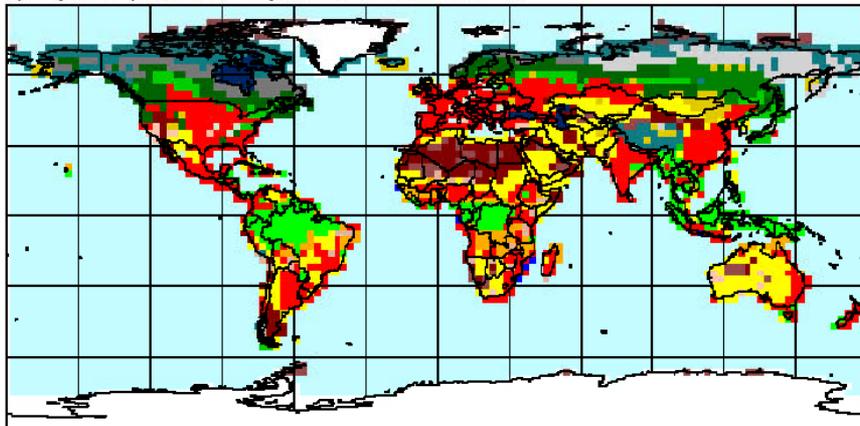
a) LSM original present day land cover: LSMIc



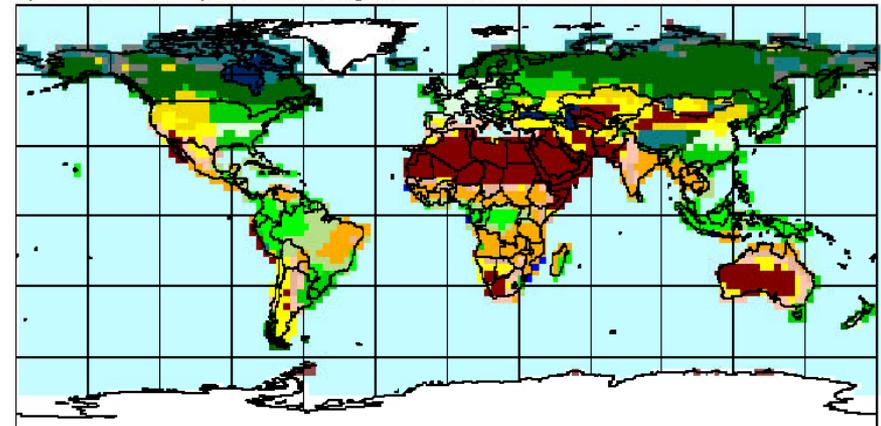
b) IMAGE 2.2 present day land cover: IMAIc



c) Hybrid present day land cover: HYBIc



d) IMAGE 2.2 potential vegetation land cover: POTIc



LSM Land Cover Types

	0 - Ocean		8 - Broadleaf decid		15 - Forest crop		22 - Semi-Desert
	1 - Ice		10 - Tropical broadleaf		17 - Cool grassland/steppe		26 - Crop
	2 - Desert		11 - Trop seasonal decid tree		18 - Warm grassland		27 - Forest wetland
	3 - Needleleaf evergreen		12 - Savanna		19 - Tundra		28 - Non-forest wetland
	4 - Needleleaf decid		13 - Evergreen forest tundra		20 - Evergreen shrub		
	6 - Temp mixed forest		14 - Decid forest tundra		21 - Decid Shrub		



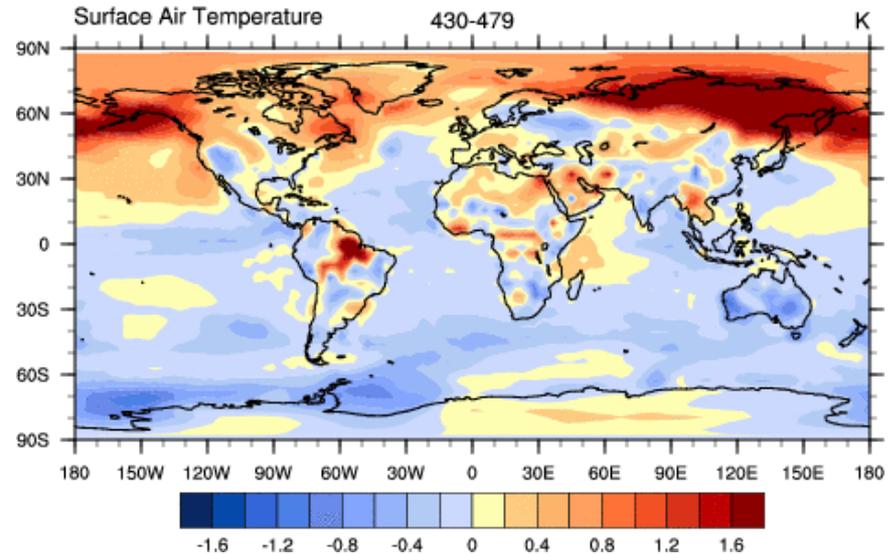
PCM Uncertainty v.s. Historical Land Cover

PRESENT DAY UNCERTAINTY

- Arctic – albedo
- Amazon – latent heat flux
- Australia – albedo



Present Day (IMAGE) Land Surface minus control



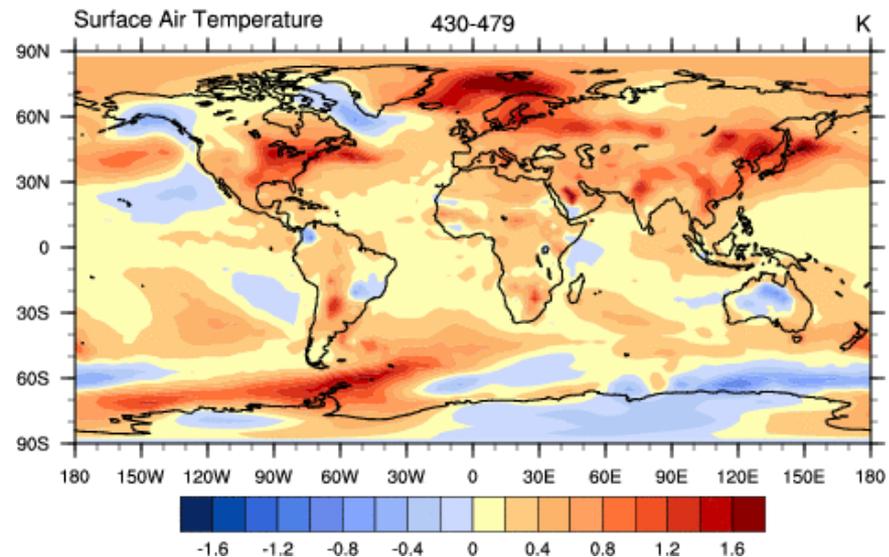
HISTORICAL CHANGE

Climate difference from land cover classification is as large as the climate difference from land cover change

- Primarily shift due to agriculture

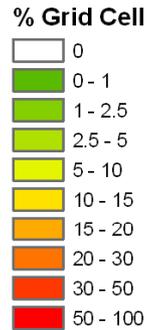
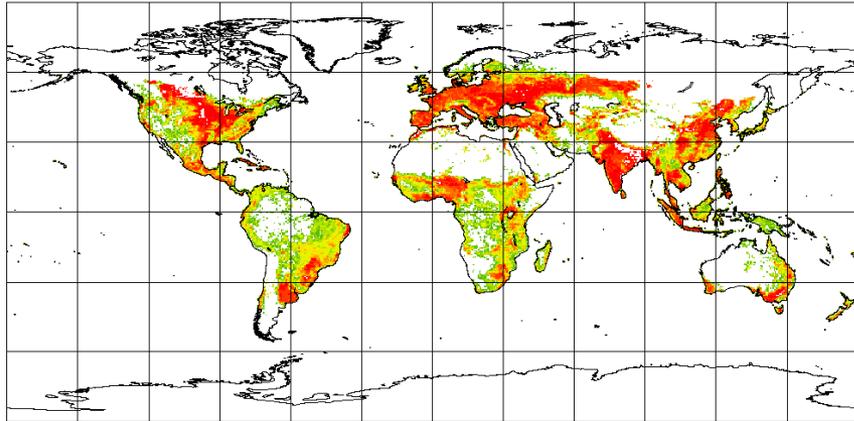


Natural Vegetation minus Present Day (IMAGE)

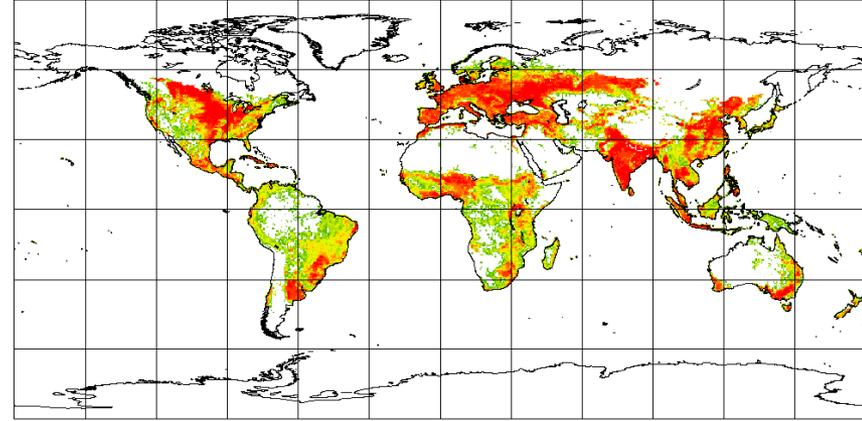


Creating datasets order of entry: Agriculture

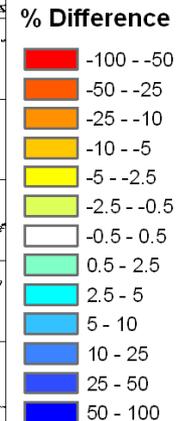
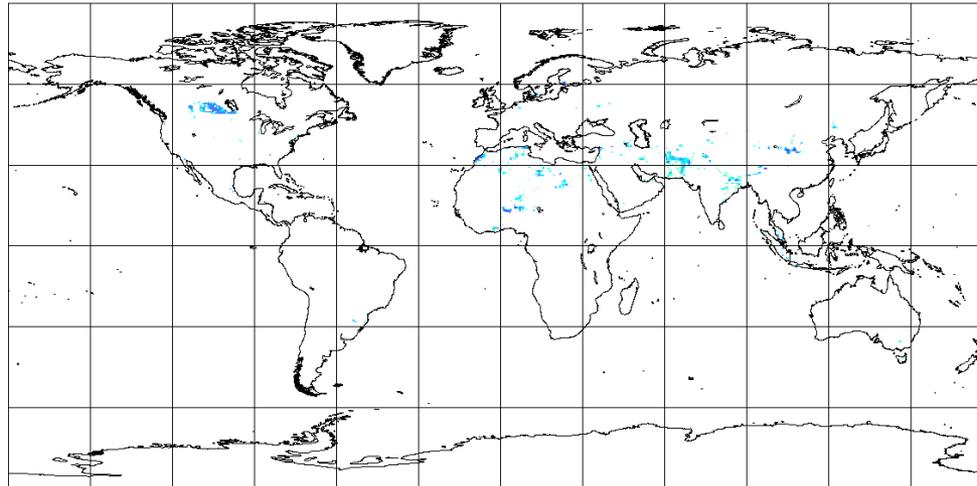
Human Activity Prioritized



MODIS Physical Information Prioritized



Difference

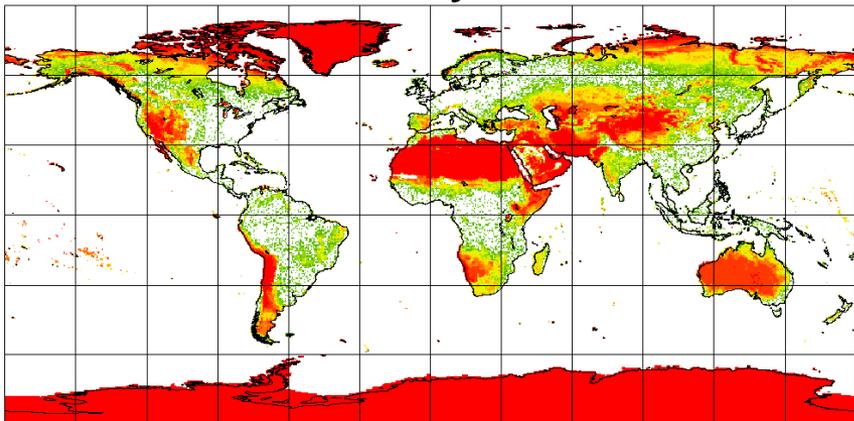


Order of entry
 Urban
 Agriculture
 Pasture/Grazing
 Bare ground
 Forest
 Shrub
 Grass

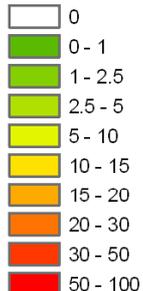
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Creating datasets order of entry: Bare

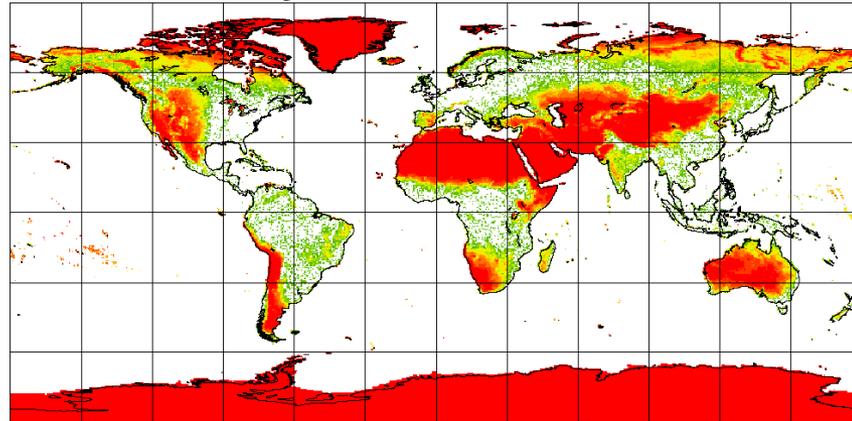
Human Activity Prioritized



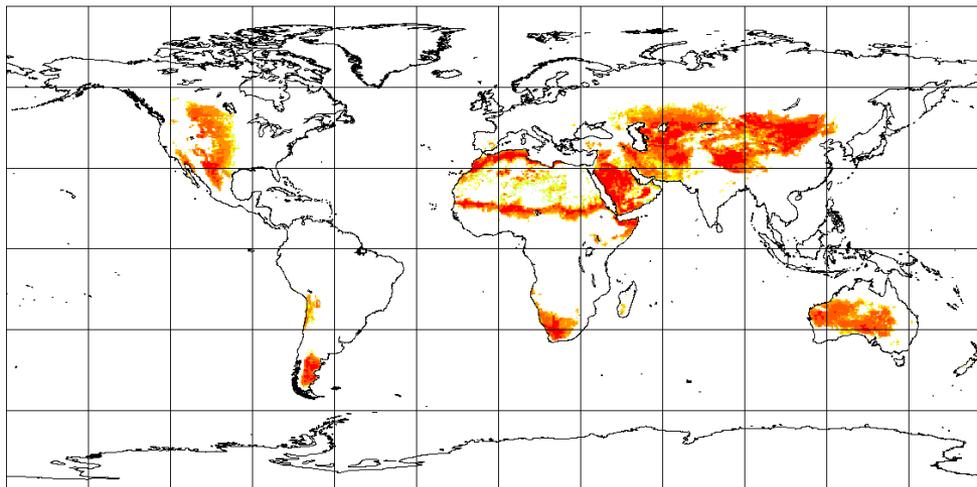
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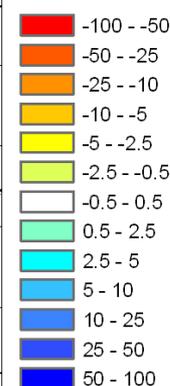
MODIS Physical Information Prioritized



Difference



% Difference



Order of entry

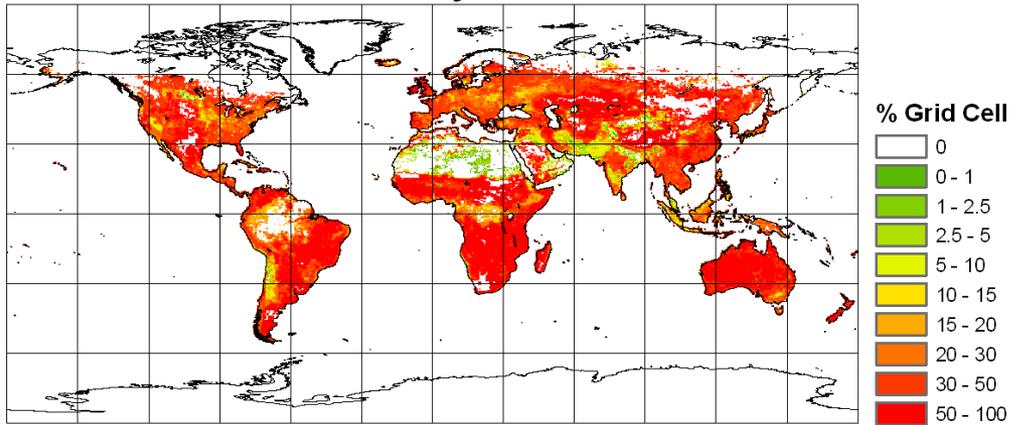
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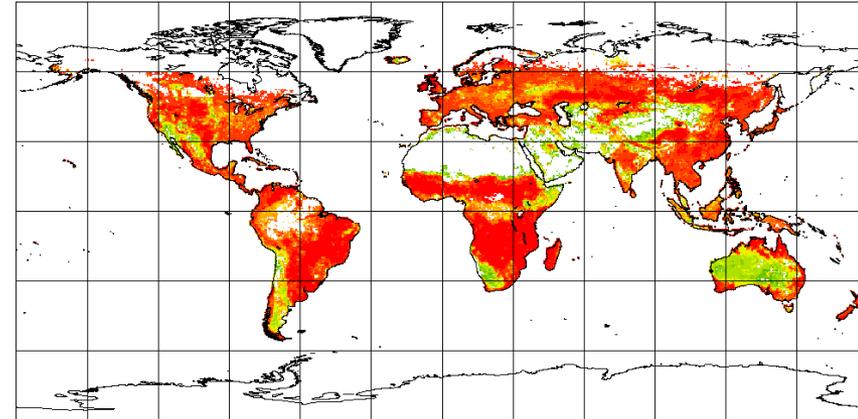
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Creating datasets order of entry: Grasses

Human Activity Prioritized



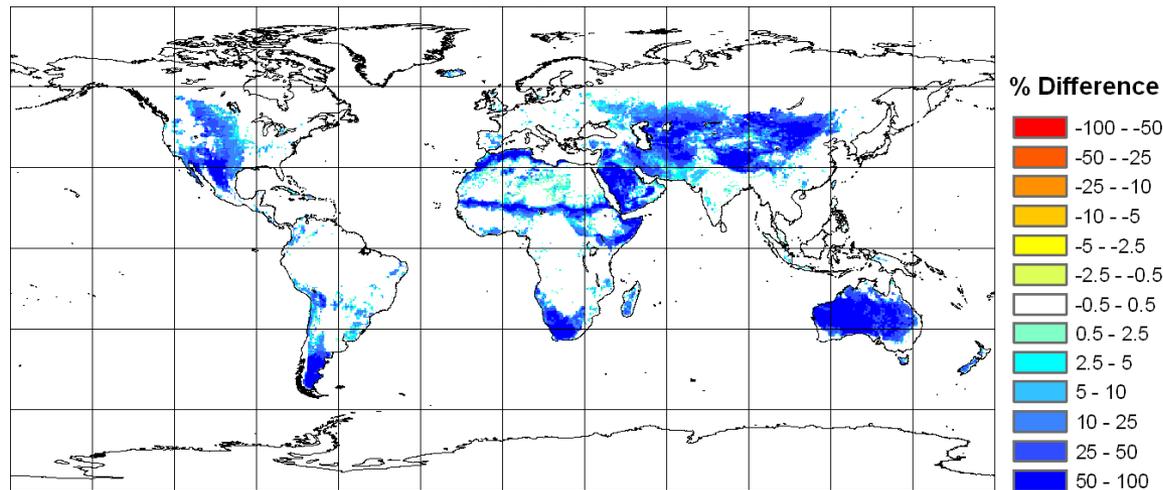
MODIS Physical Information Prioritized



Order of entry

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Difference



Order of entry

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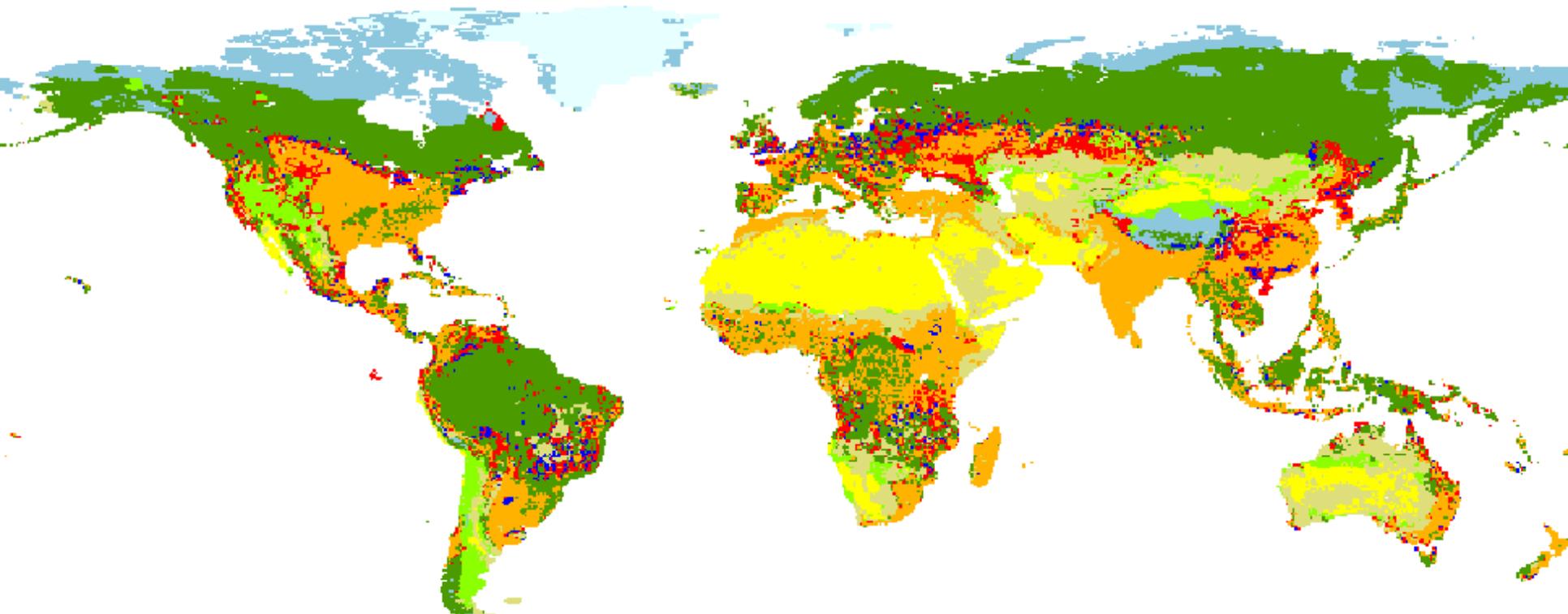


What do we mean by croplands or agriculture





Land use/cover pattern in IMAGE '3 W/m²' mitigation scenario (2100)



- | | | | |
|--|--|--|--|
|  Forests |  Ice |  Agriculture |  Bio-energy |
|  Grass |  Tundra |  Ext. grassland |  C-plantation |
|  Desert | | | |

Source: Van Vuuren



Deforestation





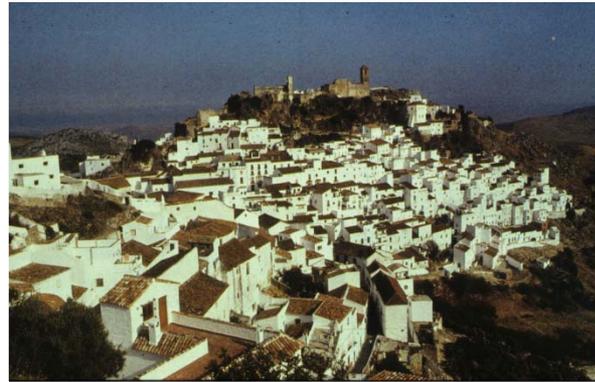
Deforestation

To simulate deforestation we need:

- Deforestation activities to be prescribed
- Can be managed human land – treated like agriculture
- Can be incorporated through a DVGM
- Should include carbon sinks associated with deforestation
- Should incorporate succession changes
- Need information on tree species favored by humans
- Include type of logging/burning

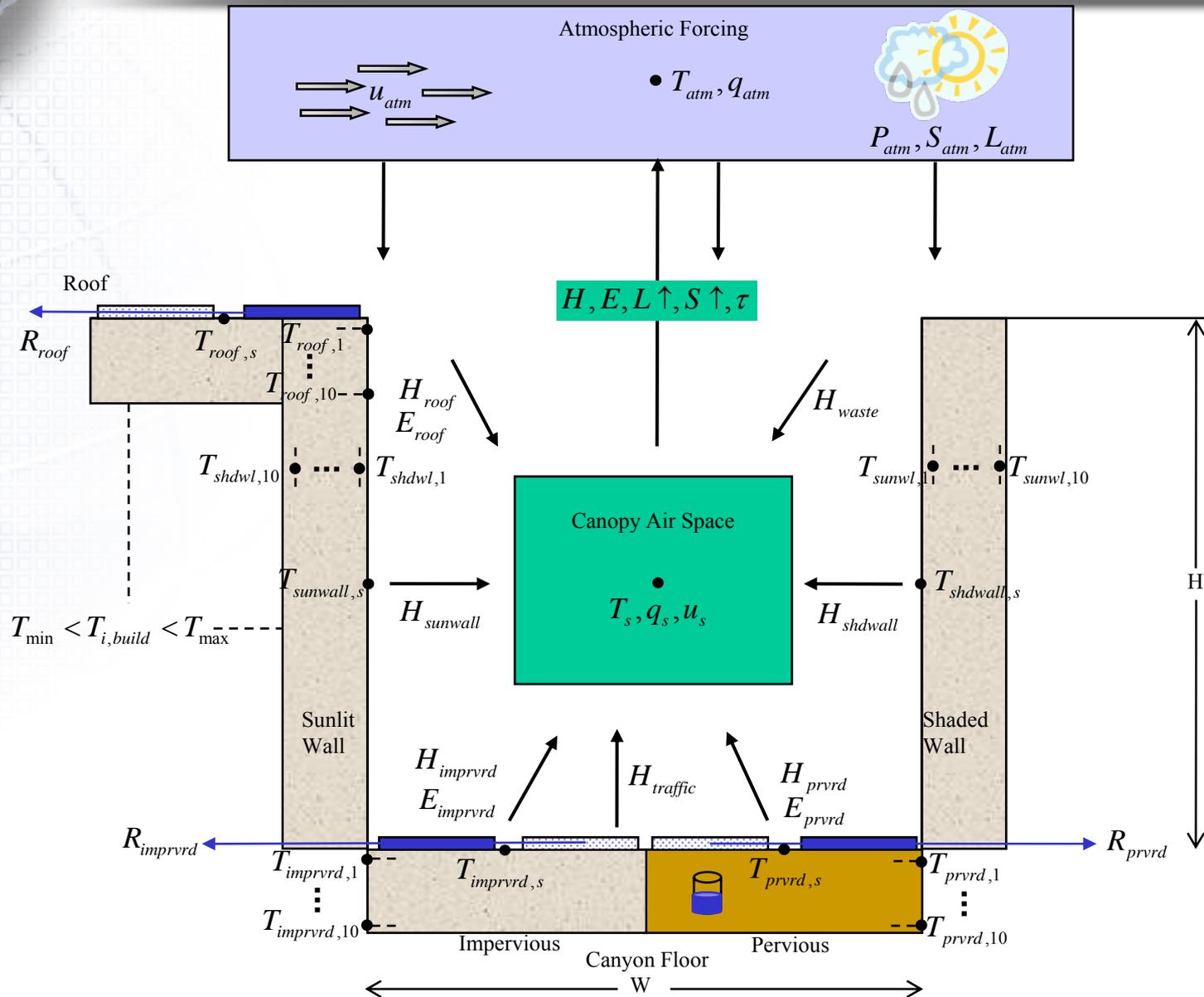


Urbanization





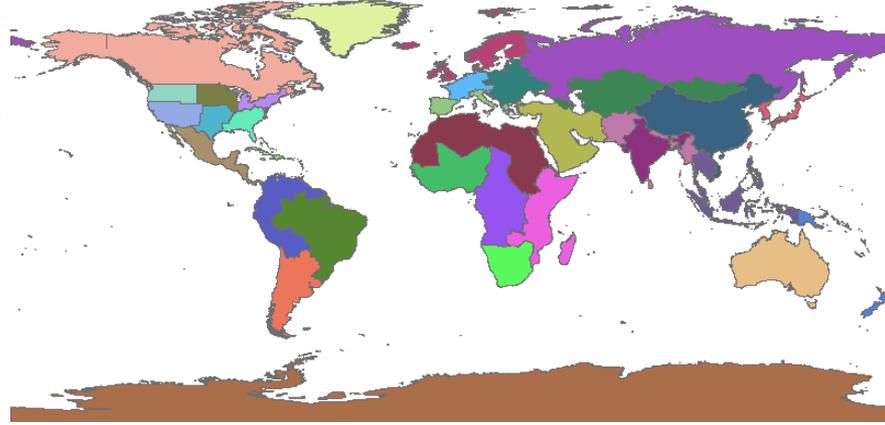
Example: Urban canyon type model





Example: Urban Input data

Global Regions

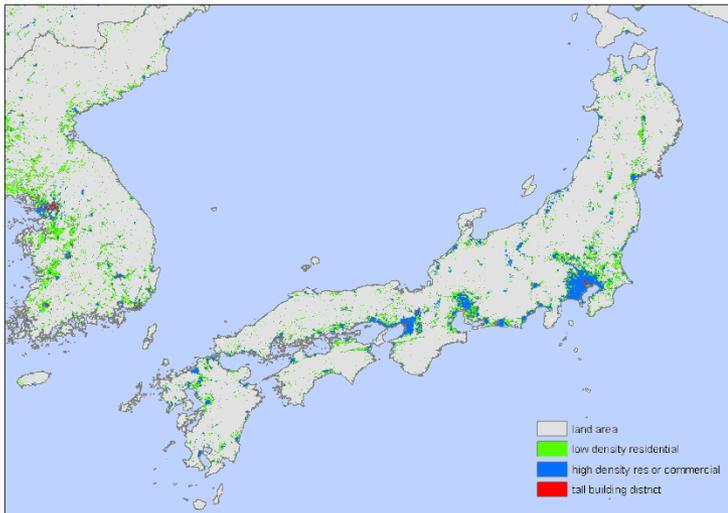


→ To Model

Urban Extent

- 4 classes

Urban areas of Japan and Korea



Urban Properties

- *Height*
- *H/W ratio*
- *Vegetated fraction*
- *Roof fraction*

Wall properties

- *Albedo*
- *Thermal properties*
- *Radiative properties*

Roof properties

Road properties

Interior temperature settings



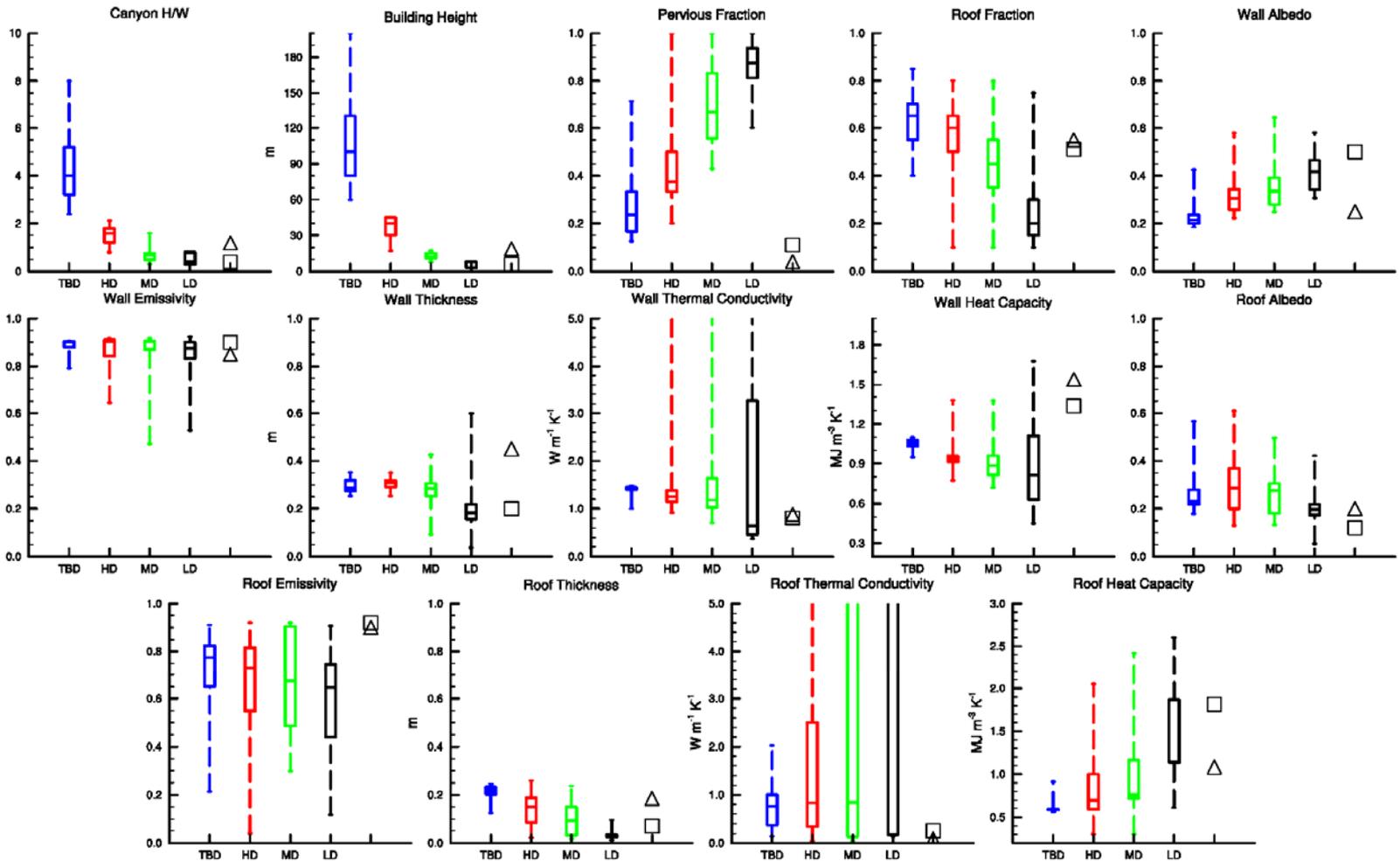
Example: Urban Input data

Urban Class	H/W	Building Heights (m)	Vegetative Fraction (%)	Population Density (km ²)	Typical Building Types
Tall Building District (TBD)	4.6	40-200+	5-15	14,000 - 134,000+	Skyscrapers
High Density (HD) Residential/Commerical/Industrial	1.6	17-45	15-30	5,000 - 80,000+	Tall apartments, office bldgs, industry
Medium Density (MD) Residential	0.7	8-17	20-60	1,000 - 7,000	3-5 story apartment bldgs, row houses
Low Density (LD) Residential	0.5	3-8	50-85	250 - 2,000	Wood frame or corrugated metal homes

Preliminary data and results

Example: Urban Input data

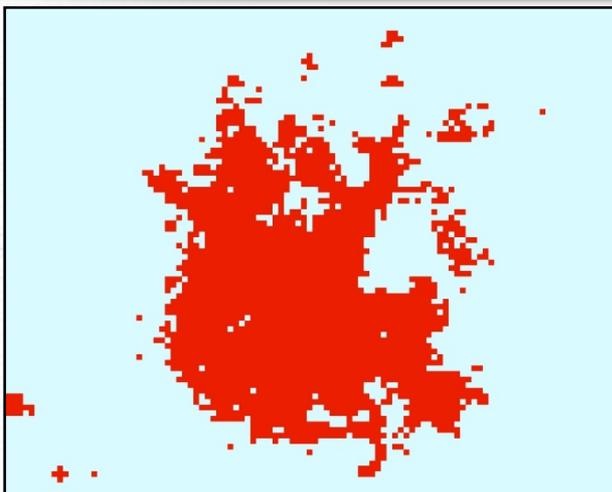
Global Urban Properties



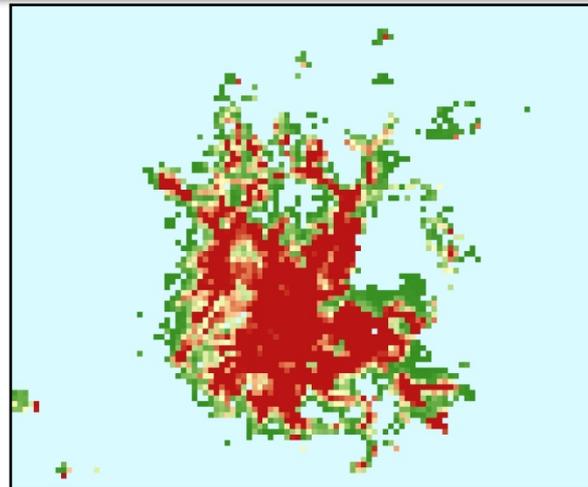
Preliminary data and results



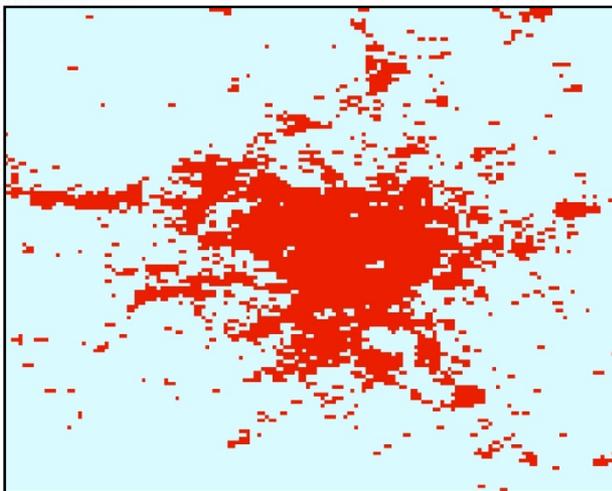
Global Urban Characteristics Dataset



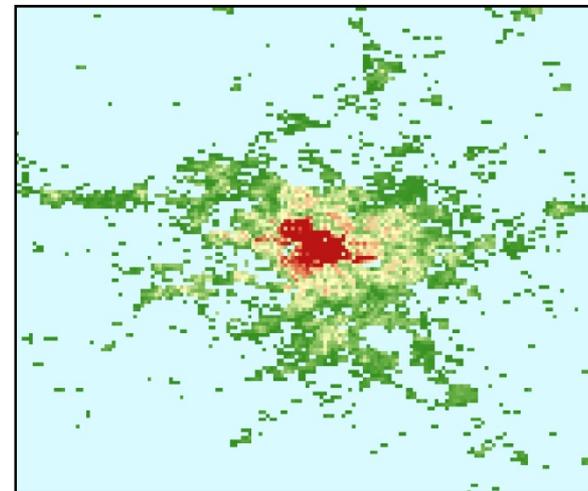
MODIS Mask of Mexico City



Mexico City (*Landsat*)



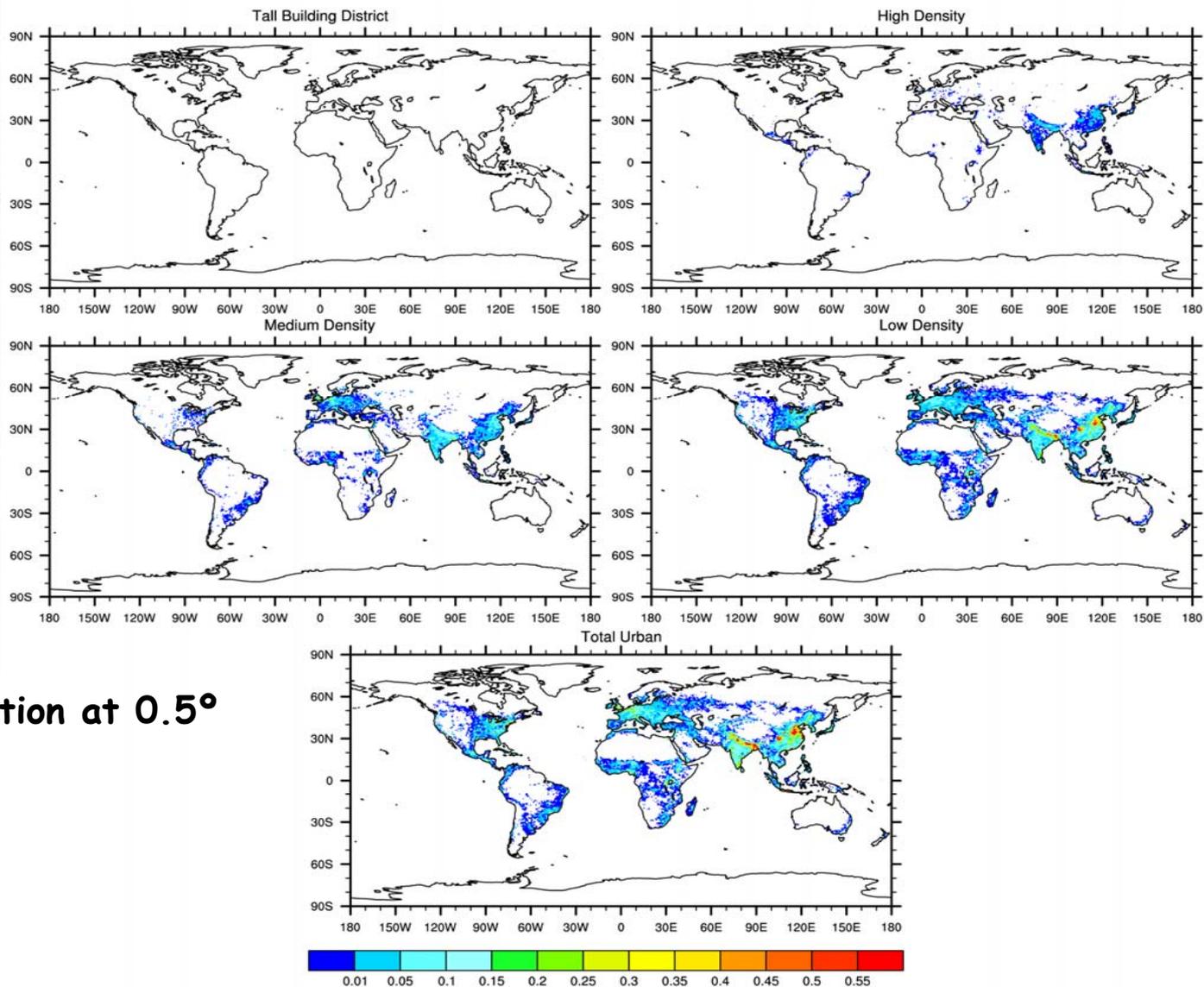
MODIS Mask of Paris



Paris (*Landsat*)



Example: Urban Input data



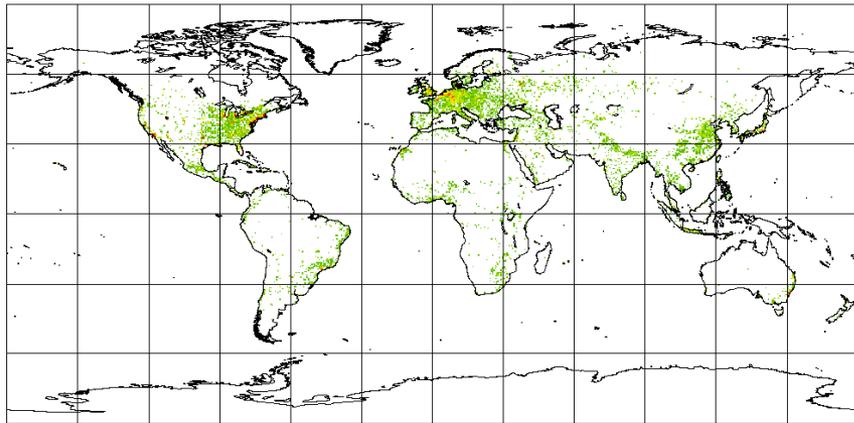
Urban Fraction at 0.5°

Preliminary data and results

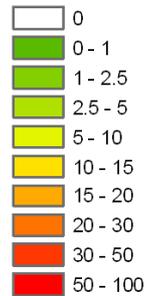


Urban land cover

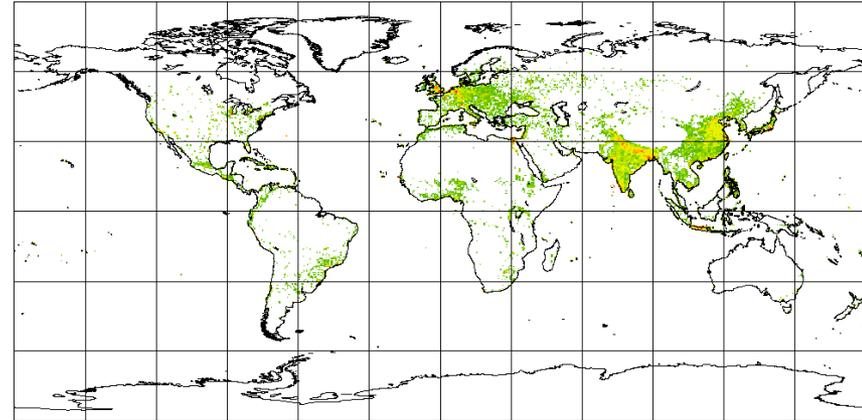
HYDE 3.0



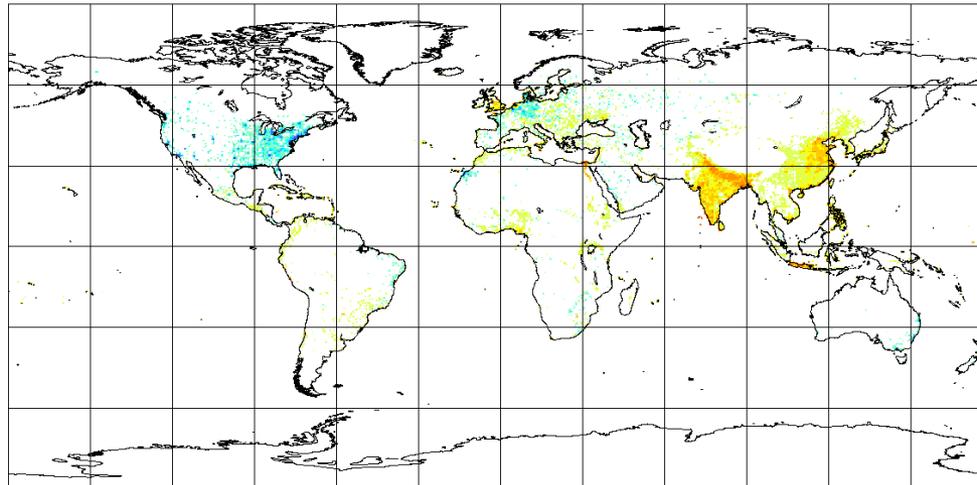
% Grid Cell



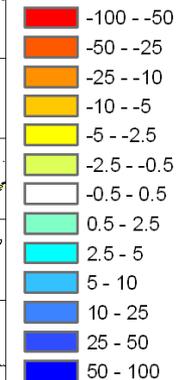
Jackson and Feddema 2004



Difference



% Difference





Major world population centers 1-20

Rank	Metro area	Country	Population	Area (km ²)	Pop (Pop/km ²)
1	Tokyo	Japan	32,450,000	8,014	4,049
2	Seoul	South Korea	20,550,000	5,076	4,048
3	Mexico City	Mexico	20,450,000	7,346	2,784
4	New York City	United States	19,750,000	17,884	1,104
5	Mumbai	India	19,200,000	2,350	8,170
6	Jakarta	Indonesia	18,900,000	5,100	3,706
7	São Paulo	Brazil	18,850,000	8,479	2,223
8	Delhi	India	18,600,000	3,182	5,845
9	Osaka-Kobe-Kyoto	Japan	17,375,000	6,930	2,507
10	Shanghai	China	16,650,000	5,177	3,216
11	Metro Manila	Philippines	16,300,000	2,521	6,466
12	Hong Kong-Shenzhen	China	15,800,000	3,051	5,179
13	Los Angeles	United States	15,250,000	10,780	1,415
14	Kolkata	India	15,100,000	1,785	8,459
15	Moscow	Russia	15,000,000	14,925	1,005
16	Cairo	Egypt	14,450,000	1,600	9,031
17	Buenos Aires	Argentina	13,170,000	10,888	1,210
18	London	United Kingdom	12,875,000	11,391	1,130
19	Beijing	China	12,500,000	6,562	1,905
20	Karachi	Pakistan	11,800,000	1,100	10,727

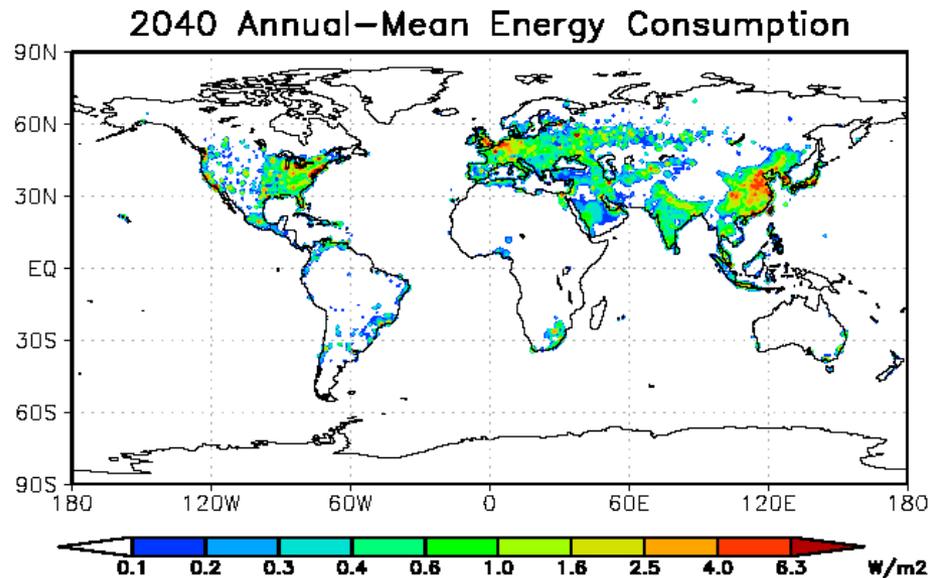
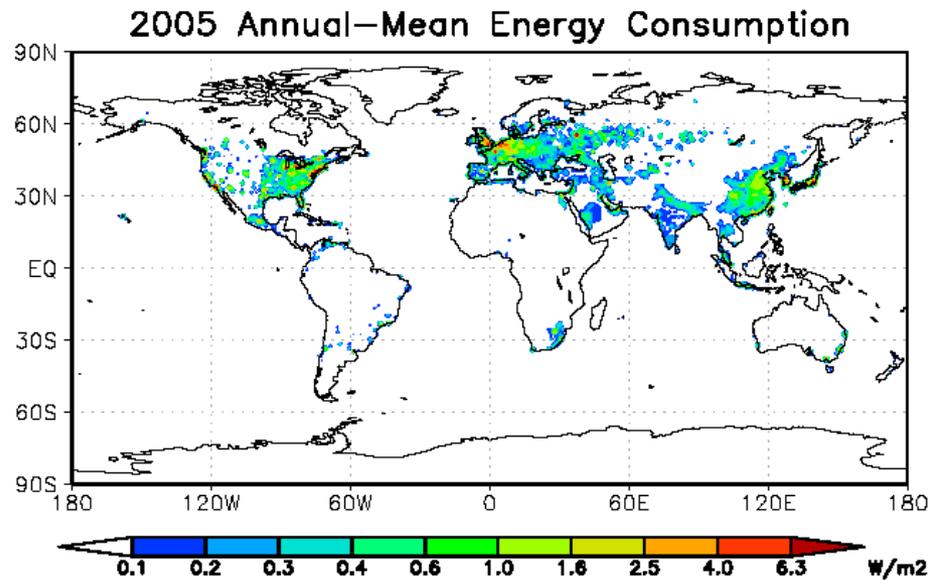


Major world population centers 1-20

300	Raleigh	Raleigh	USA	1,510,000
301	Gwangju (Kwangju)	Gwangju	South Korea	1,500,000
302	Peshāwar	Peshawar	Pakistan	1,500,000
303	Qiqihar	Qiqihar	China	1,500,000
304	Santa Cruz	Santa Cruz	Bolivia	1,500,000
305	Kampala	Kampala	Uganda	1,490,000
306	Luoyang	Luoyang	China	1,490,000
307	Makkah	Mecca	Saudi Arabia	1,490,000
308	Nashville (-Davidson)	Nashville	USA	1,490,000
309	Marseille	Marseille	France	1,480,000
310	Rotterdam	Rotterdam	Netherlands	1,480,000 incl. Dordrecht
311	Vārānasi	Benares	India	1,470,000
312	Kolhāpur	Kolhapur	India	1,460,000 incl. Sangli
313	Lubumbashi	Lubumbashi	Congo (Dem. Rep.)	1,450,000
314	Tabrīz	Tabriz	Iran	1,450,000
315	Taizhou (Jiaojiang)	Taizhou	China	1,450,000
316	Davao	Davao	Philippines	1,440,000
317	Weifang	Weifang	China	1,440,000
318	Lyon	Lyon	France	1,430,000
319	Ciudad Juárez	Ciudad Juárez	Mexico	1,420,000
320	Khulna	Khulna	Bangladesh	1,420,000



Human energy consumption



Source: Mark Flannery
Very preliminary data



Example: How can we use the urban model

1. Impact of urbanization on climate

- Heat islands
- Simulate impact of different mitigation strategies

2. Simulate impact of different mitigation strategies

- High low density urban systems
- Albedo and rooftop garden impacts

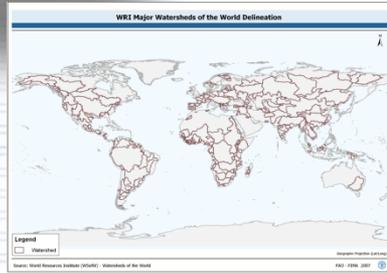
3. Impact of climate on urban populations

- Relate urban climate back to the urban population used to make up each urban land cover class
- Example impact analysis – how do changes in urban growing degree days affect the number of generations of mosquitoes in a season (e.g. malaria)

4. Evaluate how urban impacts affect the instrumental record

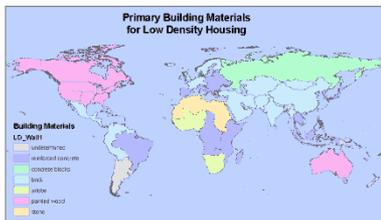
Flexible data management schemes

Raw data

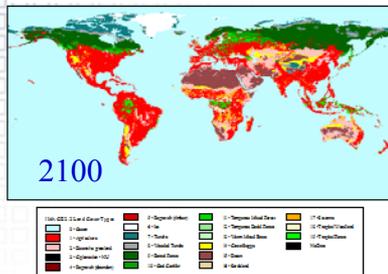


Watershed
Management
Decisions

Vector/
Polygon
Datasets

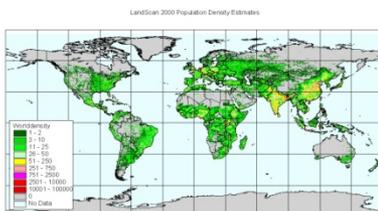


National/Regional
Policy Information

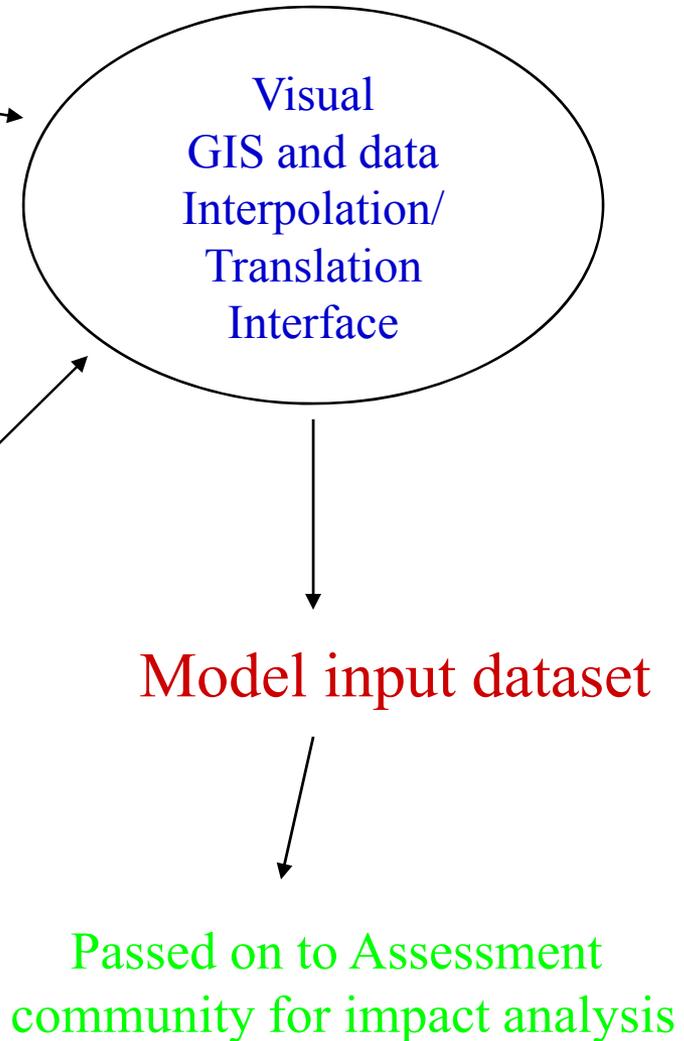


Land Cover
0.5 degree
resolution

Gridded/
Raster
Datasets



Population/urban
1 km resolution





Issues that should be considered

- **Reliability of our information about present day land cover**
- **How to construct historical and future scenarios**
- **Improve the quality of data: include properties with area estimates of a process**
- **Flexible of data input/output information systems**
- **Land models should run at their own resolution**
- **Improve processes such as ecological succession (natural and human controlled)**
- **Have canopy models that can simulate chemistry in the canopy layer**



Conclusions

How can we improve human-climate simulations

Improving human systems in ESMs need to consider:

- **Building a coordinated set of human activity models that integrate within the ESMs**
- **Incorporating mechanisms that can simulate human impacts and degradation by degrees**
- **Building human decision models (IAMs) that integrate well with human activity models within the ESM**
- **Developing new and improved input data/information about human activities**
- **Improving coordination between input data and data used for assessment**
- **Developing output that targets specific communities or human activities**



THE END