The WCS Climate Assessment Project
conceptual approach and outputs

WILDLIFE CONSERVATION SOCIETY

MACARTHUR
The John D. and Catherine T. MacArthur Foundation

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Gashora, Rwanda
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Philip Thornton – ILRI
Ruth Doherty – University of Edinburgh
Michel Masozera, Amy Pokempner and WCS Rwanda staff

For climate data: researchers and research stations through Albertine Rift region

General Principles of Adaptation

1. Reduce non-climate stressors

2. Manage for ecological function and protection of biological diversity

3. Establish buffer zones and connectivity

4. Implement “proactive” management strategies

5. Increase monitoring and facilitate management under uncertainty

Requires baseline measurements and understanding of relationship between climatology and ecology.

Only weakly developed in Albertine Rift context

From “Adaptation 2009” discussion paper by Glick, Staudt, Stein

WCS Albertine Rift Climate Assessment – conceptual approach

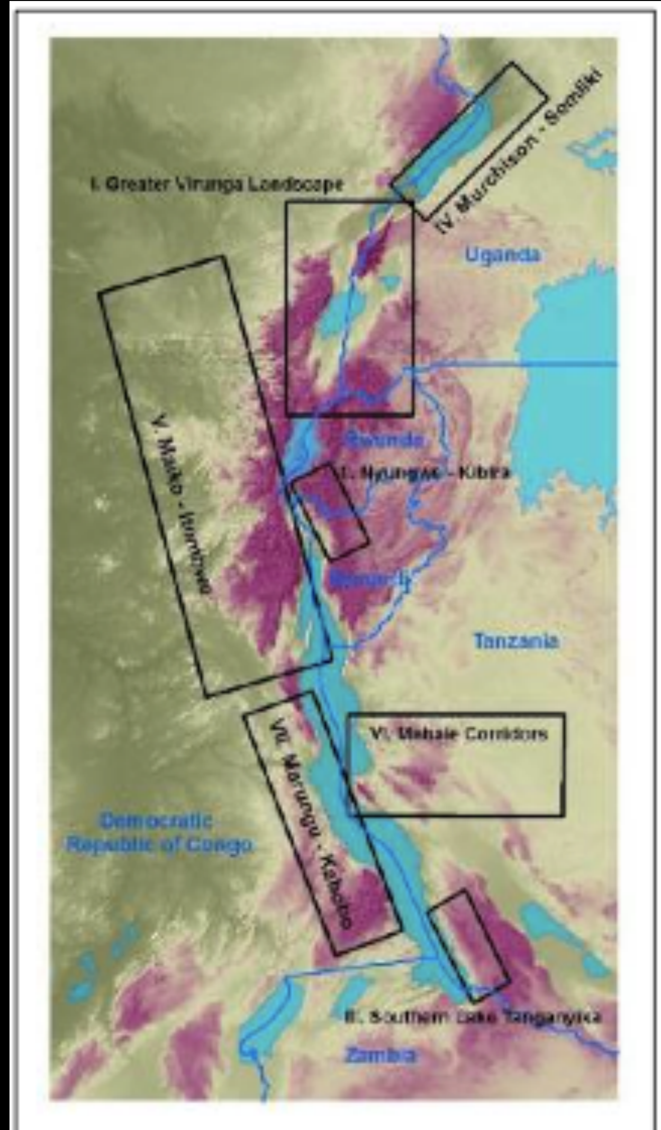
1. Climatological baseline studies
2. Ecological modeling using climate model inputs
3. Monitoring for climate change
4. Stakeholder consultation and outreach
5. Implement adaptation activities
6. Repeat process every 5-10 years

Complex topography characterizes the Albertine Rift

High variability in climatic conditions across space:

- Temperature is largely a function of elevation, proximity to great lakes
- Rainfall is much more complex, influenced by landform configurations

Topography: primary climatic control



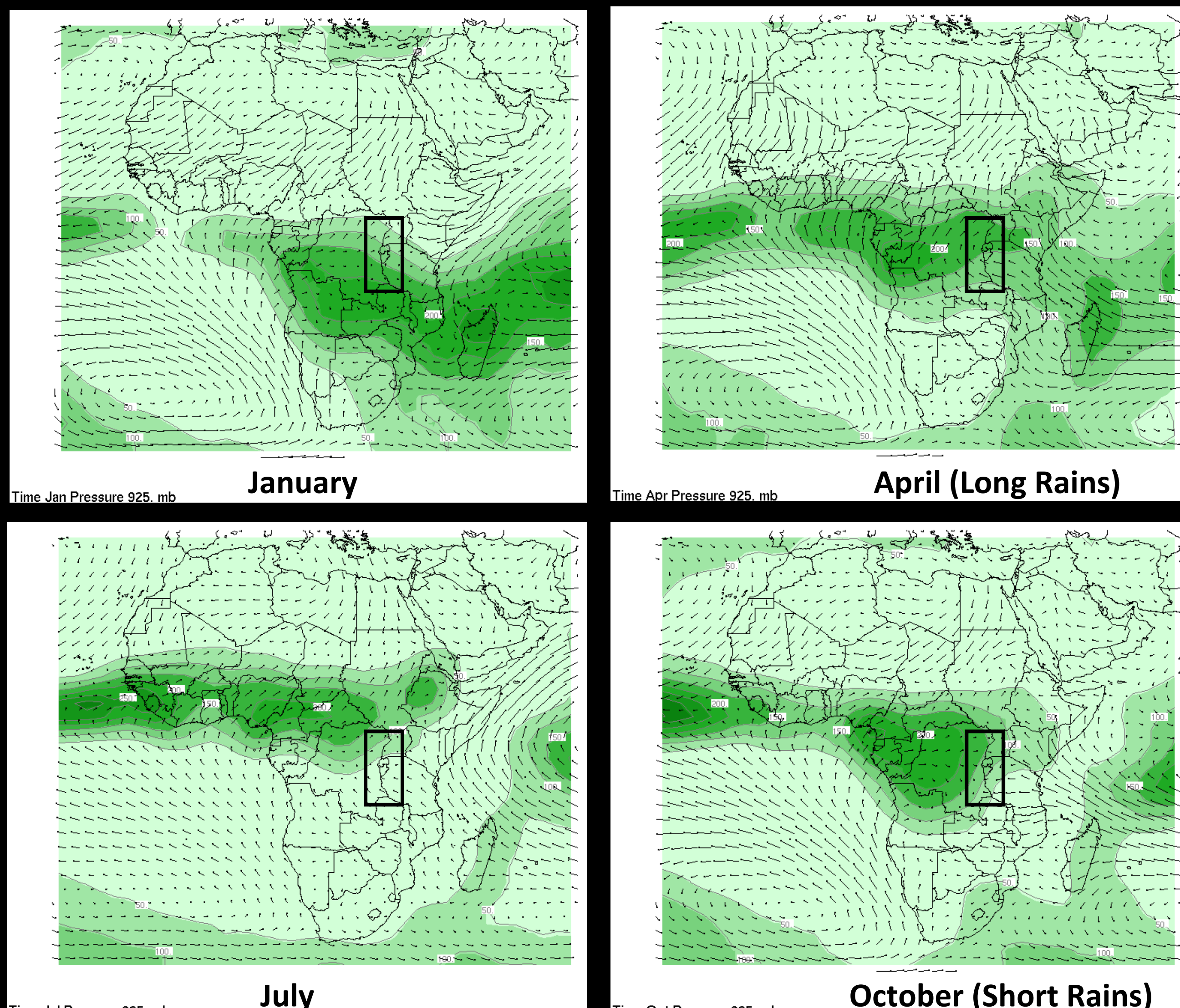
Core biodiversity conservation landscapes examined in WCS Climate Assessment

Controls over regional climate

Spatial variability largely governed by topography and land surface type
= local forcing

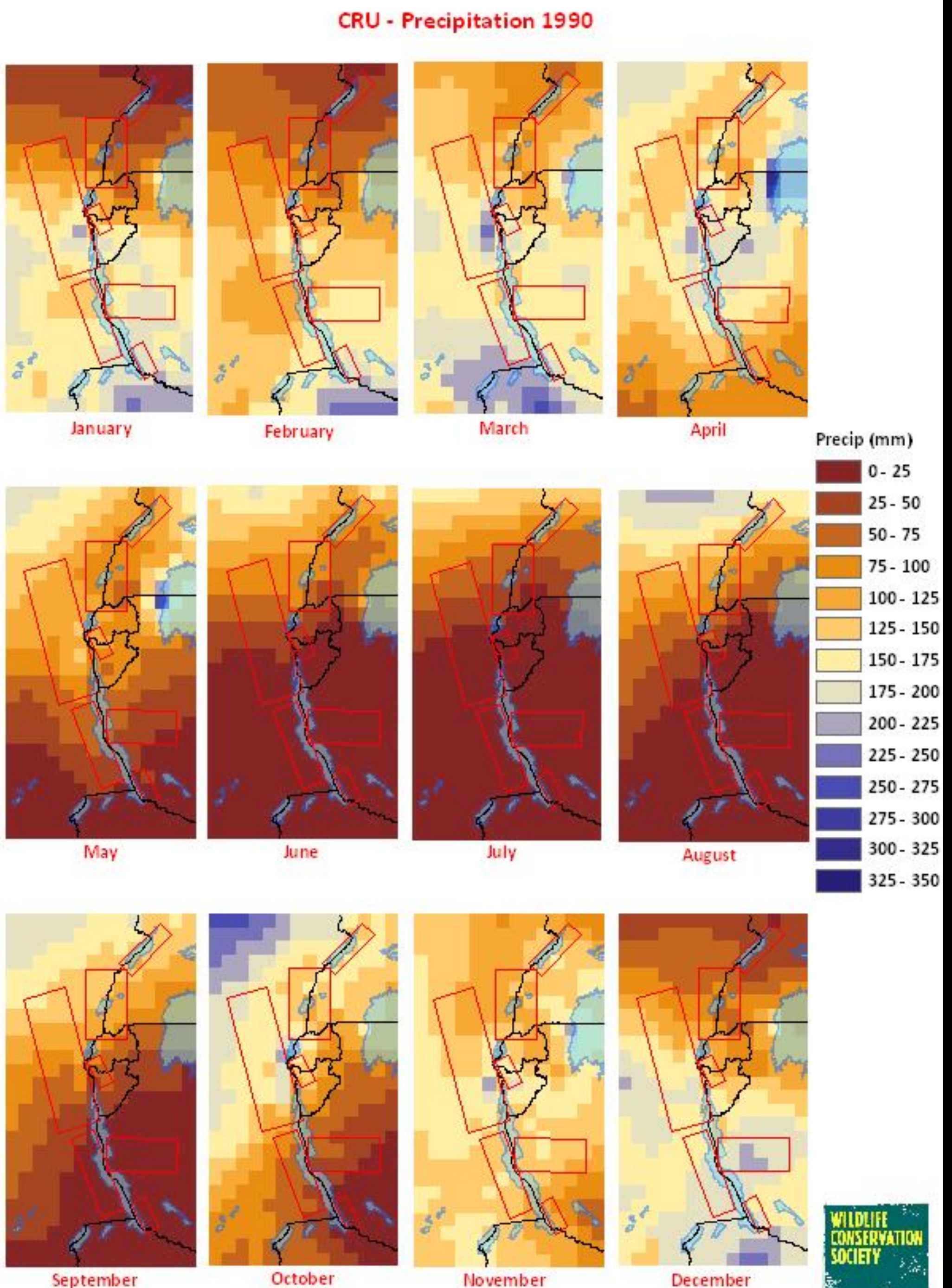
Seasonal to annual variability influenced by factors far outside region, especially sea surface temperature patterns
= external forcing

Continental scale precipitation seasonality



Precipitation climatology

Climatological representation of monthly mean precipitation amount over the Albertine Rift project domain based on 1980-1999 interpolated data.



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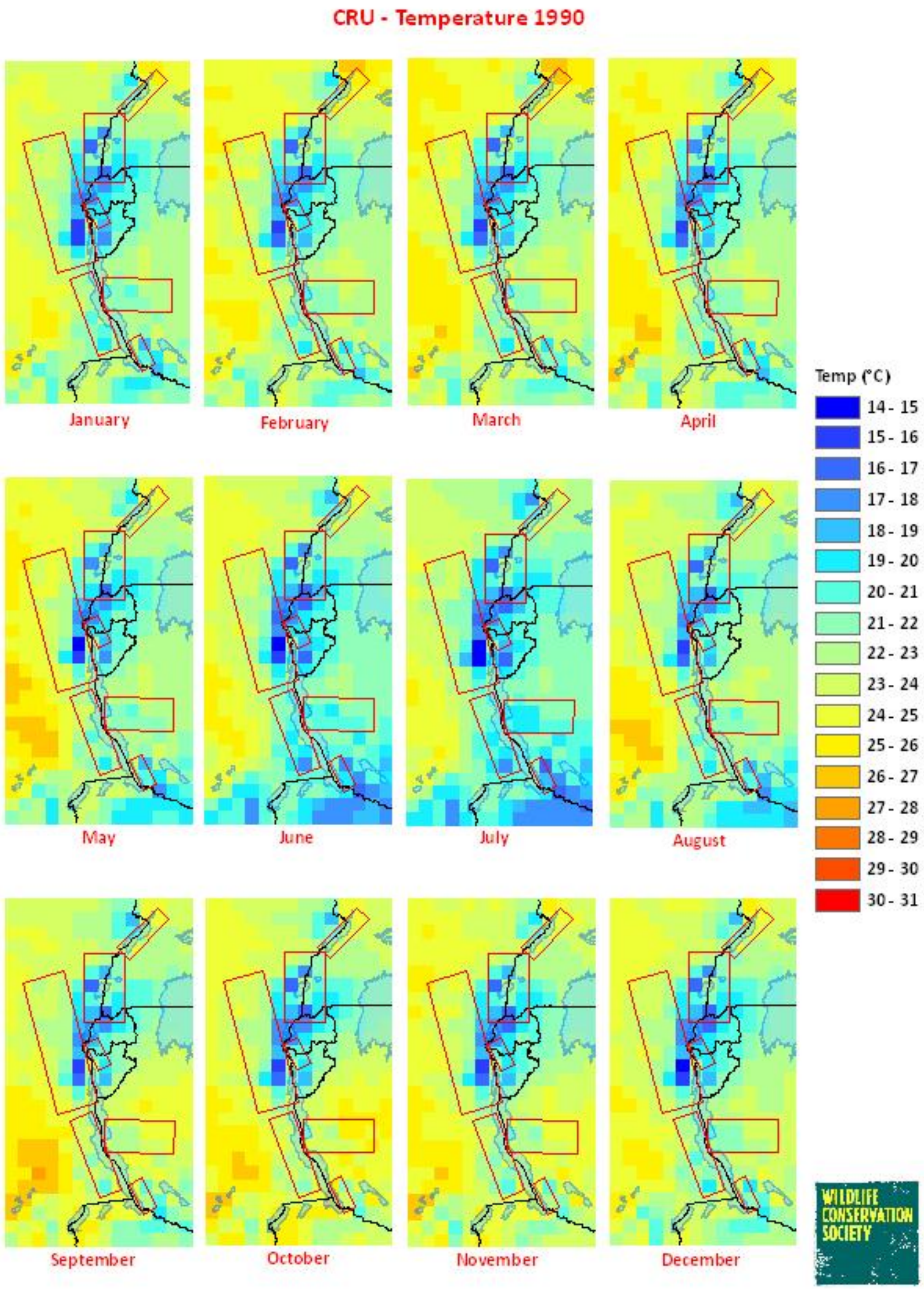
Temperature climatology

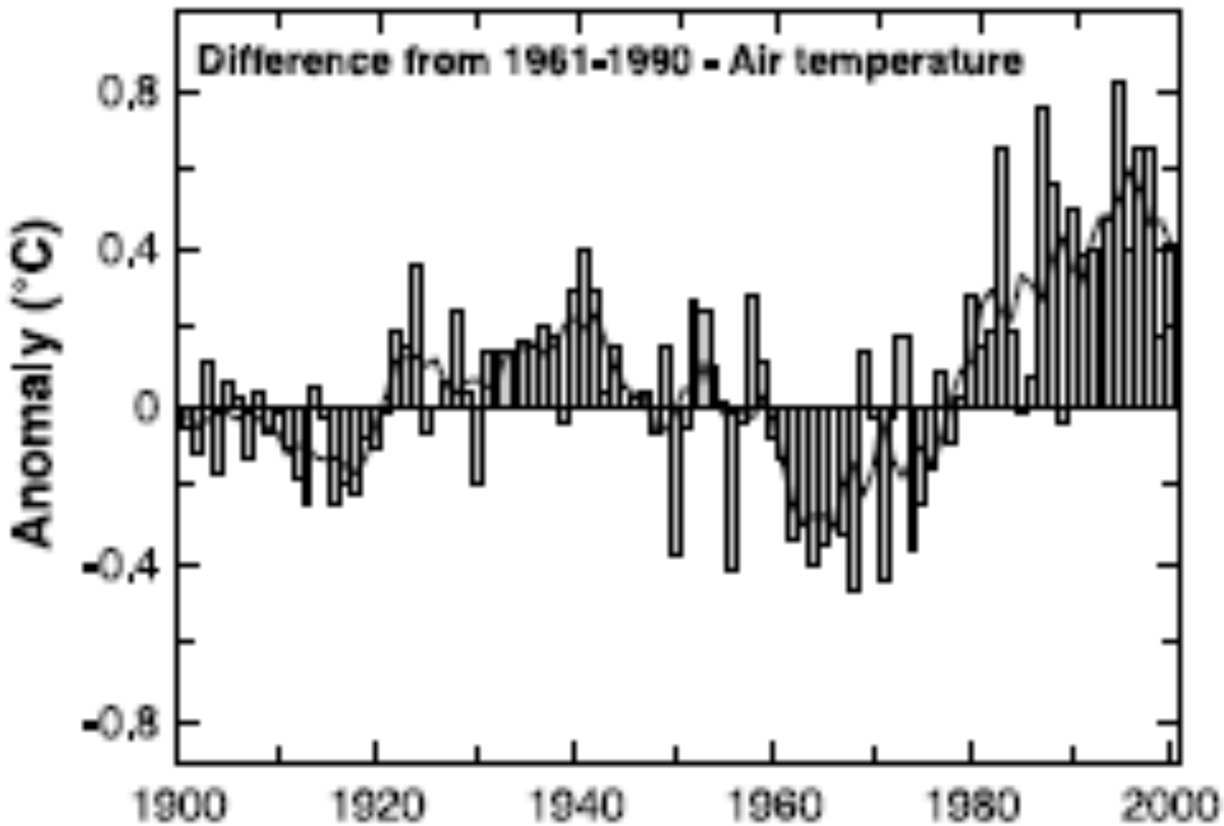
Climatological representation of monthly mean surface temperature over the Albertine Rift project domain based on 1980-1999 interpolated data.

Spatial variation remains fixed in place over time, reflecting control of terrain elevation over temperature.



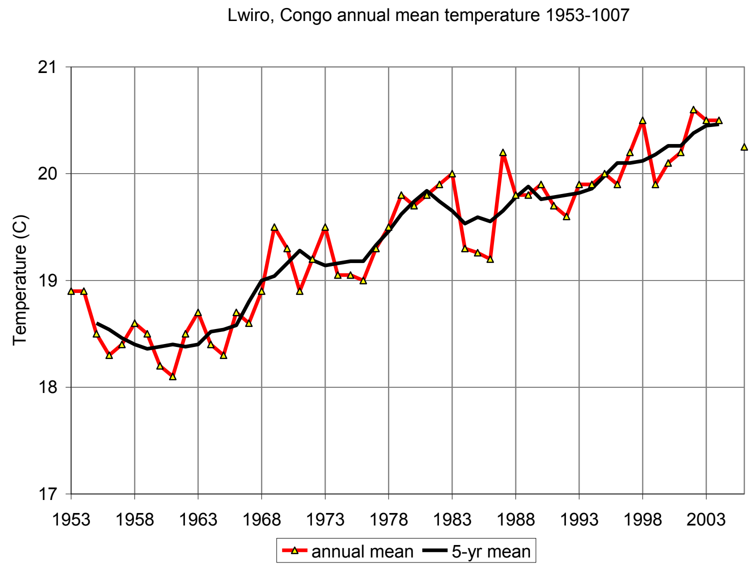
East African annual temperature trends

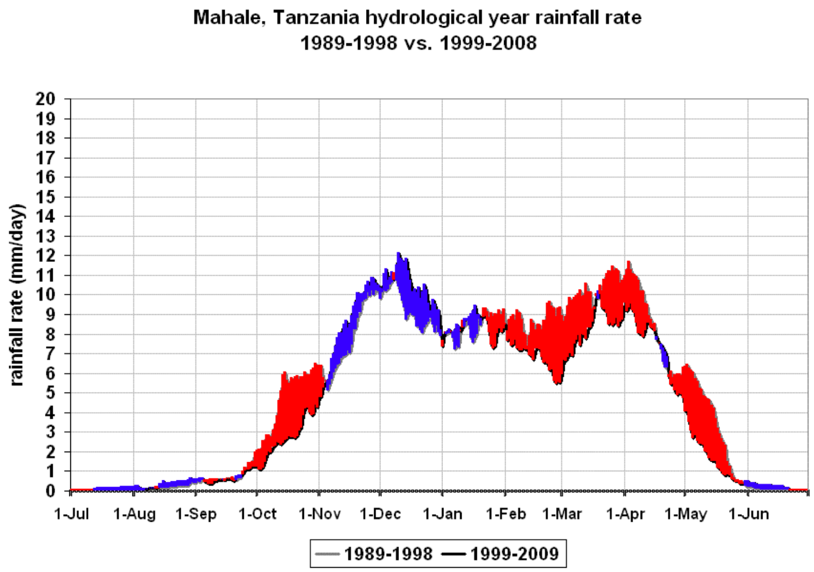
anomalies relative to 1961-1990 mean

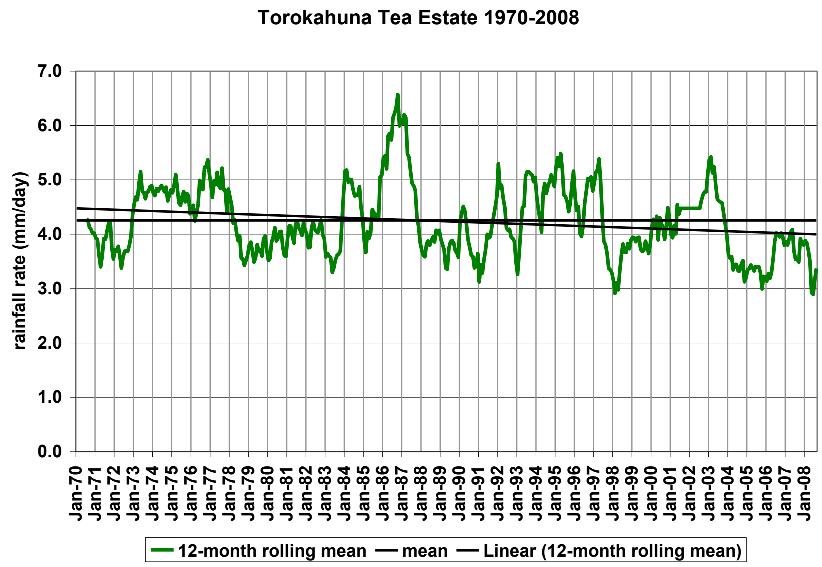


Cullen et al, Geophysical Research Letters 2006

Identify trends and variability in existing climate data



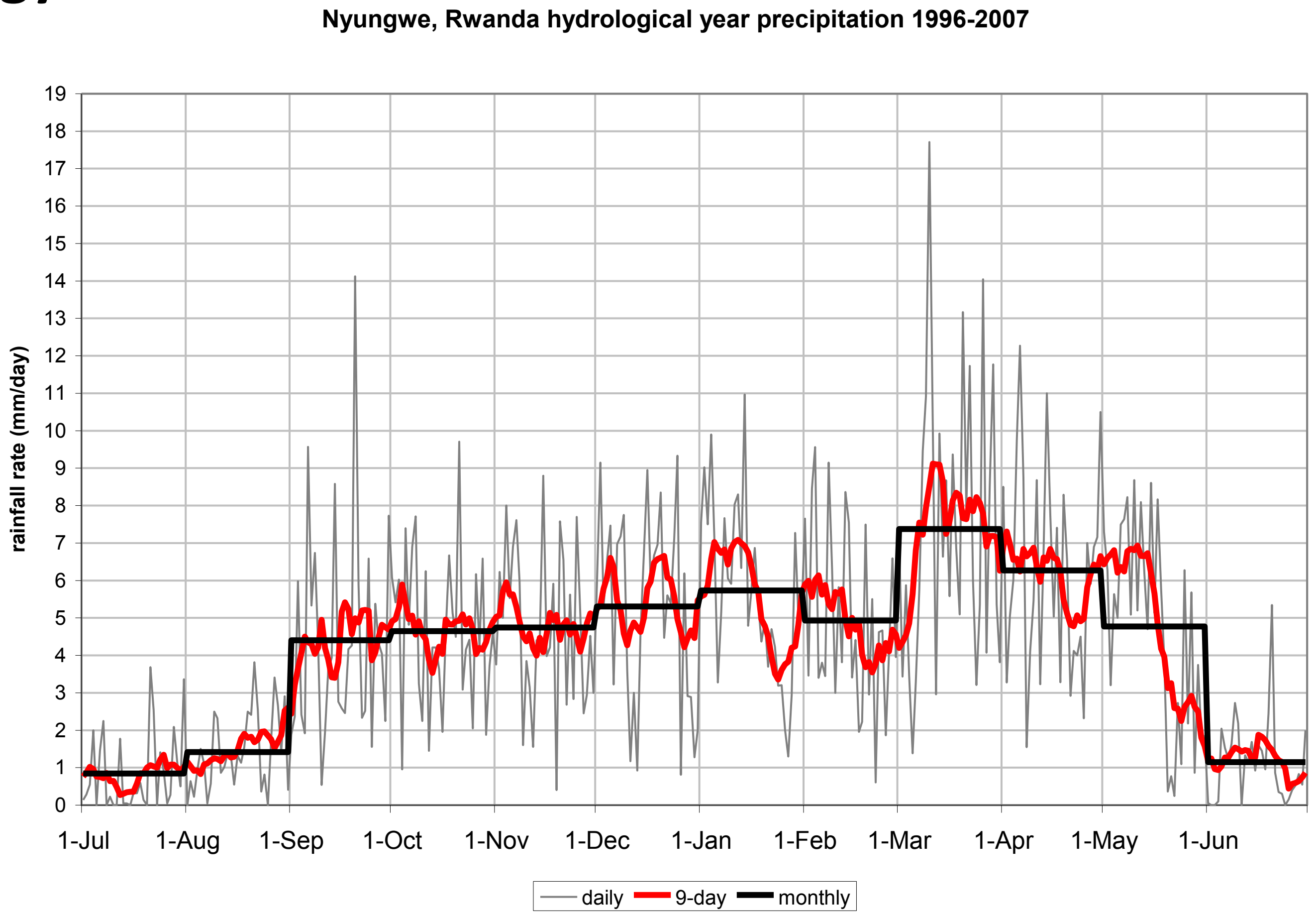




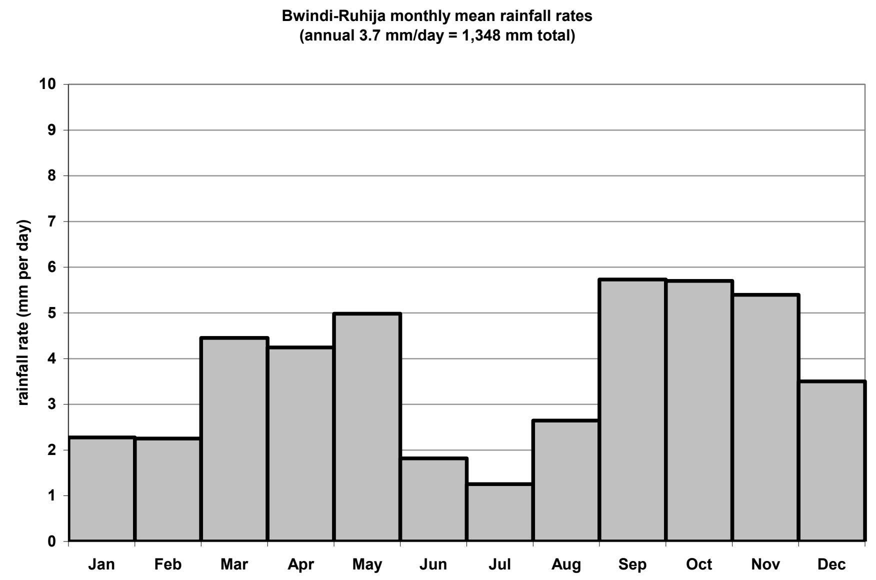
Nyungwe annual rainfall climatology

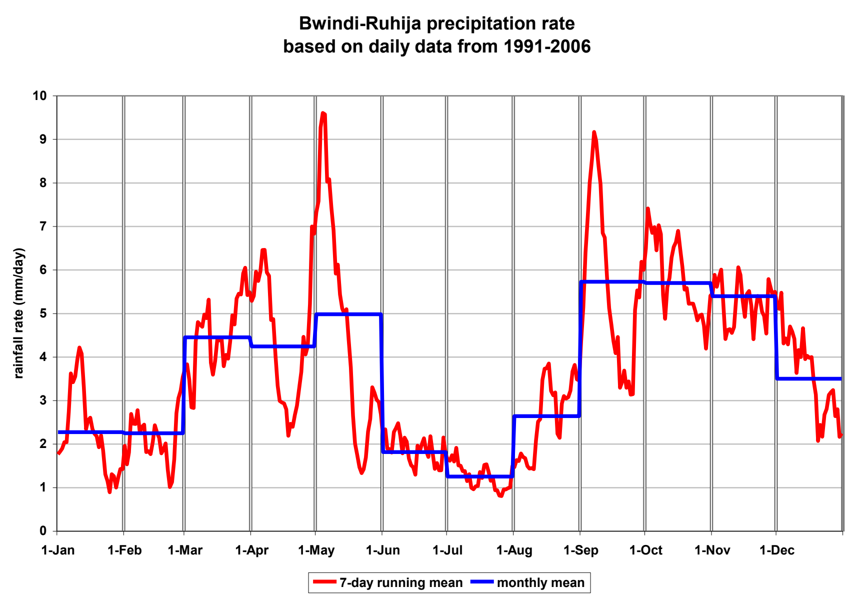
Wet season begins and ends abruptly! Not evident in monthly mean data

Indication of two short dry periods around 25 January and 1 March: Climate change may either eliminate these or intensify them.

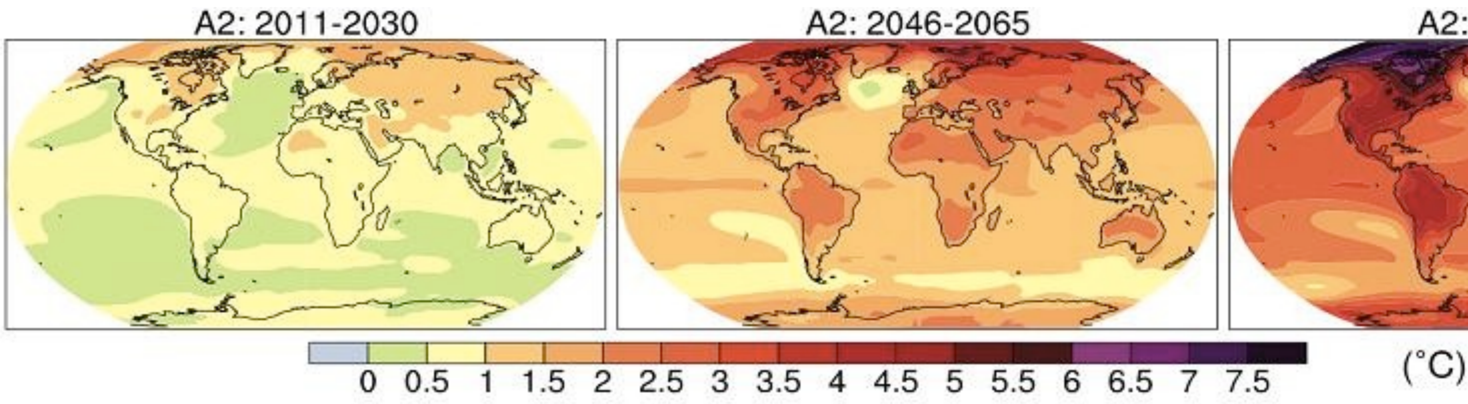


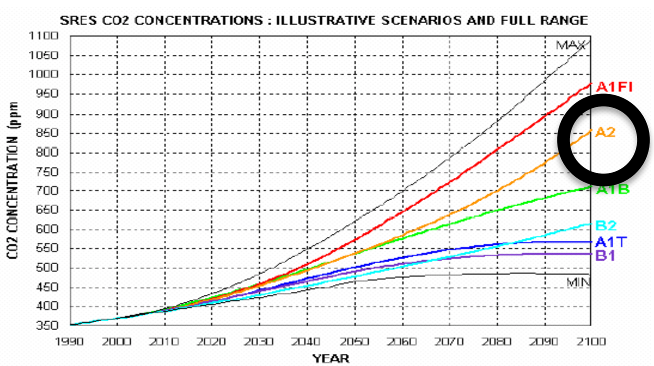
Annual rainfall climatology at Bwindi NP, Uganda

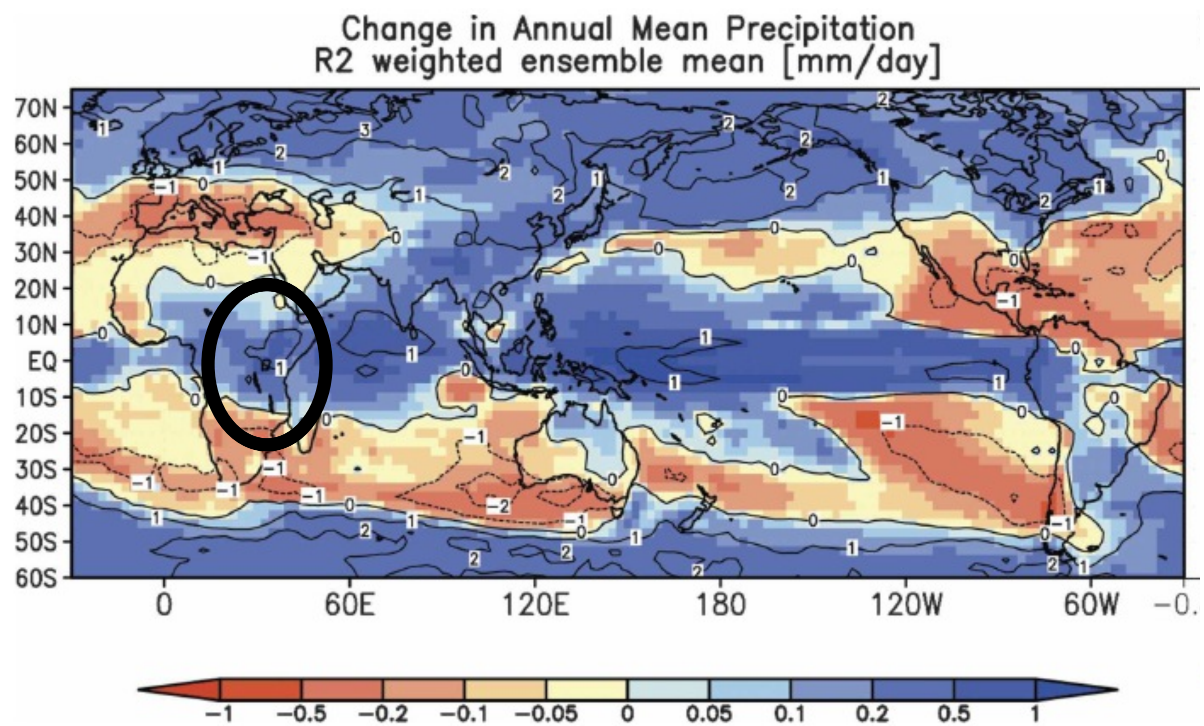




IPCC A2 scenario





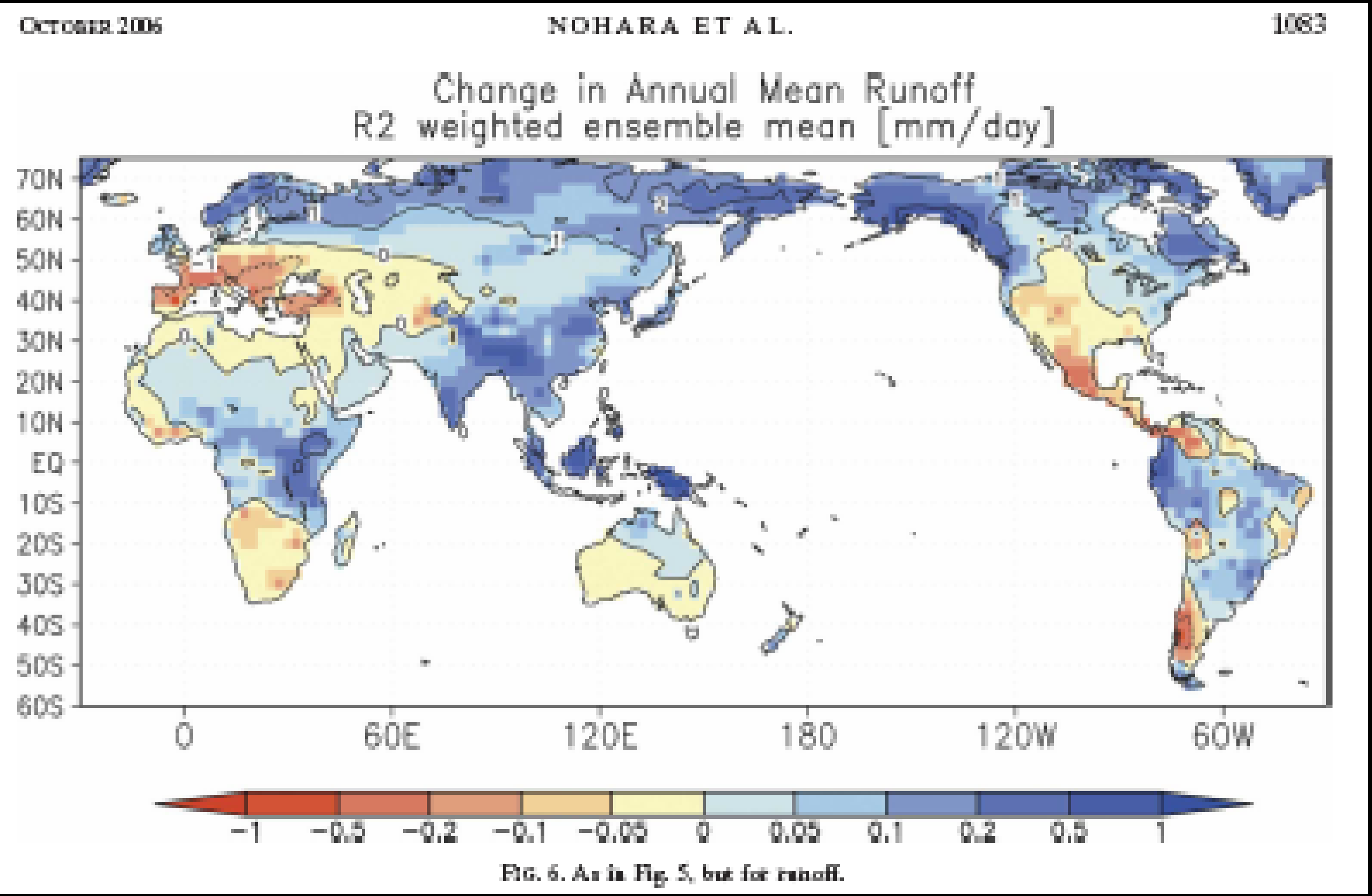


IPCC multi-model projections for end of 21st century compared to present

Nohara et al.,*Journal of Hydrometeorology,* 2006

River discharge changes in 2100

derived product combining modeled precipitation and evaporation

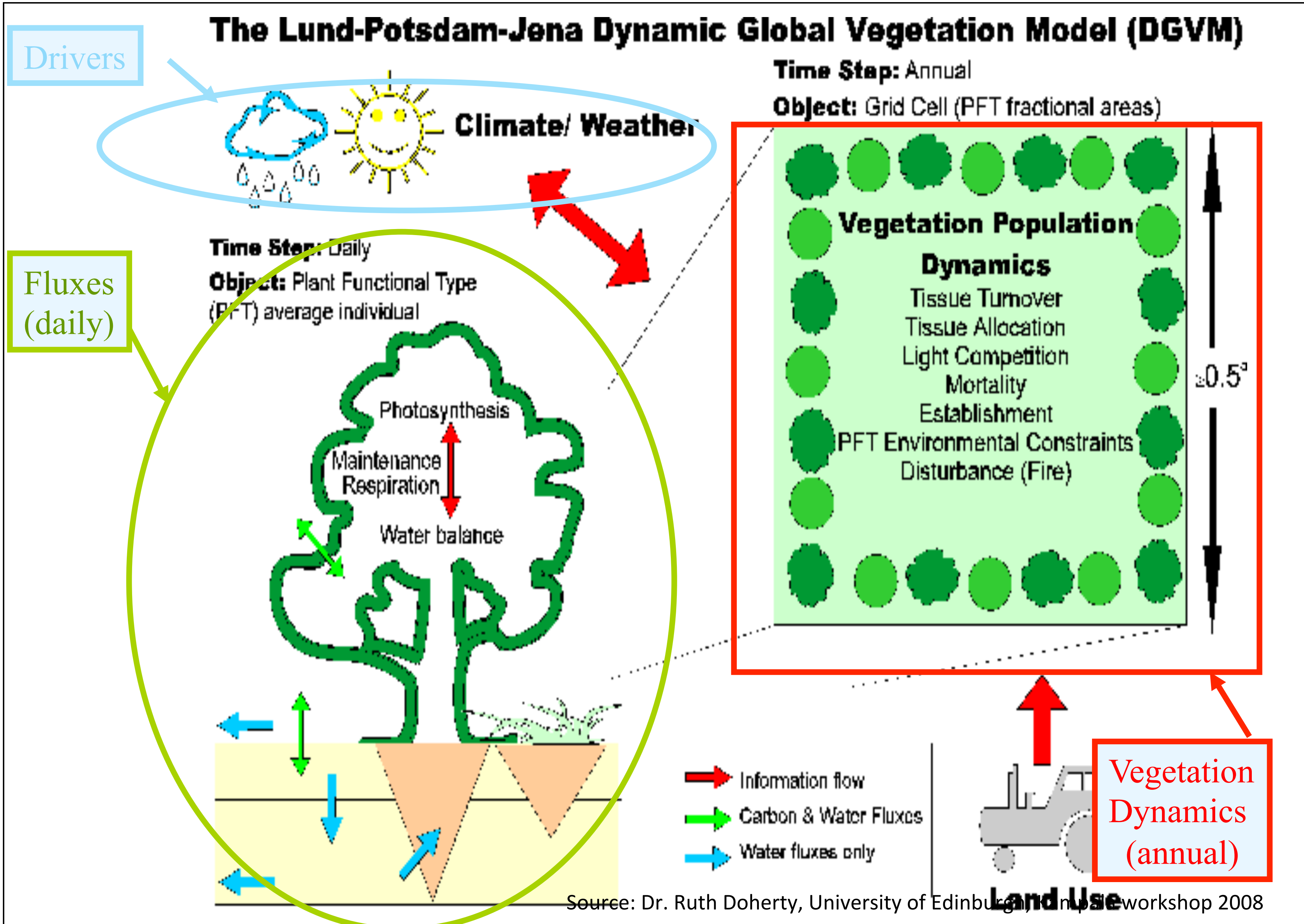


Impact of Climate Change on River Discharge Projected by Multimodel Ensemble
Nohara et al.,*Journal of Hydrometeorology,* 2006

Lund-Potsdam-Jena Vegetation Model simulations

- Driven by climate and soils inputs, LPJ simulates:
  - Daily: carbon and water fluxes
  - Annually: vegetation dynamics and competition amongst 10 Plant Functional Types (PFTs)
- Average grid-cell basis with a 1-year time-step
- Spin-up period of 1000 years to develop equilibrium vegetation and soil structure at start of simulation

Source: Dr. Ruth Doherty, University of Edinburgh, Kampala workshop 2008



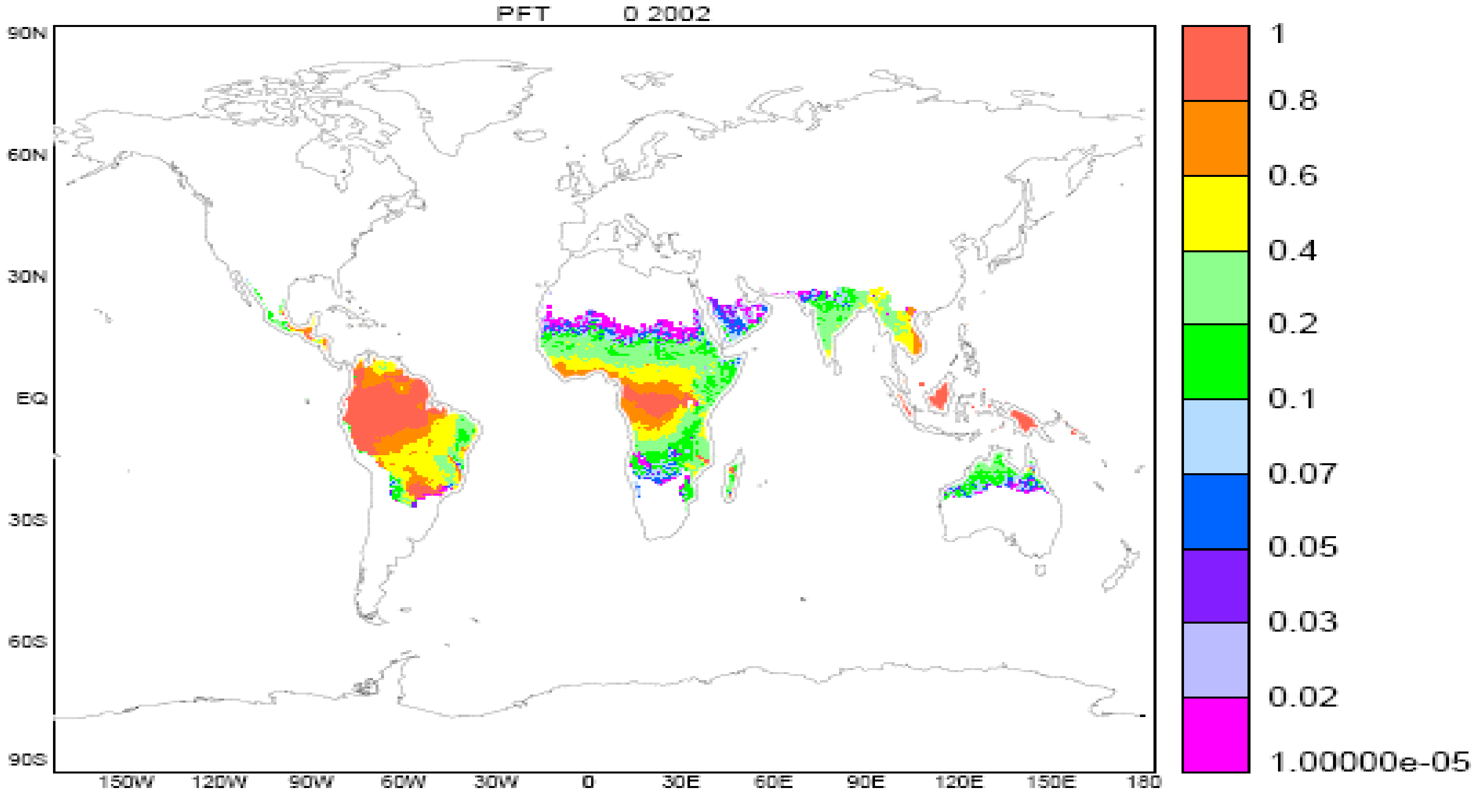
Source: Dr. Ruth Doherty, University of Edinburgh, Kampala workshop 2008

LPJ Outputs

For each grid cell LPJ produces annual values for:

- Net Primary Production
- Net Ecosystem Production
- Plant Functional Type
- Heterotrophic respiration
- Vegetation carbon
- Soil carbon
- Fire carbon
- Run-off
- Evapotranspiration

Tropical Broadleaf Evergreen Tree



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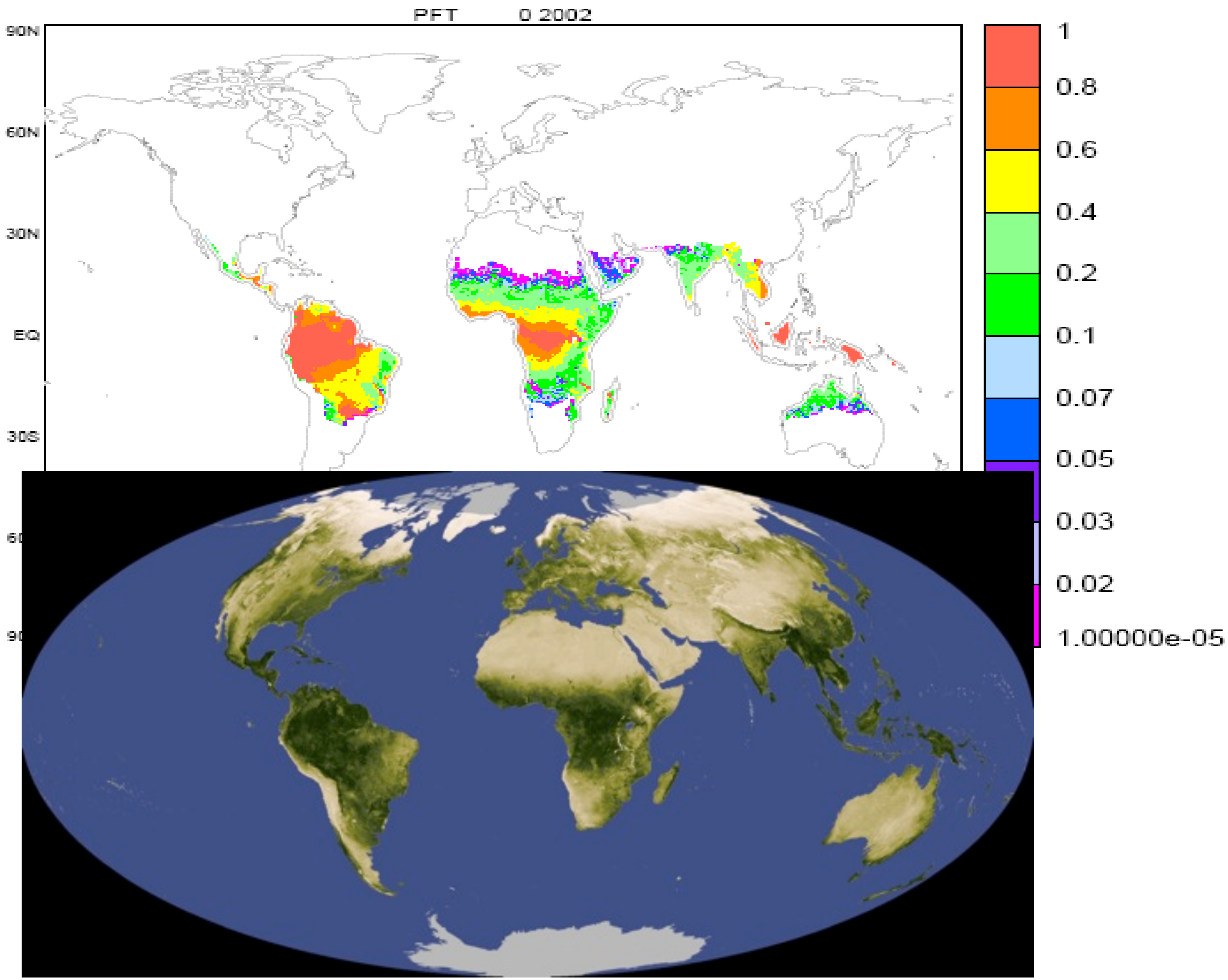
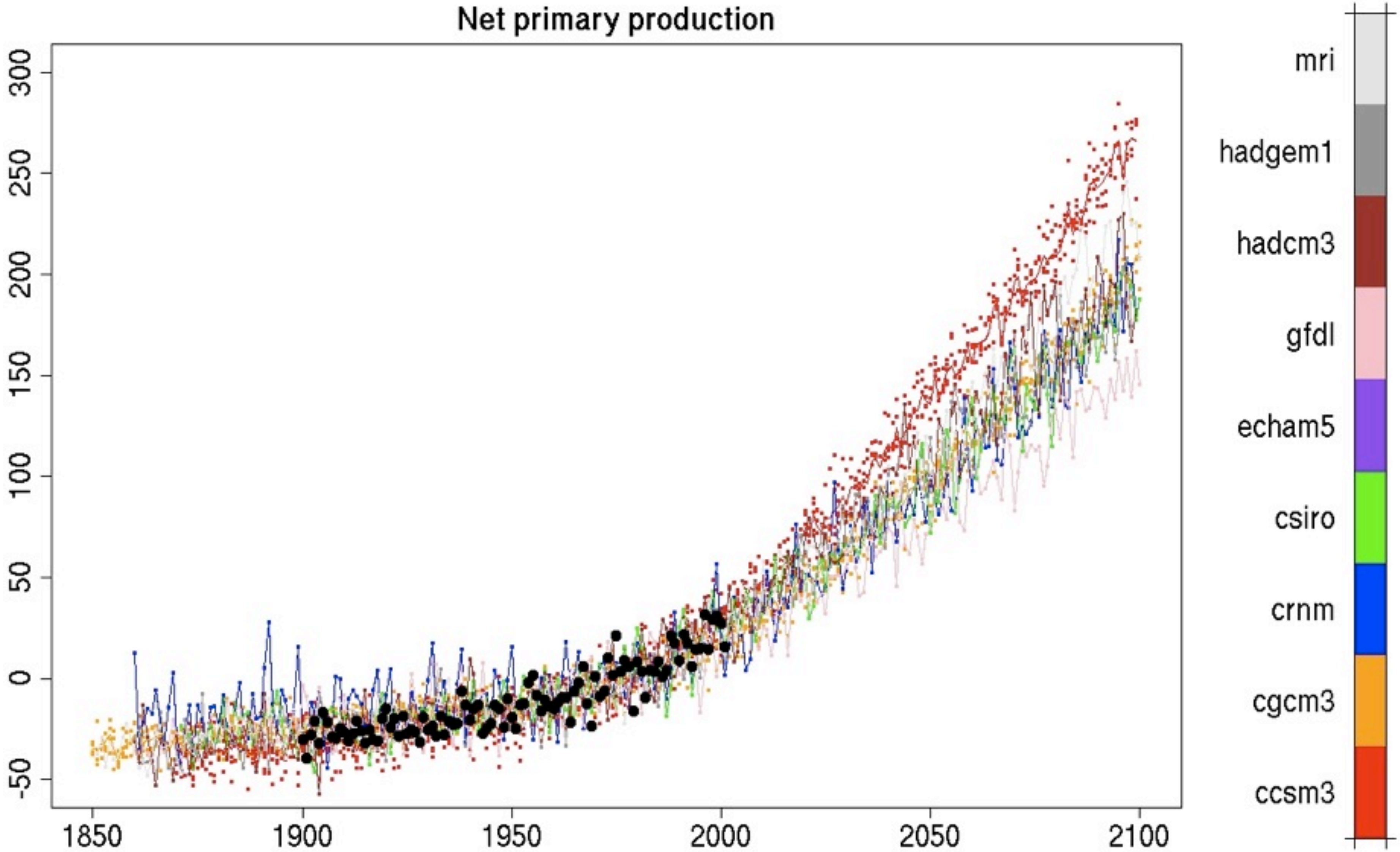
Tropical Broadleaf Evergreen Tree



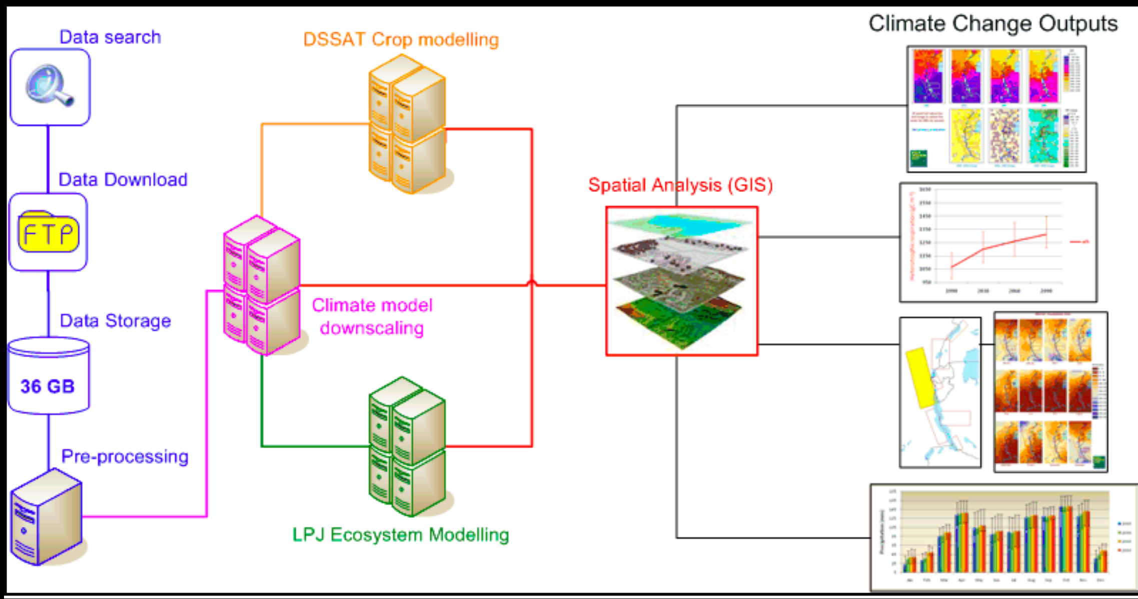
Source: Dr. Ruth Doherty, University of Edinburgh, Kampala workshop 2008

NPP



Source: Dr. Ruth Doherty, University of Edinburgh, Kampala workshop 2008

Procedure used to generate ecologically meaningful products specific to the Albertine Rift from raw, low resolution climate model output



Picton Phillips and Seimon (2010)

OUTPUT PARAMETERS

1. Climatological variables
- Monthly mean temperature (°C)
- Monthly mean precipitation amount (mm)
- Monthly mean cloud cover (% sky coverage)

2. Carbon Fluxes
- Net Primary Production (NPP)
- Land-Atmosphere flux
- Carbon Loss from Fire
- Heterotrophic respiration (Rh)

3. Carbon Pools
- Vegetation Carbon
- Soil Carbon
- Litter Carbon
- Annual Total Carbon

4. Hydrological Variables
- Total Runoff (mm)
- Actual Evapotranspiration (mm)

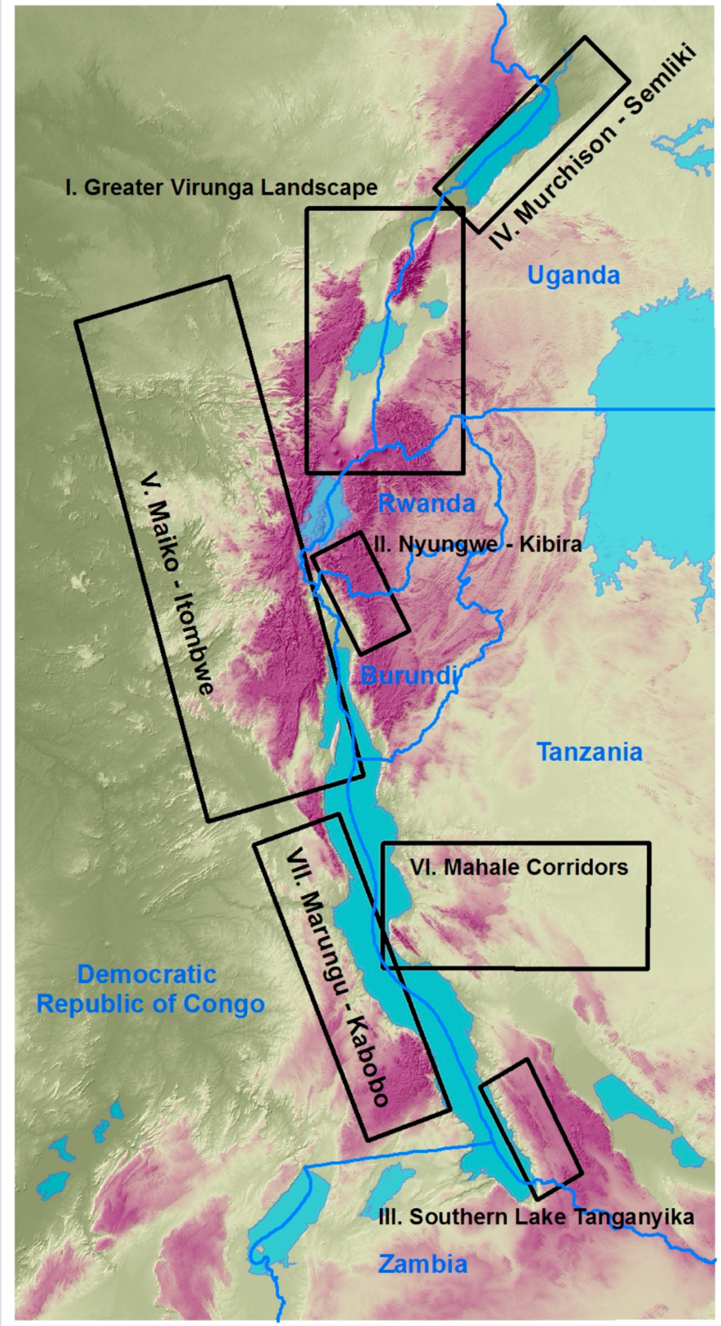
5. Vegetation and agriculture
- Annual Phaseolus Bean Yield (kg ha^{-2})
- Annual *Brachiaria decumbens* Yield (kg ha^{-2})
- Annual Maize Yield (kg ha^{-2})
- Fractional Cover of Plant Functional Type (%0

Downscaled GCM output statistics averaged over the Albertine Rift model domain – A2 emissions scenario

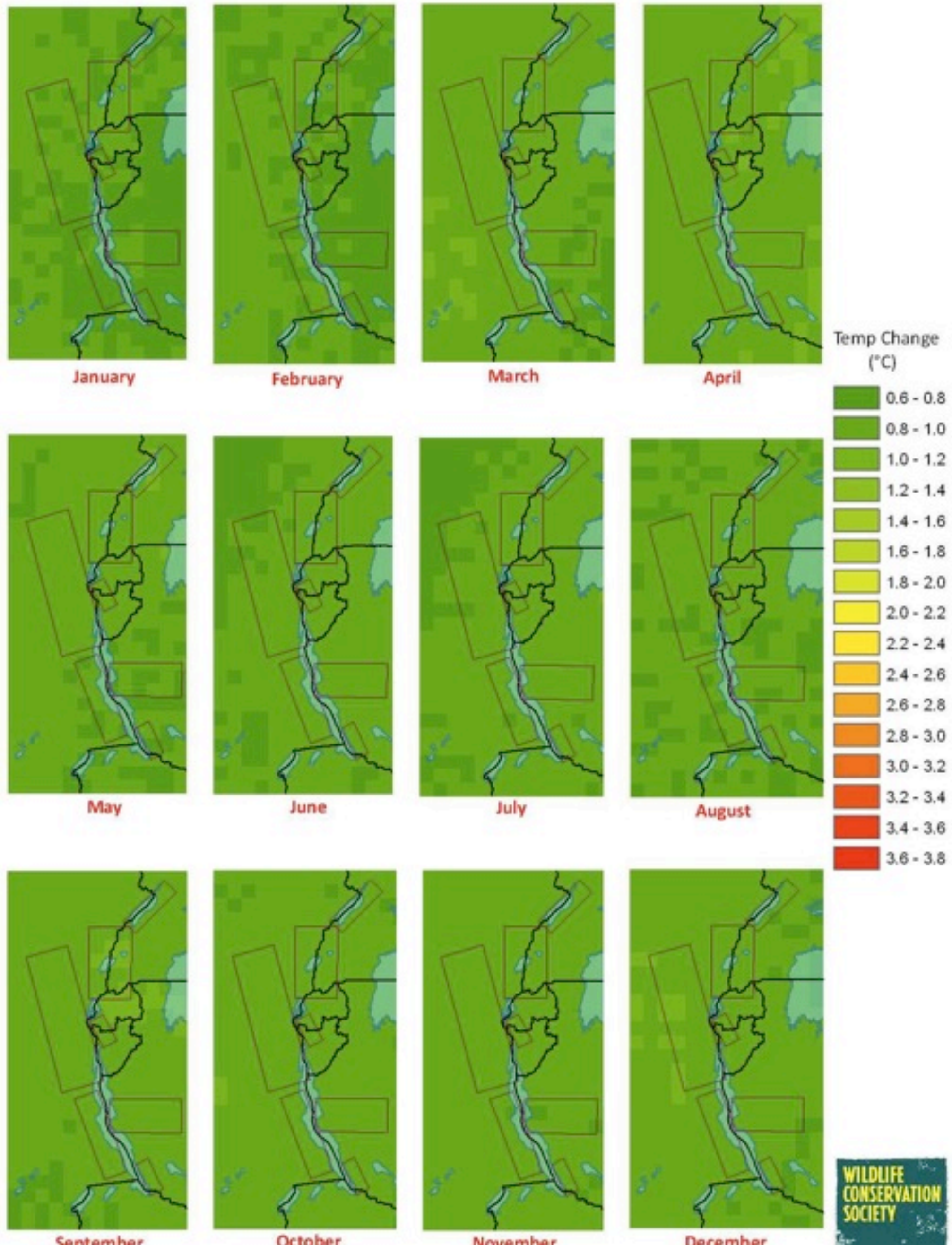
Baseline | Future →

		1990	2030	2060	2090	
Mean annual temperature	*Max*	26.0	27.0	28.1	29.7	°C
	Mean	**22.7**	**23.6**	**24.7**	**26.3**	
	Min	15.0	16.0	17.1	18.7	
Mean annual precipitation	*Max*	1887	1900	1968	2098	mm
	Mean	**1199**	**1233**	**1287**	**1406**	
	Min	821	875	938	1057	
Mean annual cloud cover	*Max*	82.6	82.4	81.7	81.9	%
	Mean	**67.2**	**67.4**	**66.9**	**67.1**	
	Min	42.4	43.2	43.2	43.4	

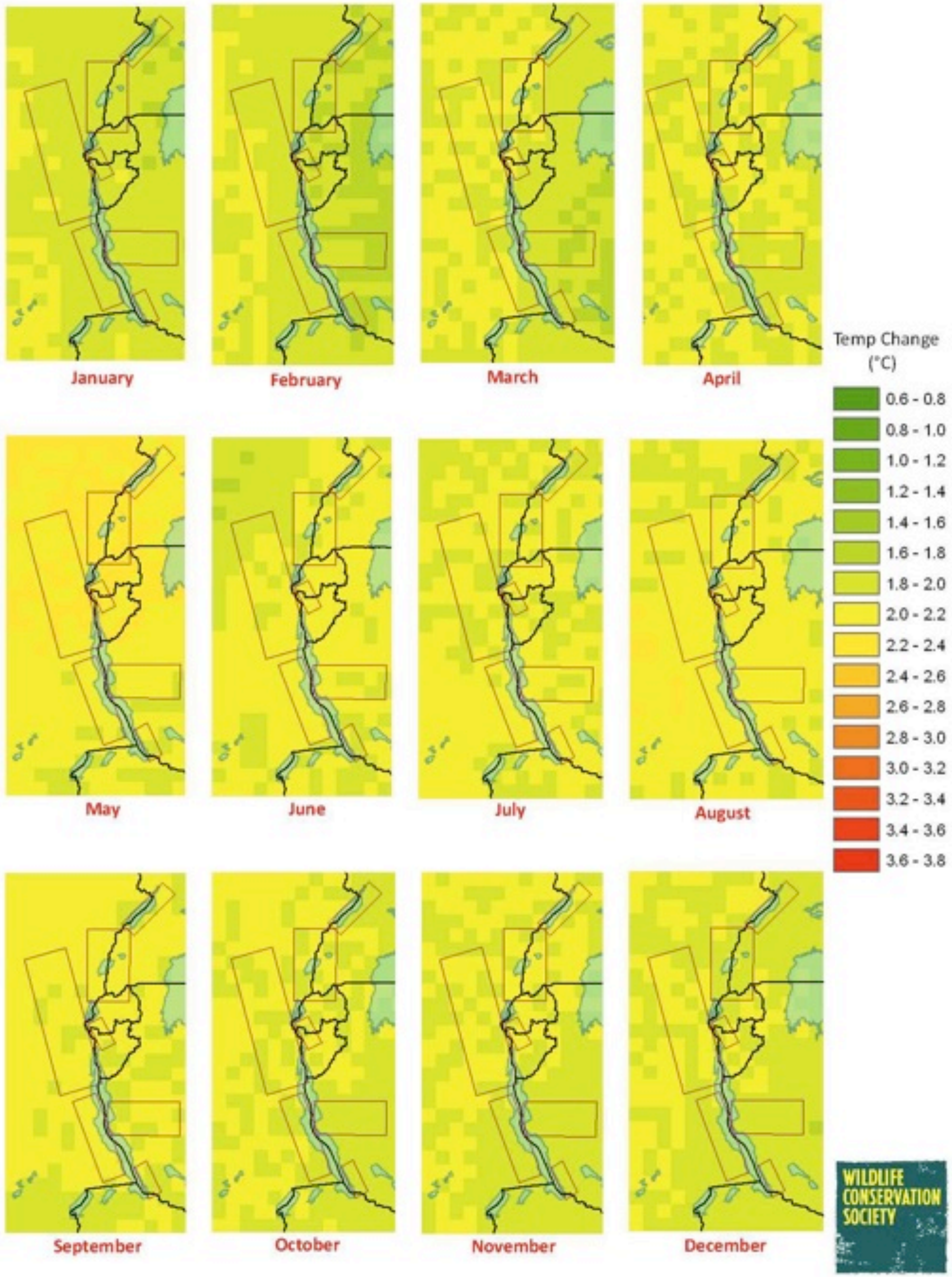
Max & Min = gridpoint extremes across the project domain
Mean = average of all gridpoints.



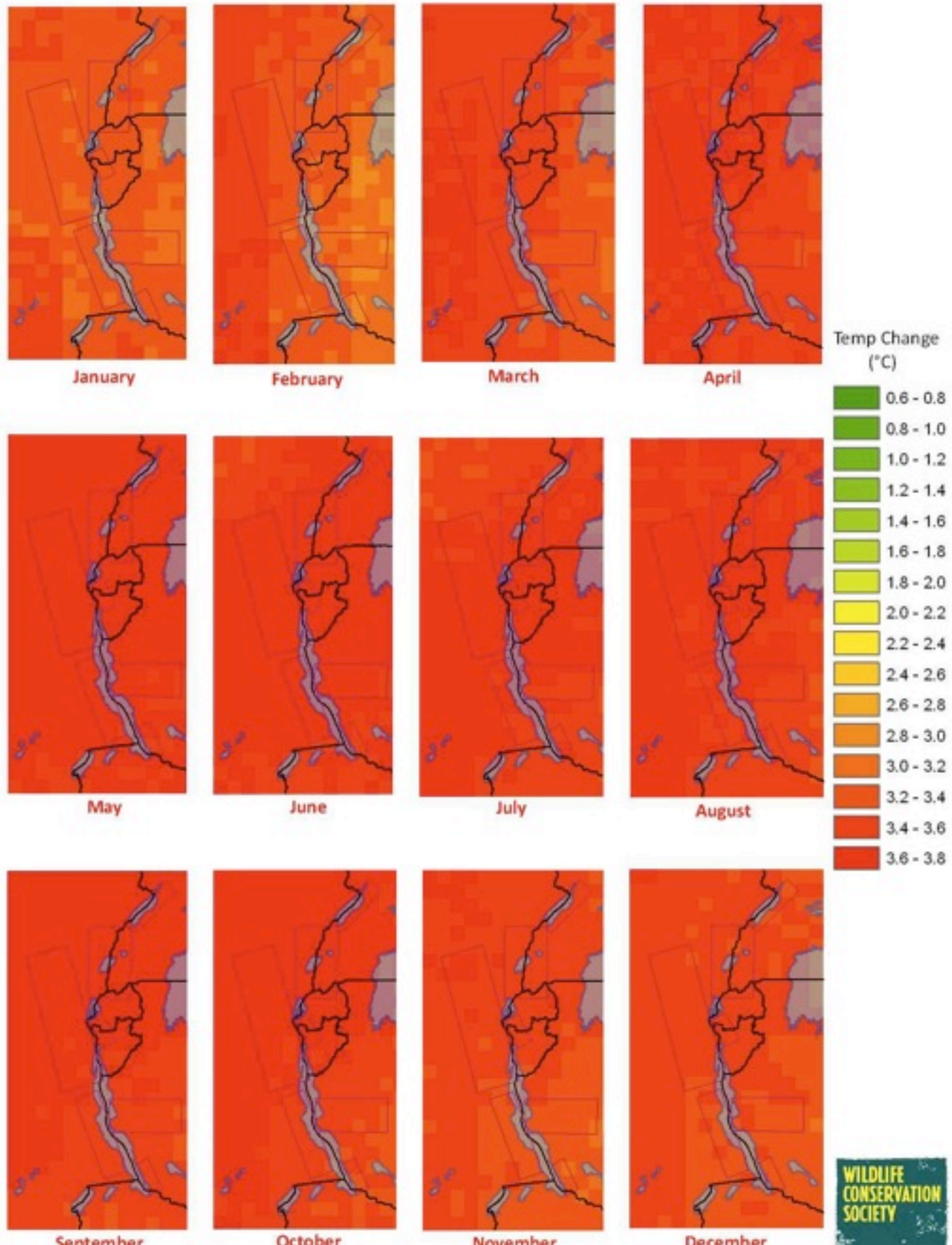
SRES A2 - Temperature Change 1990 - 2030



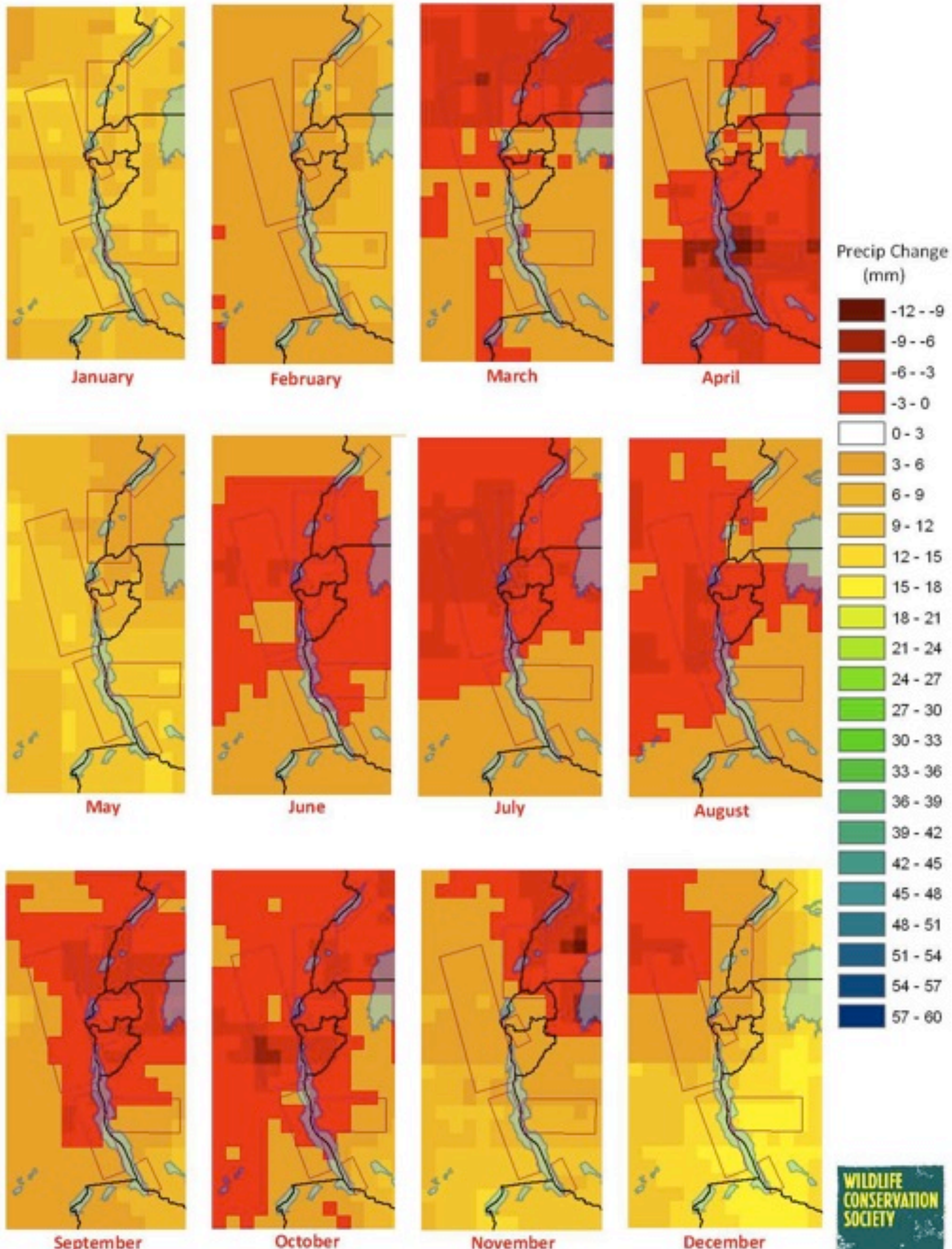
SRES A2 - Temperature Change 1990 - 2060



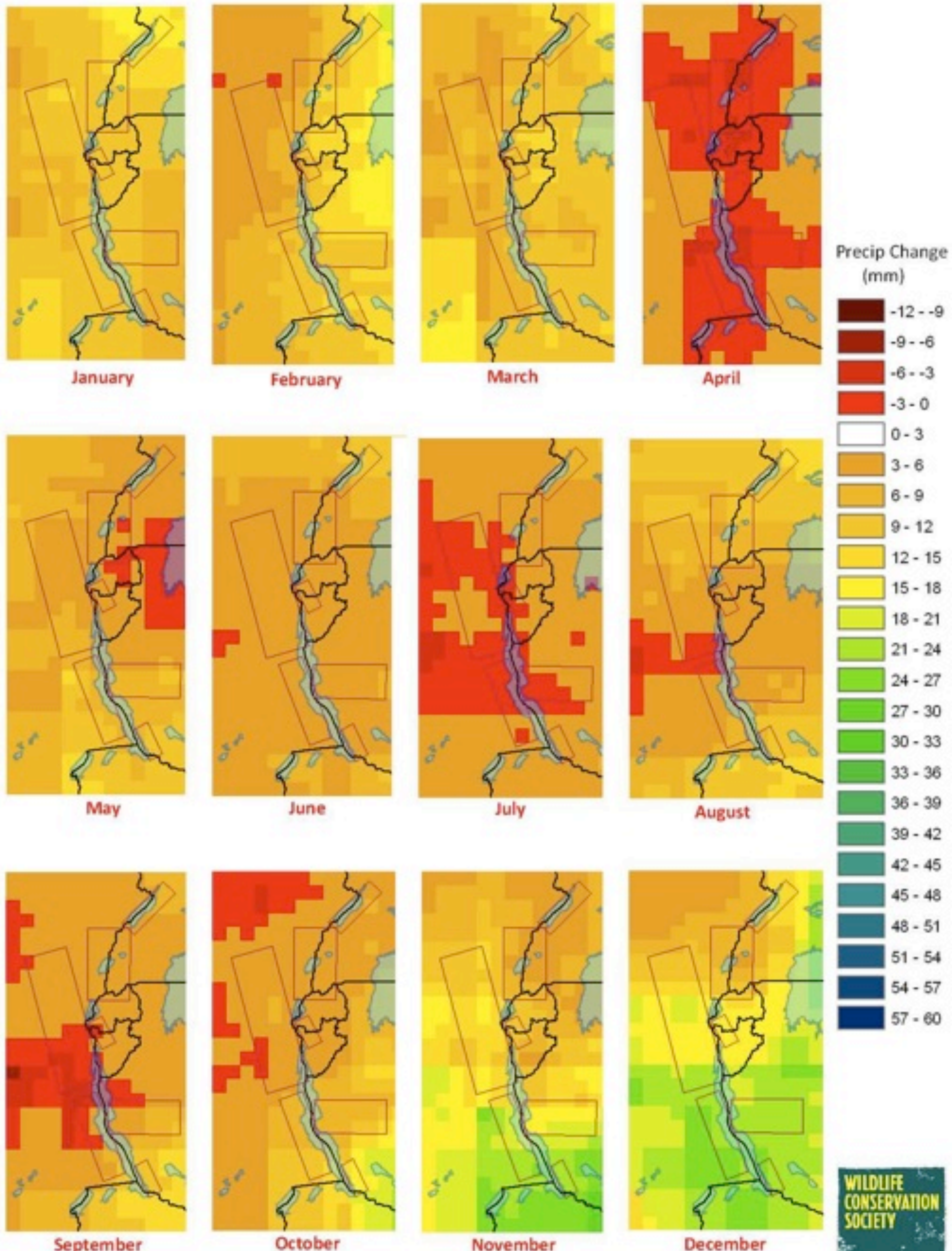
SRES A2 - Temperature Change 1990 - 2090



SRES A2 - Precipitation Change 1990 - 2030



SRES A2 - Precipitation Change 1990 - 2060



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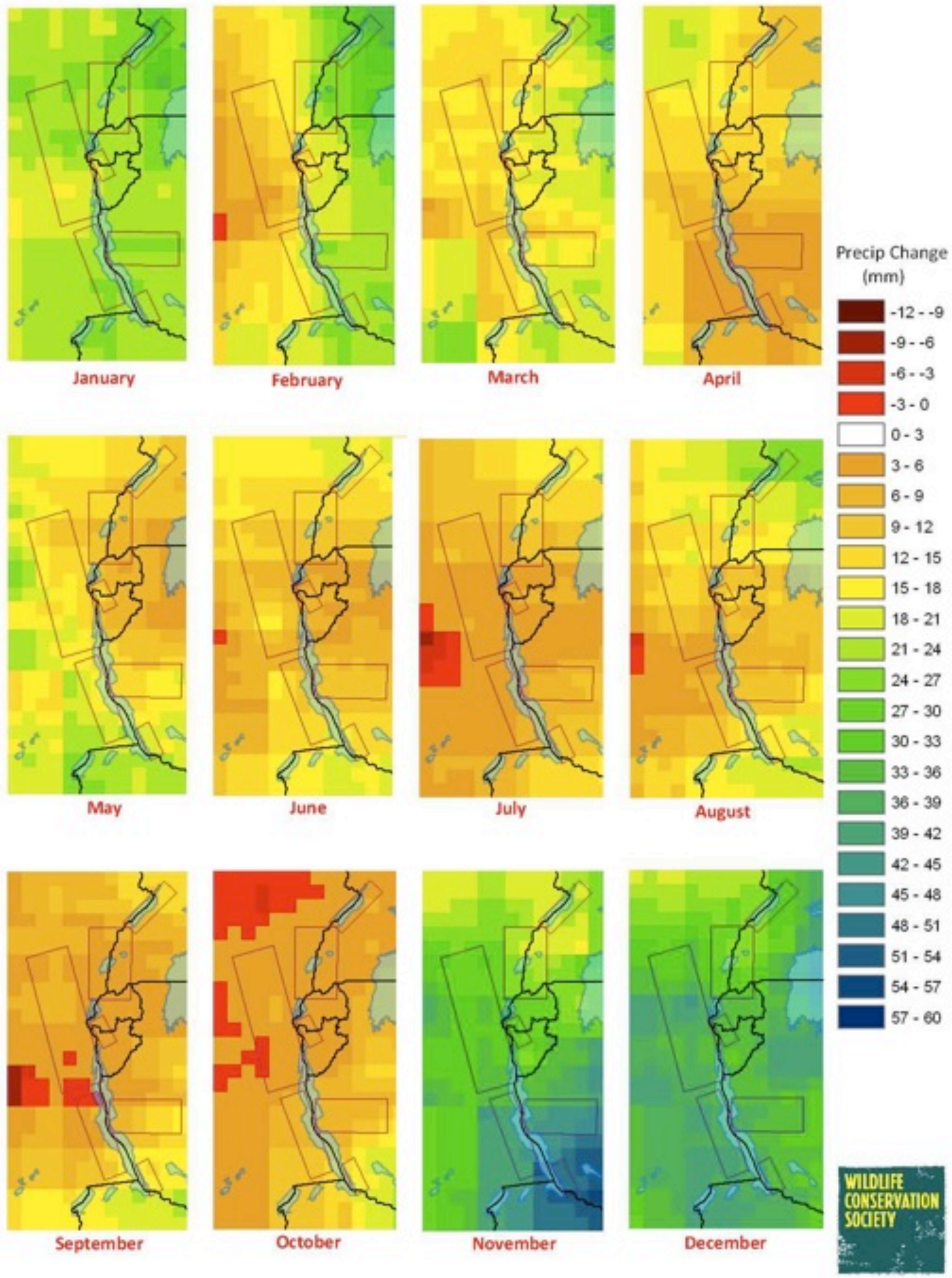
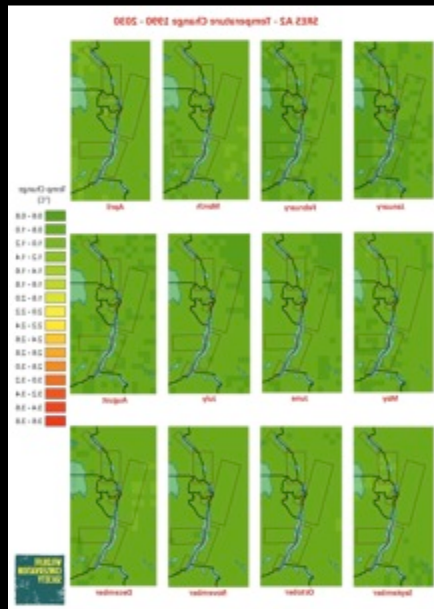
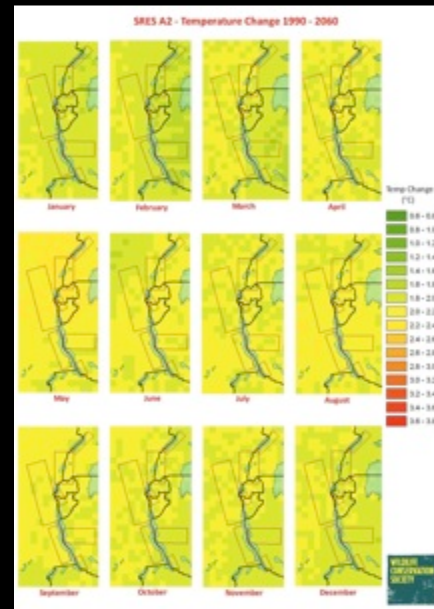
SRES A2 - Precipitation Change 1990 - 2090

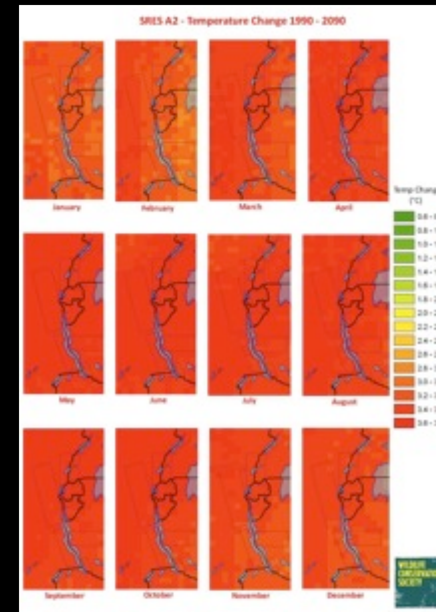


Downscaled climate parameters – A2 scenario

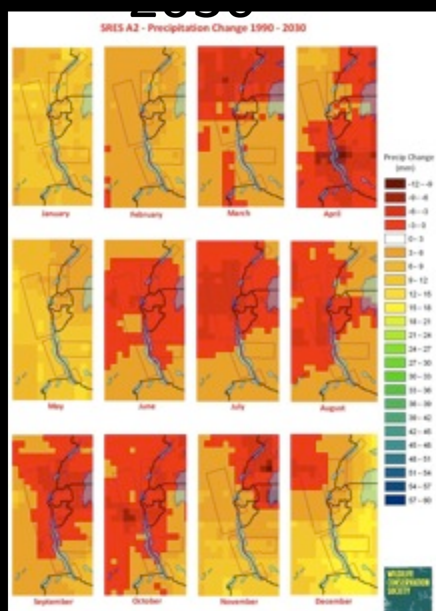
Monthly temperature changes (A2)

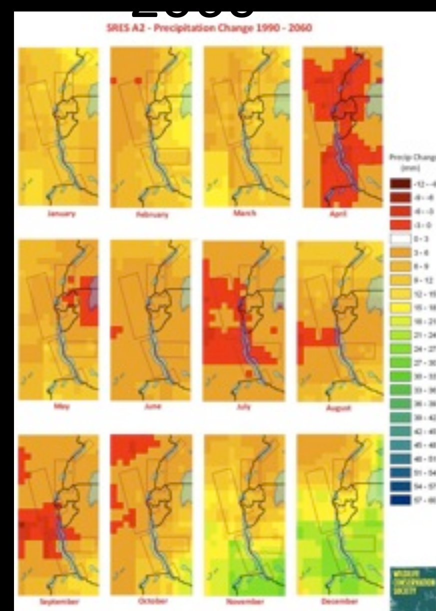


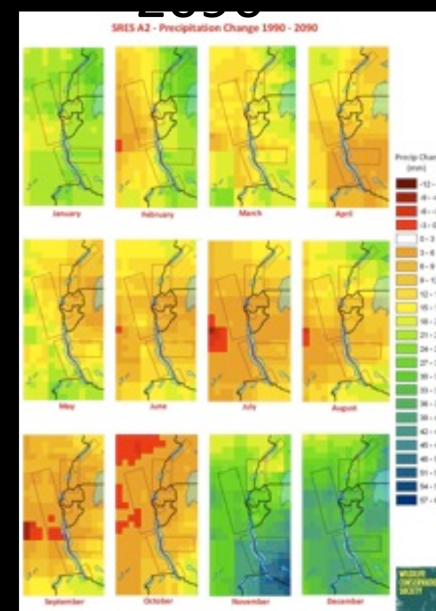




Monthly precipitation changes (A2)







Albertine Rift temperature projections – 21st century

- In the A2 simulations, temperature increases occur at an steepening rate during the course of the 21st century.

- All locations will experienced strong and sustained warming relative to current conditions.

- Lapse rate: temperatures change as a function of elevation in tropical atmospheres average 5-6°C per 1000m of elevation

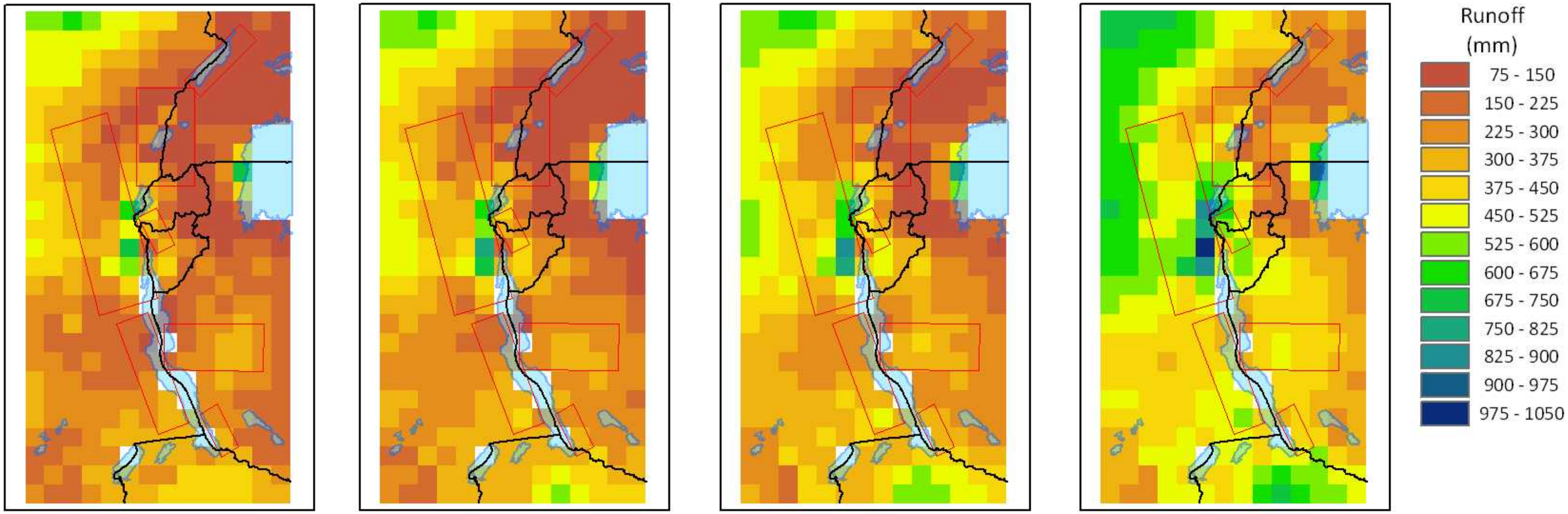
Region-wide thermal increase of 3.6°C under the A2 scenario would translate to displacements in the range of **600-720 meters**.

Albertine Rift precipitation projections – 21st century

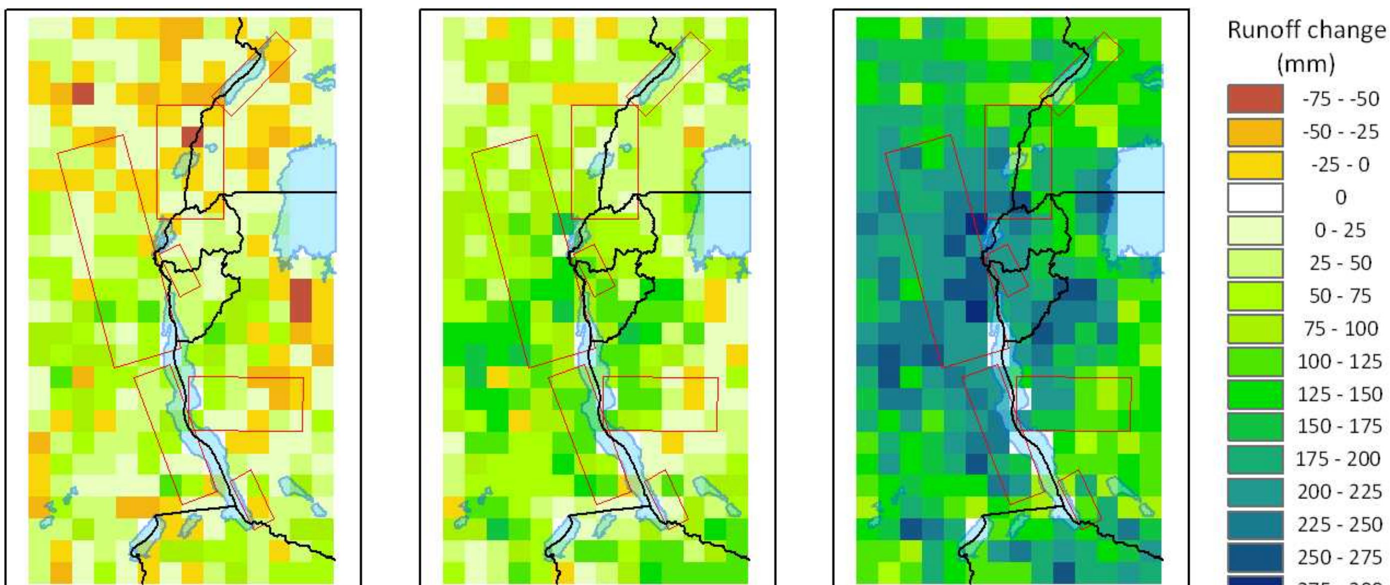
- A2 simulations: precipitation changes are both high in magnitude and vary by location across the Albertine Rift
- Increase in net annual precipitation. Relative to the 1990, rainfall increases by 3%, 7% and 17% in 2030, 2060 and 2090, respectively.
- Redistribution in fraction of rainfall during twin wet seasons. From mid-century onward: large increase in November-December rainfall little net change in March April.

LPJ predicted hydrological variables and change in hydrological variables under the SRES A2 scenario

Total runoff



1990 | 2030 | 2060 | 2090



1990 - 2030 Change | 1990 - 2060 Change | 1990 - 2090 Change

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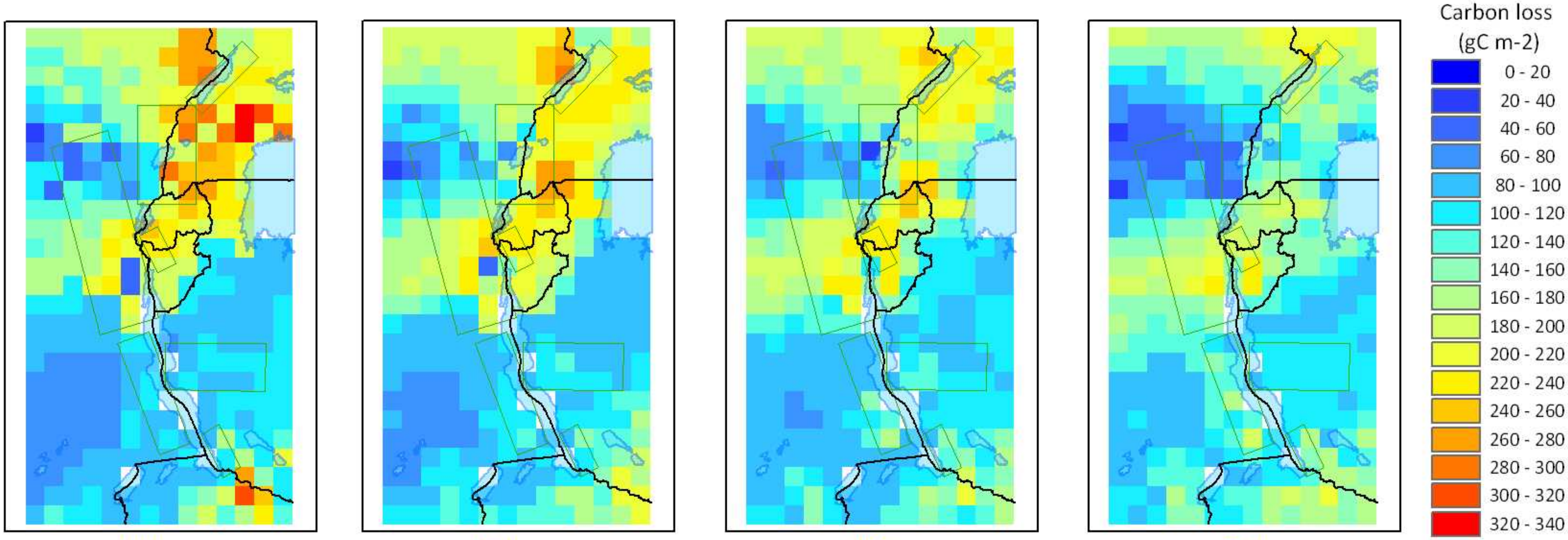
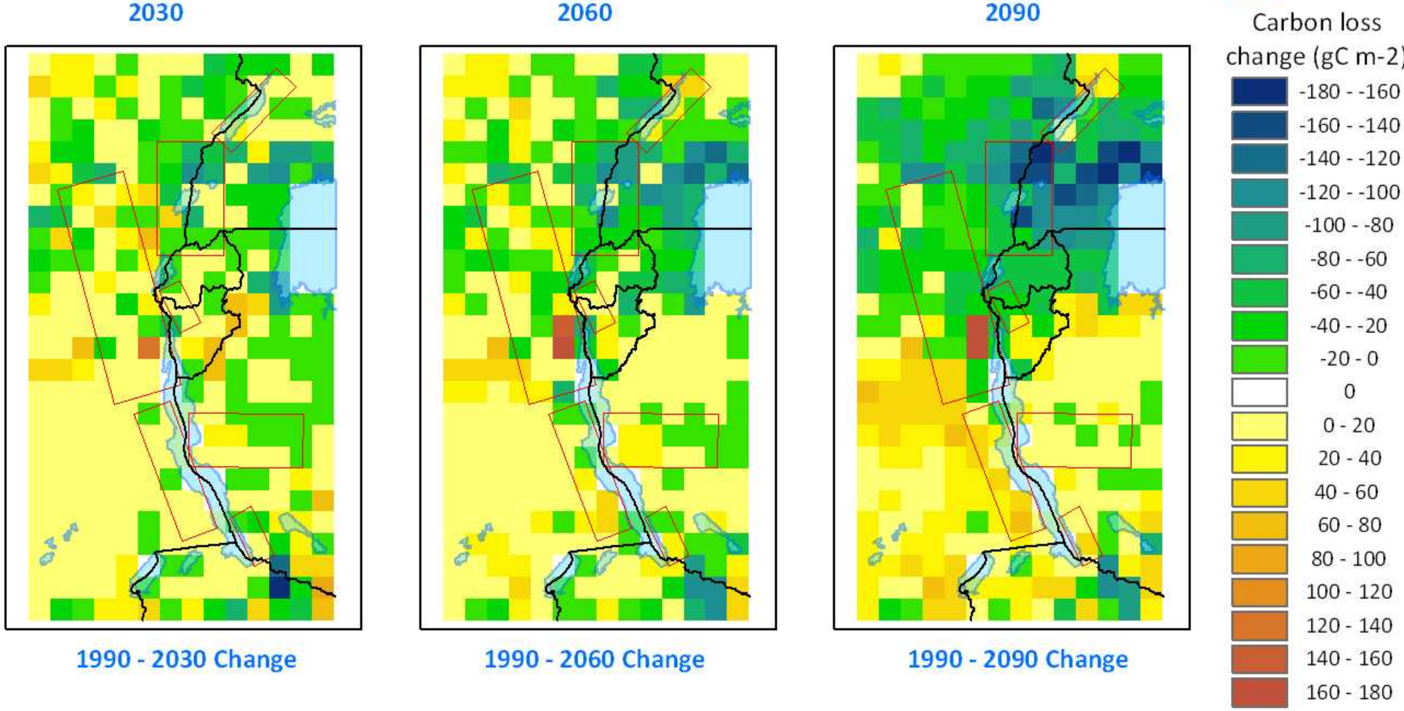


1990 2030 2060 2090

LPJ predicted carbon flux and change in carbon flux under the SRES A2 scenario

Carbon loss from fire



1990 - 2030 Change 1990 - 2060 Change 1990 - 2090 Change

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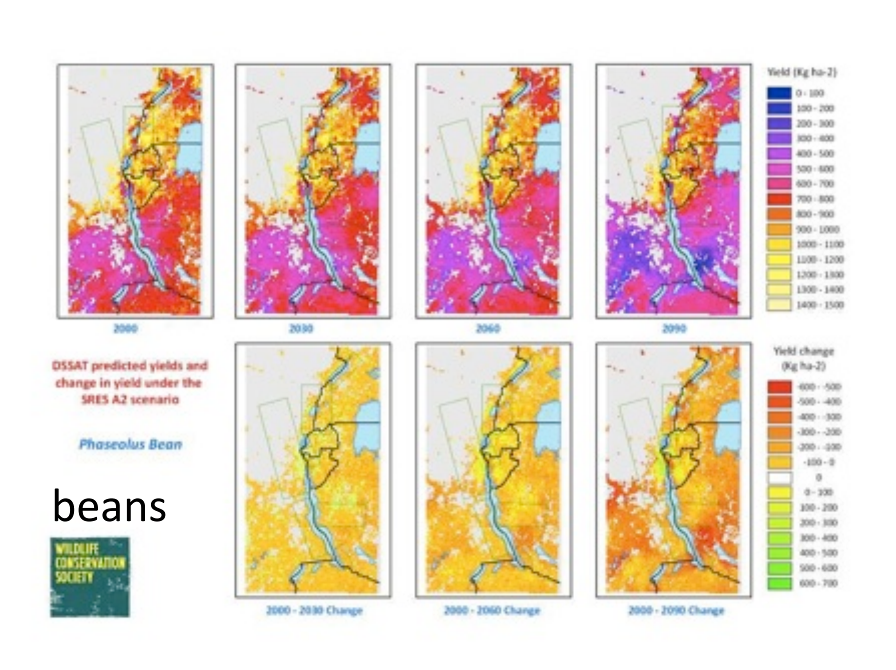
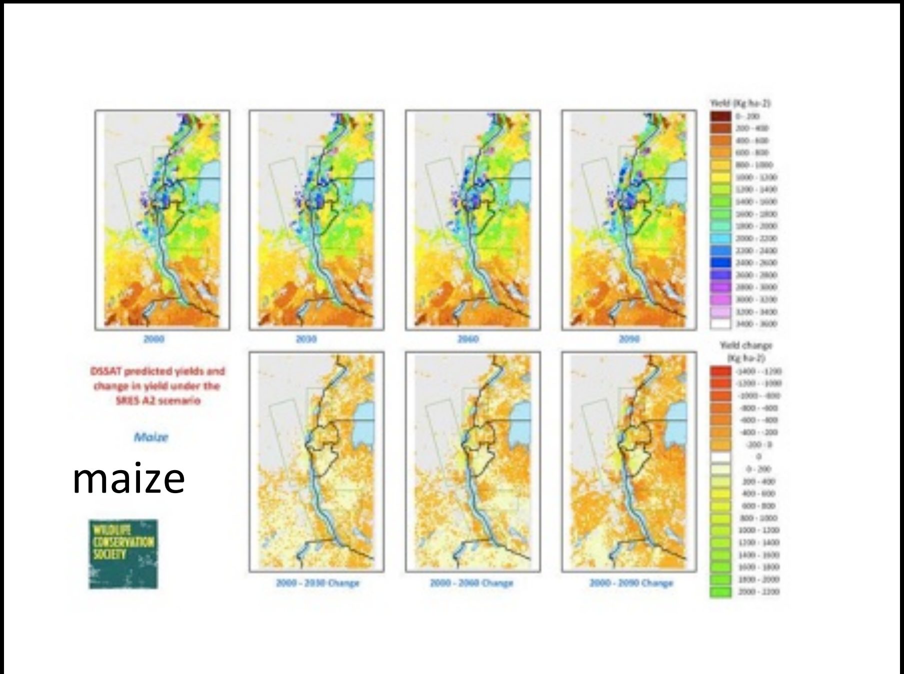
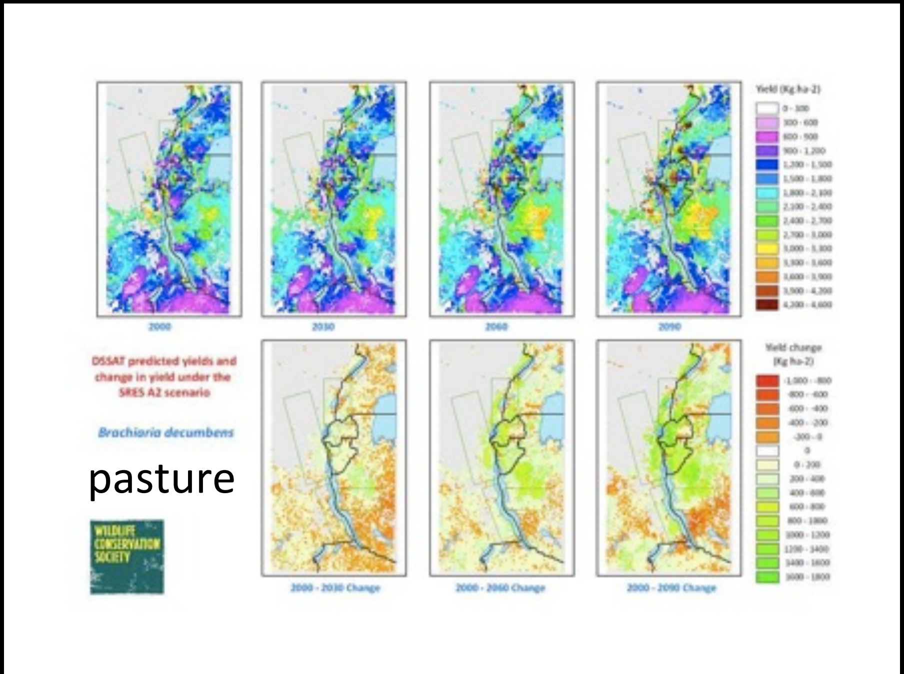
Modeled changes in crop yields

Crop model output can serve as indicators of human response in rain-fed agricultural regions

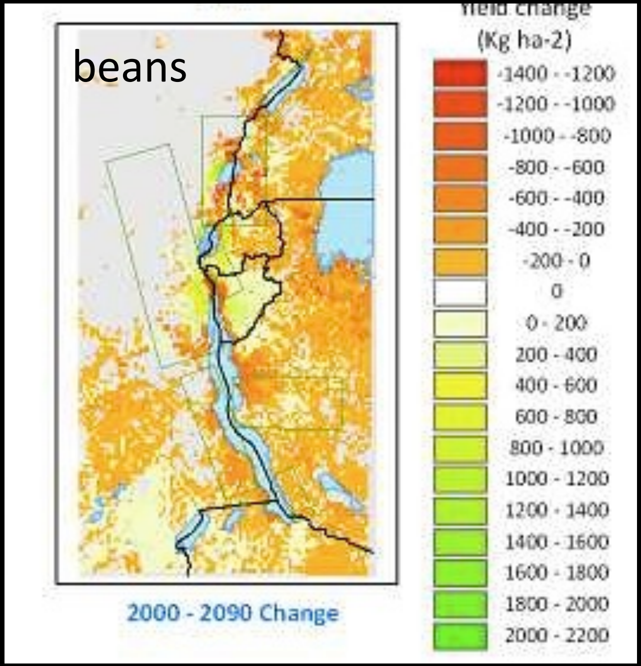


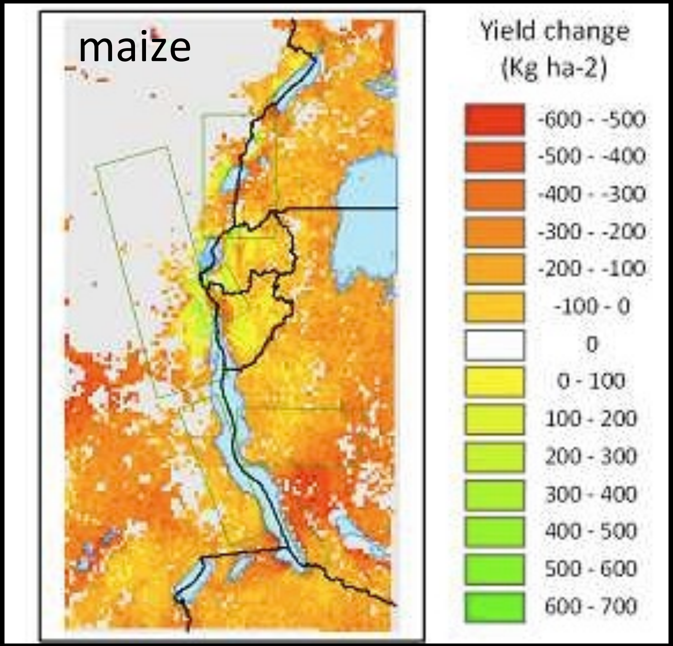


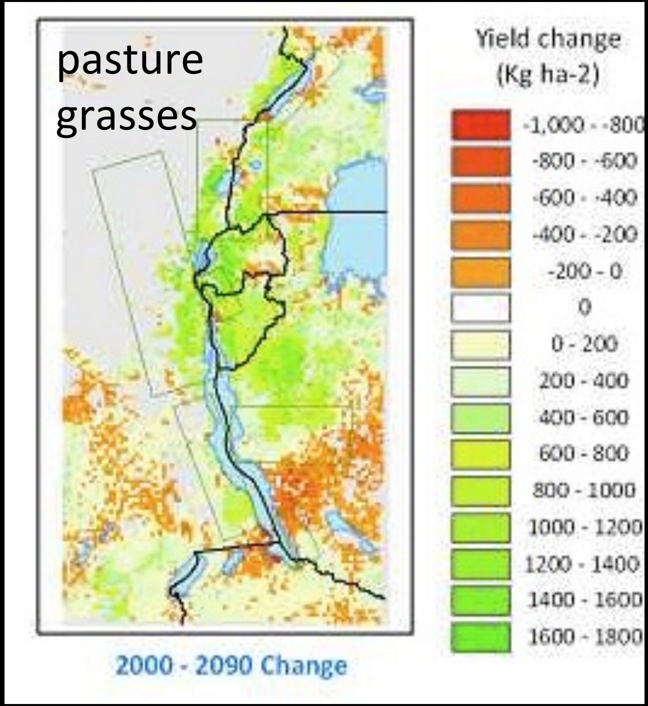


Modeled change in crop yields by 2090 under the A2 scenario

Suggests greatly increased pressure on highlands for food production







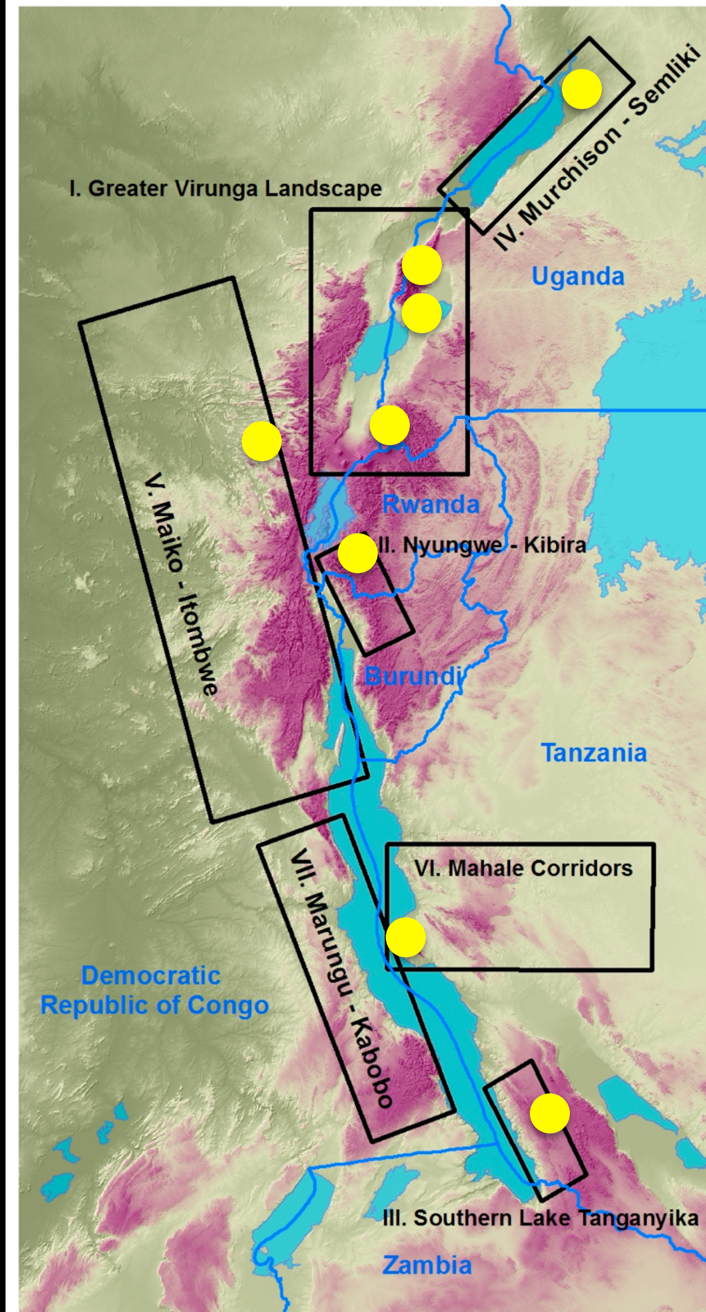
Comprehensive Monitoring for Climate Change Adaptation and Management in the Albertine Rift Protected Area Network

A WCS project with three principal aims:

- to build the human and infrastructural capacity of Albertine Rift countries to collect accurate data about climate, vegetation, and the impact of climate change on wildlife;
- prioritize wildlife and habitat migration corridors based on this data and on modeling;
- to provide all of this information in readily usable form to policy-makers through reports and briefings for NAPA taskforce teams, protected area authorities, and other implementing agents.

Red circles = corridors that link areas of natural habitat across an elevational gradient, potentially important for future migration with climate change.

Sites for new research grade climate monitoring in protected areas



New continental-subregional agricultural modeling projections for the year 2100:

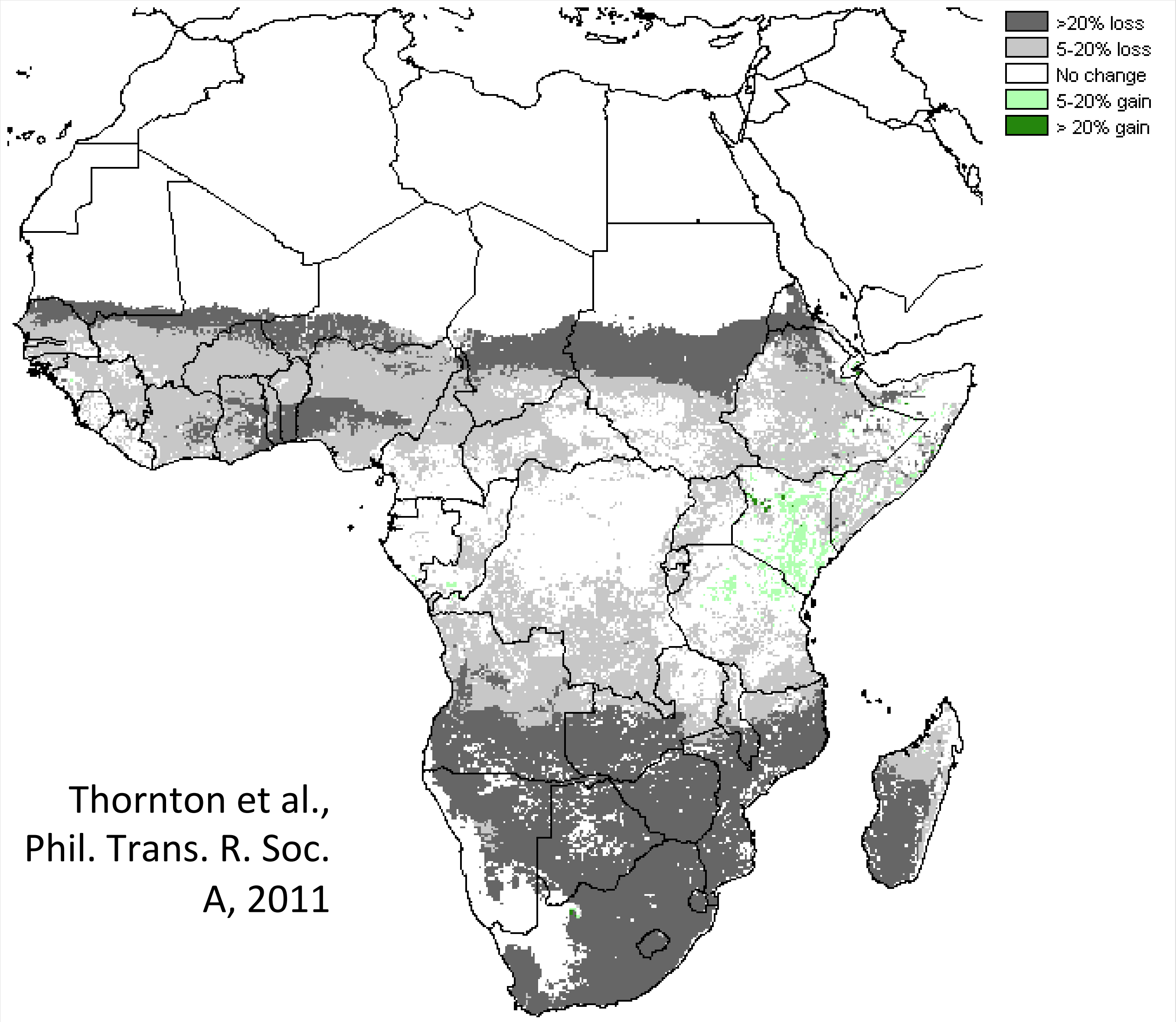
Agriculture and food systems in sub-Saharan Africa in a four-plus degree world

P K Thornton, P G Jones, P J Ericksen, A J Challinor

Phil. Trans. R. Soc. A, 2011

Ensemble mean of Length of Growing Period change estimates to the 2090s

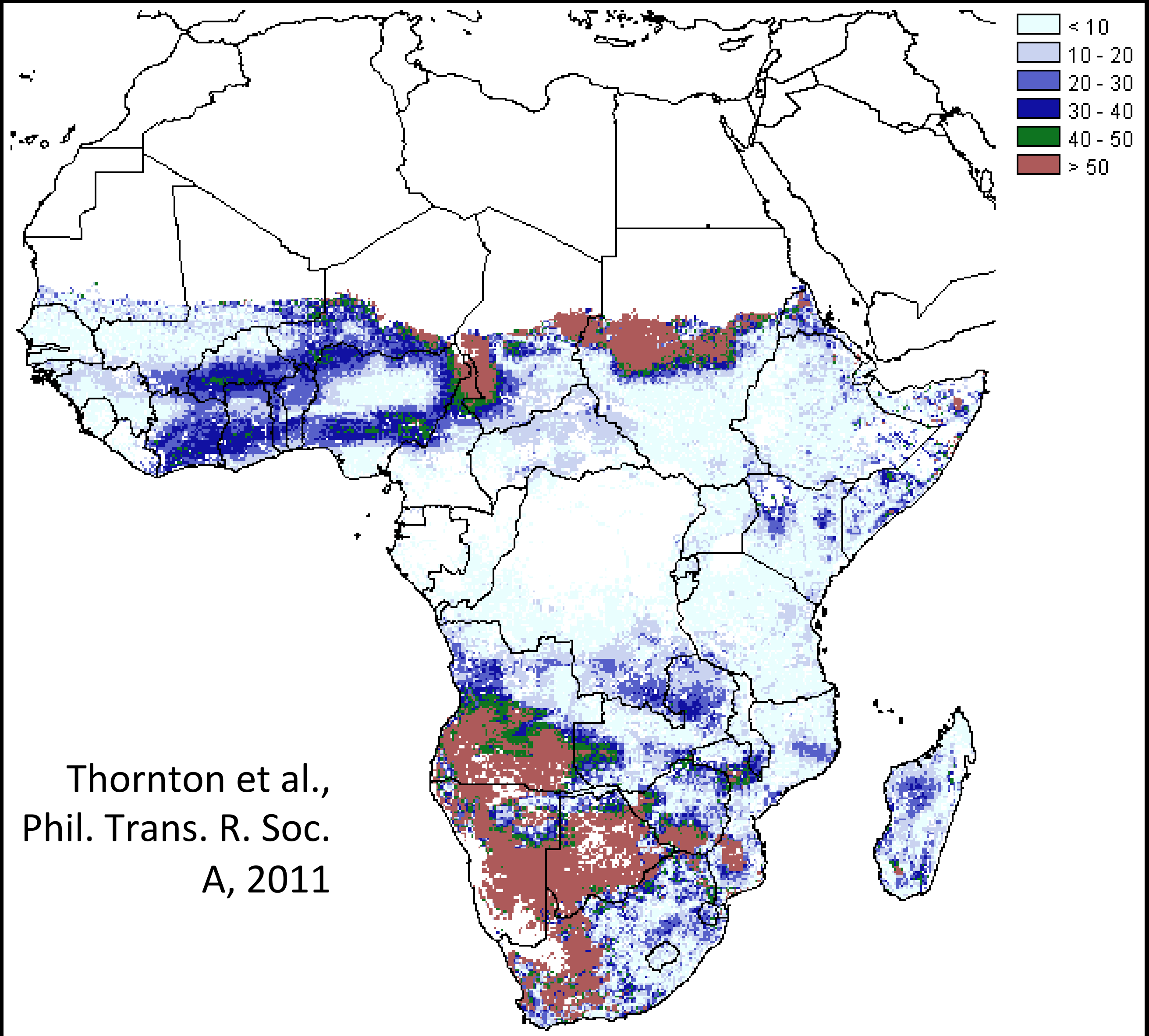
Substantial losses away from equator, some small gains in parts of E Africa



Thornton et al., Phil. Trans. R. Soc. A, 2011

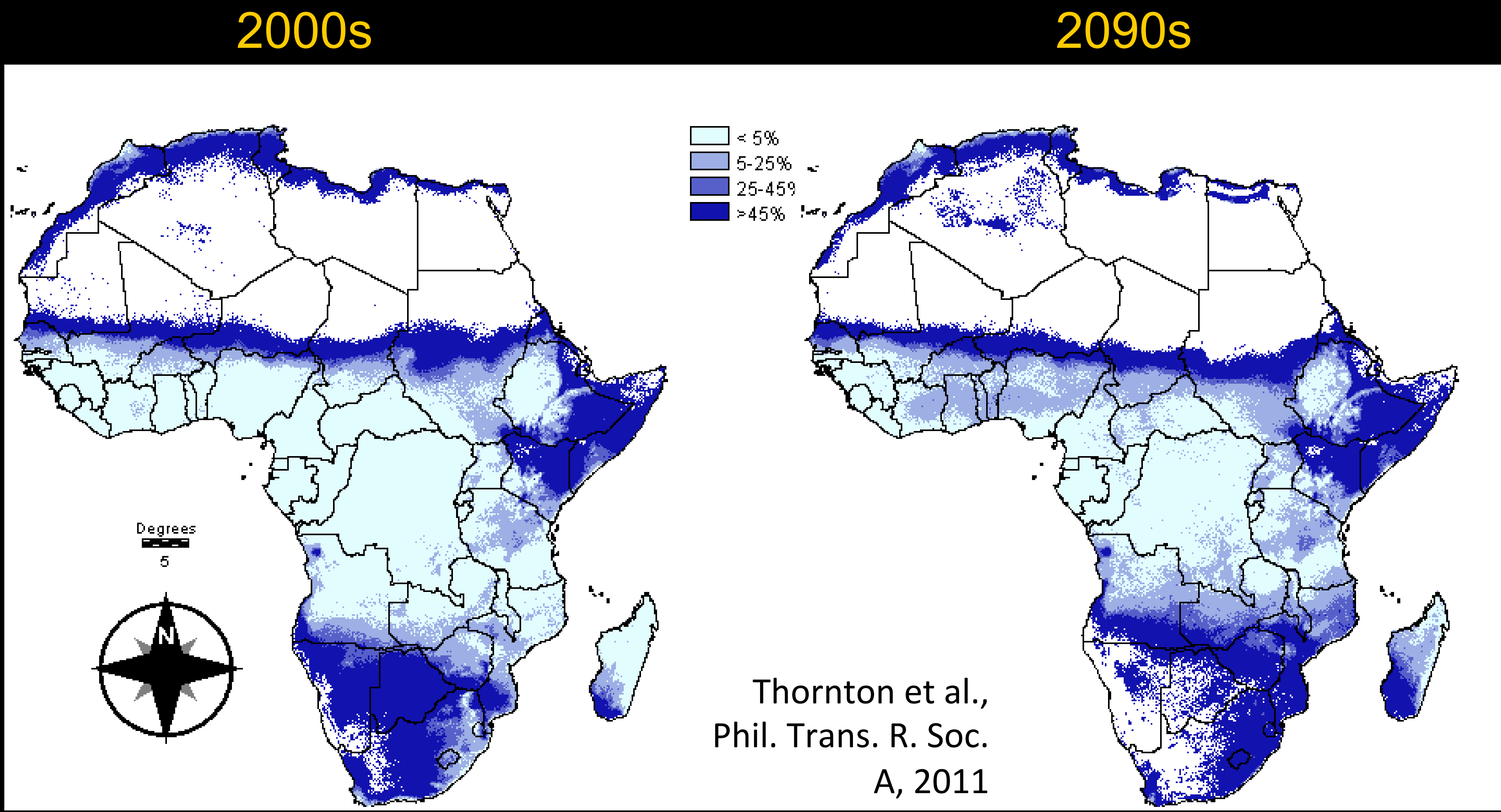
Ensemble CV (%) of LGP change estimates to the 2090s

Three zones – background small variation (<20), then higher in cropland (dark blue), then green and brown in arid-semiarid rangelands



Thornton et al., Phil. Trans. R. Soc. A, 2011

Probability of failed seasons



Mean of 14 GCMs and 3
SRES scenarios

Simulated yields (30 reps) in SSA under current conditions and in the 2090s

	2000s Yield kg/ha	2090s +5°C Yield kg/ha †	Mean % change in production †	CV of change in production % ‡
Maize				
Central	744	612	-13	23
East	954	689	-19	7
Southern	748	612	-16	22
West	764	536	-23	23
Mean	806	612	-24	19
Beans				
Central	666	175	-69	58
East	685	263	-47	6
Southern	716	220	-68	48
West	487	63	-87	47
Mean	639	182	-71	34
B. decumbens				
Central	1493	1311	-4	3
East	1745	1570	+9	7
Southern	1384	1344	+11	18
West	1498	1437	-6	27
Mean	1525	1422	-7	15

Simulated yields (30 reps) in SSA under current conditions and in the 2090s

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Central	744	612	-13	23
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West	[illegible]	[illegible]	[illegible]	23
Mean	[illegible]	[illegible]	[illegible]	19
Beans				
Central	[illegible]	[illegible]	[illegible]	58
East	[illegible]	[illegible]	[illegible]	6
Southern	[illegible]	[illegible]	[illegible]	48
West	[illegible]	[illegible]	[illegible]	47
Mean	639	182	-71	34
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Southern	1384	1344	+11	18
West	1498	1437	-6	27
Mean	1525	1422	-7	15

Low CVs of yield changes in E Africa: quite a robust result

What do the modelling results mean?

- Losses in length of growing season translate directly into crop yield decreases

- Even in the parts of E Africa that may get wetter, while growing seasons may expand, this will not necessarily translate into higher yields: increases in rainfall may be more than offset by increases in crop evapo-transpiration due to higher temperatures

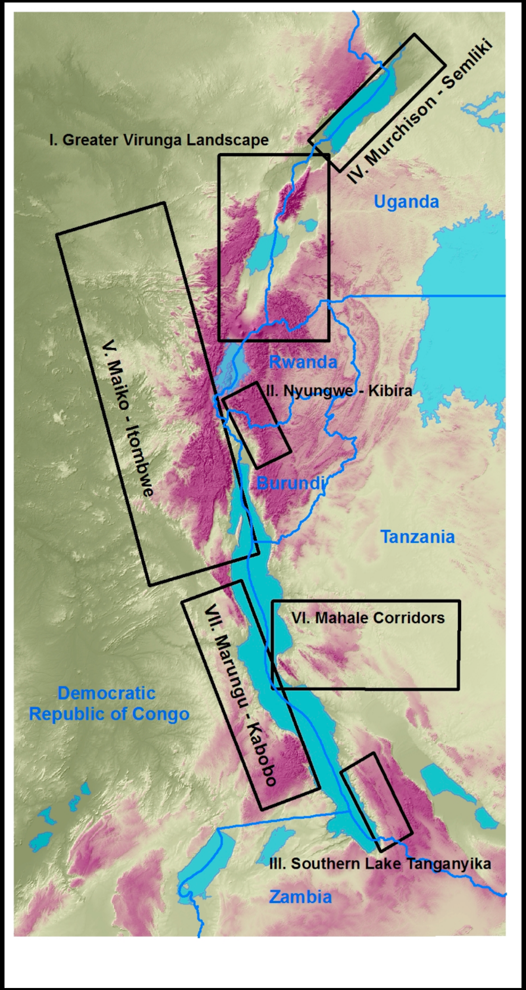
- The details of yield changes depend to some extent on the climate model and emissions scenario used: but apparently not for East Africa, where this is good consensus

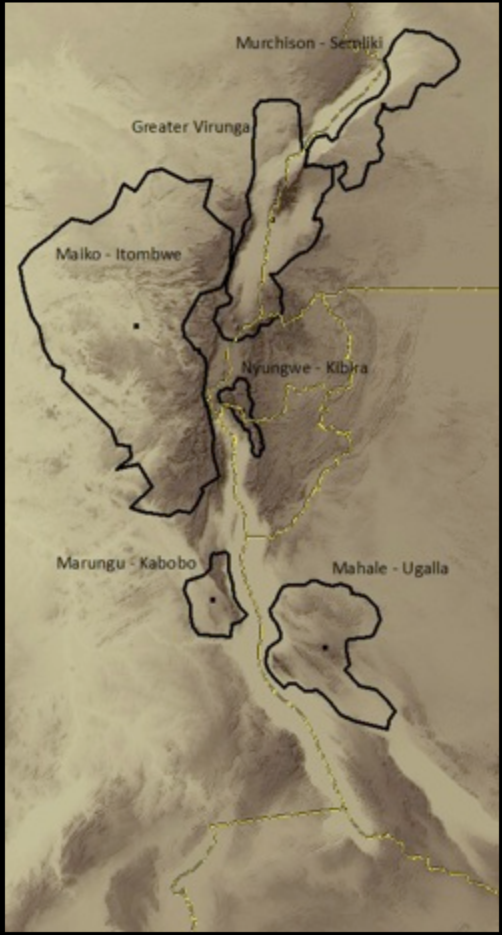
What will a +5°C agriculture look like in SSA?

- Much less food for people overall
- In many places, much higher probabilities of crop failures
- **Massive increases in intensive cropping in the highlands will be needed ("sustainable intensification")**
- Huge expansion of the marginal areas (highly uncertain cropping)
- Radical livelihood transitions (croppers to livestock keepers, abandonment of agriculture, …)

Modelling Albertine Rift Corridor response to climate change

Guy Picton Phillipps





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Intensified seasonal drought in 2009: an analogue for future dry seasons?

Volcanoes National Park, Rwanda, July 2009.

http://www.igcp.org/putting-out-the-fire/

Human pressure along park margins

Already a very intense factor for many national parks

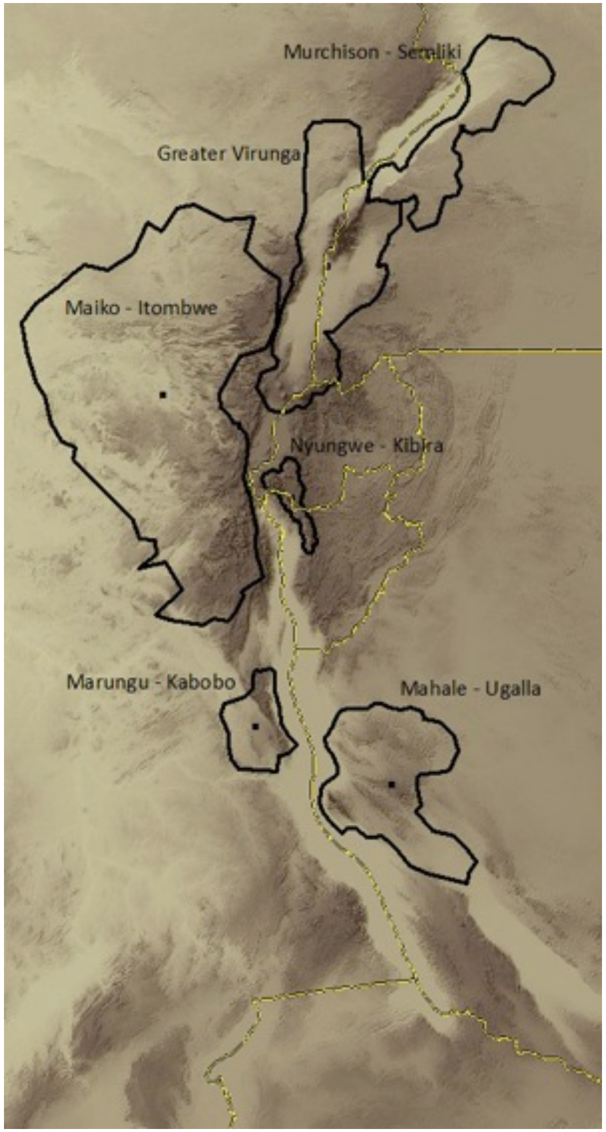
Will continue to intensify with increasing populations

Like to become much more intense around protected areas as “climate refugees” migrate to highlands to sustain food sources and livelihoods

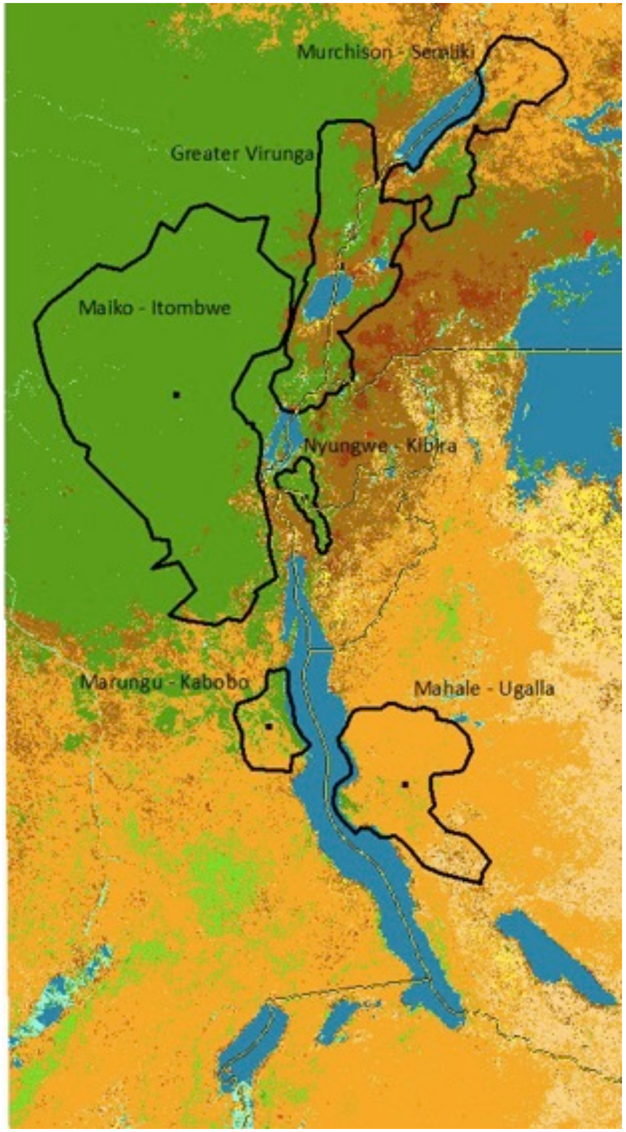
The Boundary of Volcanoes National Park, Rwanda

Photo by Andy Plumptre

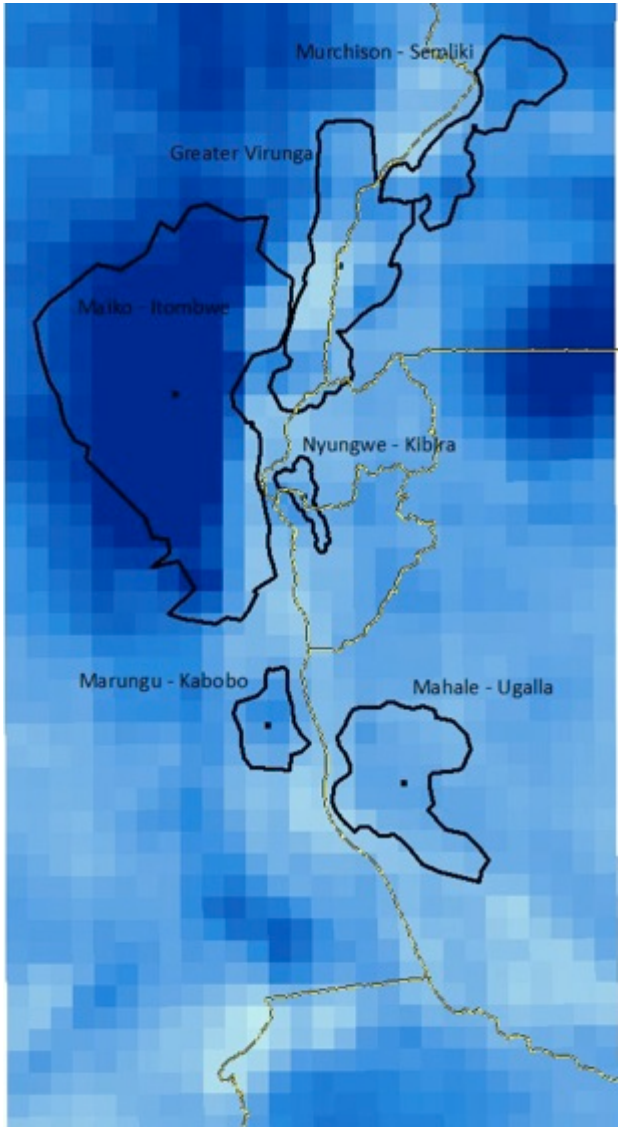
Albertine Rift Corridors



Elevation



Landcover 2001



Mean Annual Rainfall 2000 - 2009

Modelling Approach

To establish potential responses of habitats to future changes in climate, construct relationships between observable variables that can be used to predict future scenarios

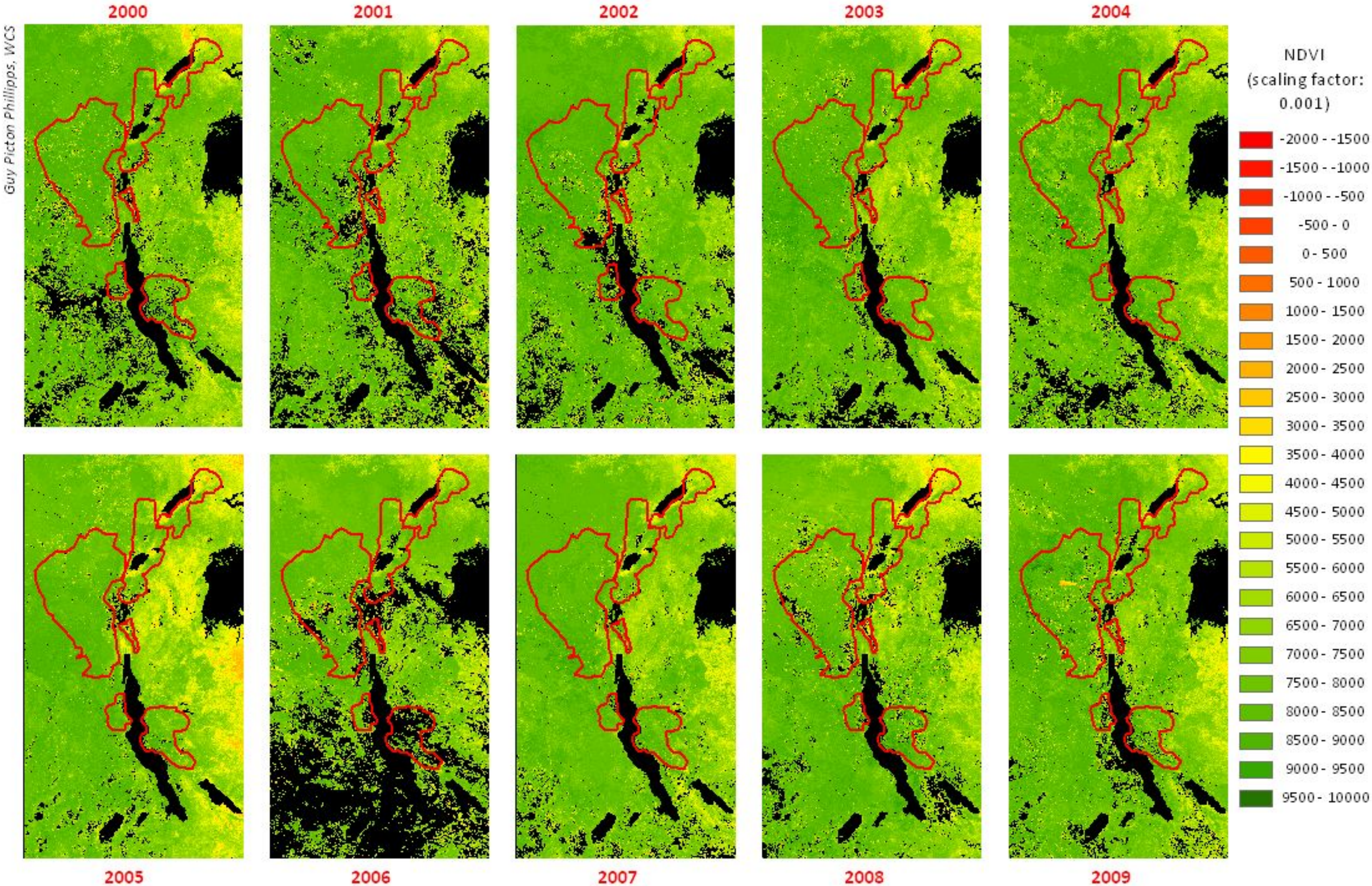
Data from a variety of remote sensing instruments offering multi-temporal scientific data at medium spatial resolution for the entire Rift

Evaluate vegetation and fire responses to rainfall variability over the last 10 years.

Based on the observed historical relationships, we plan to use future predictions of climate (statistically downscaled from IPCC Global Climate Models) to develop a model that will estimate vegetation condition and fire impacts under predicted future climate for 2030, 2060 & 2090

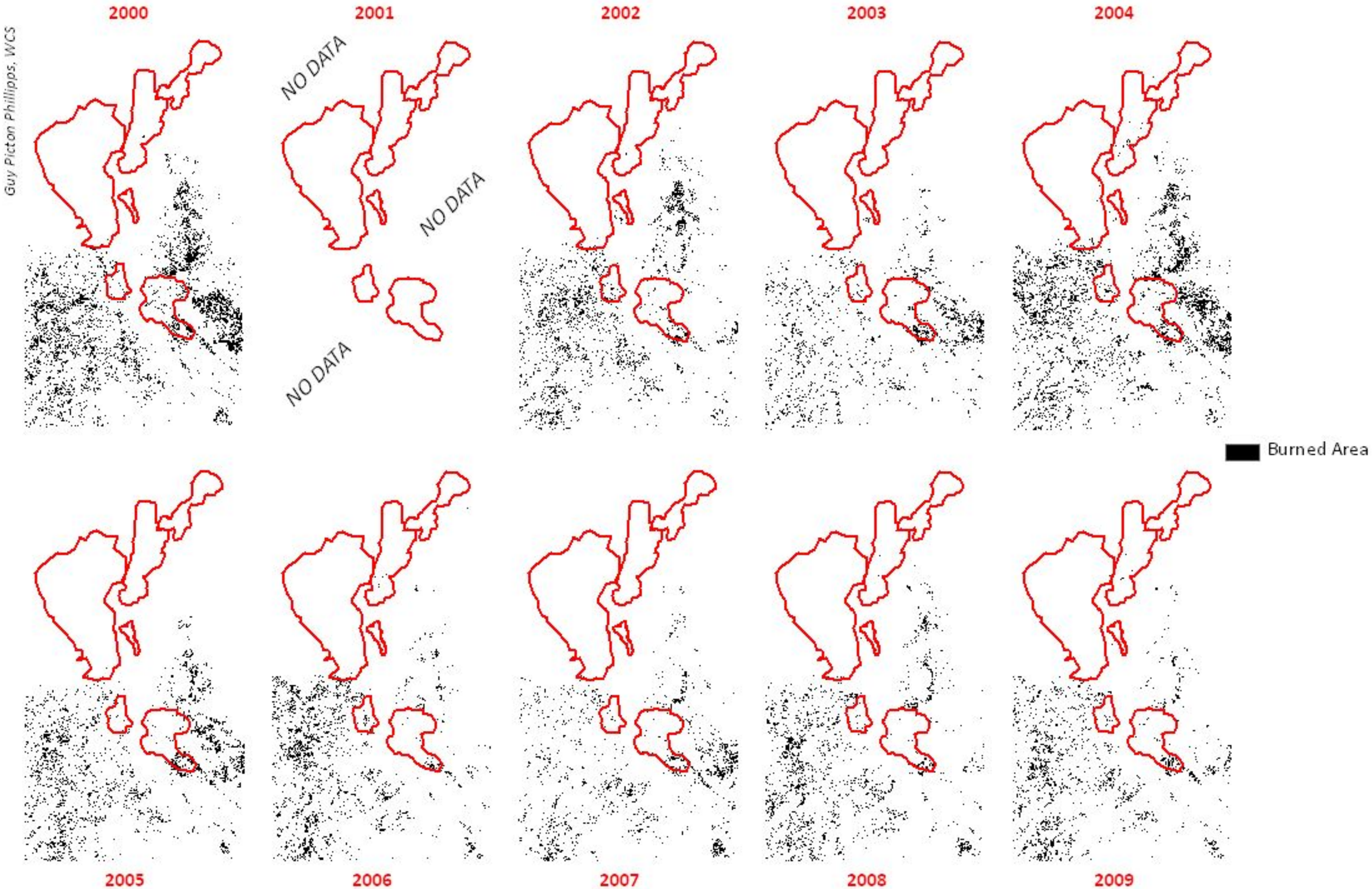
Datasets

- MODIS mod13q1 250m 16 day
  Normalised Difference Vegetation Index (NDVI), 2001 – 2009
- MODIS mcd45a1 500m monthly
  Burned Area, 2001 – 2009
- Tropical Rainfall Measuring Mission t3b43 0.25° monthly
  Rainfall Rate, 1998 – 2009
- Shuttle Radar Topography Mission 90m
  Elevation
- MODIS mod12q1 500m annual
  Landcover (2001 – 2009)



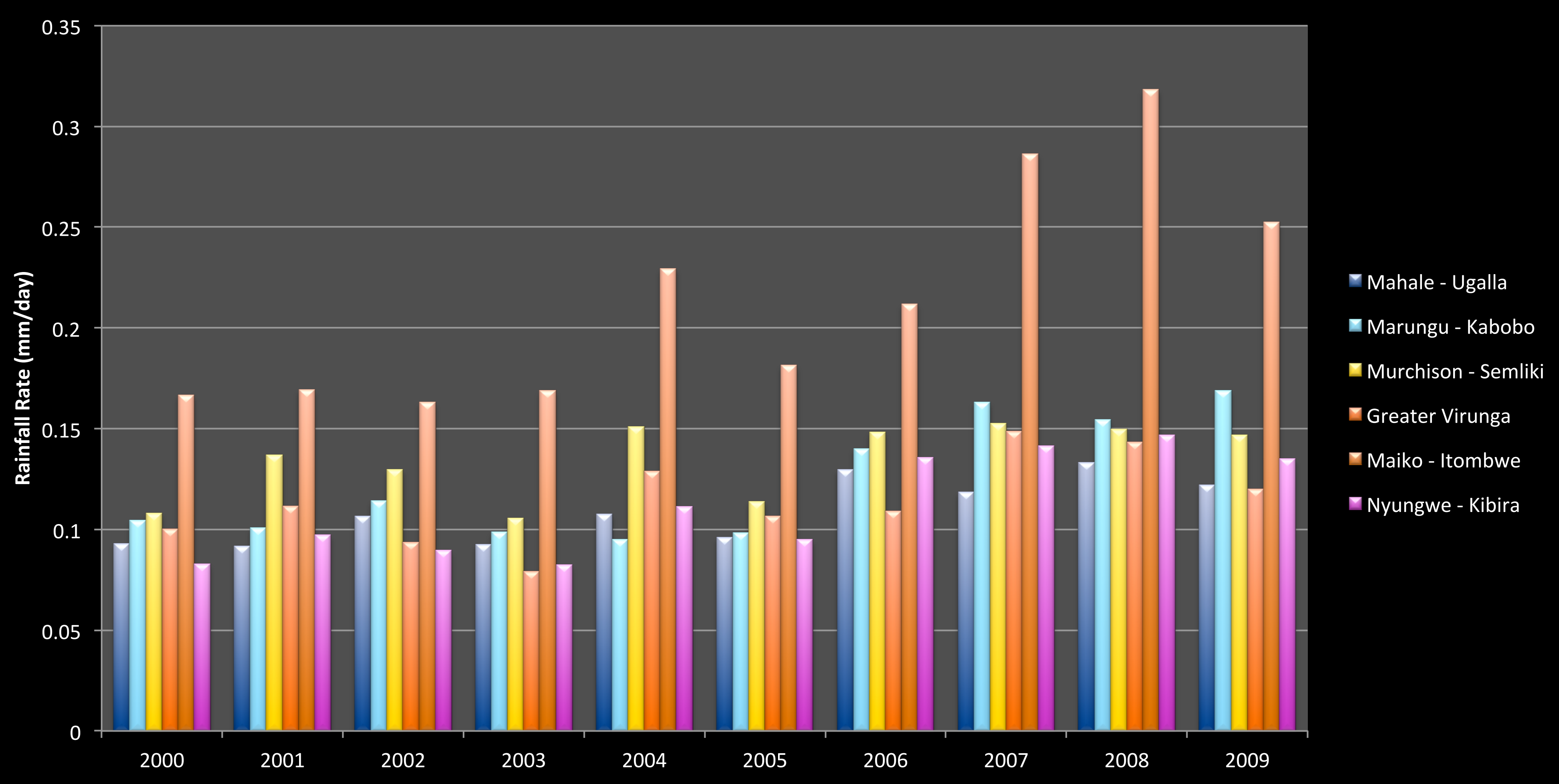
Multi-temporal Normalised Difference Vegetation Index (NDVI) images

December



Multi-temporal Burned Area images
June

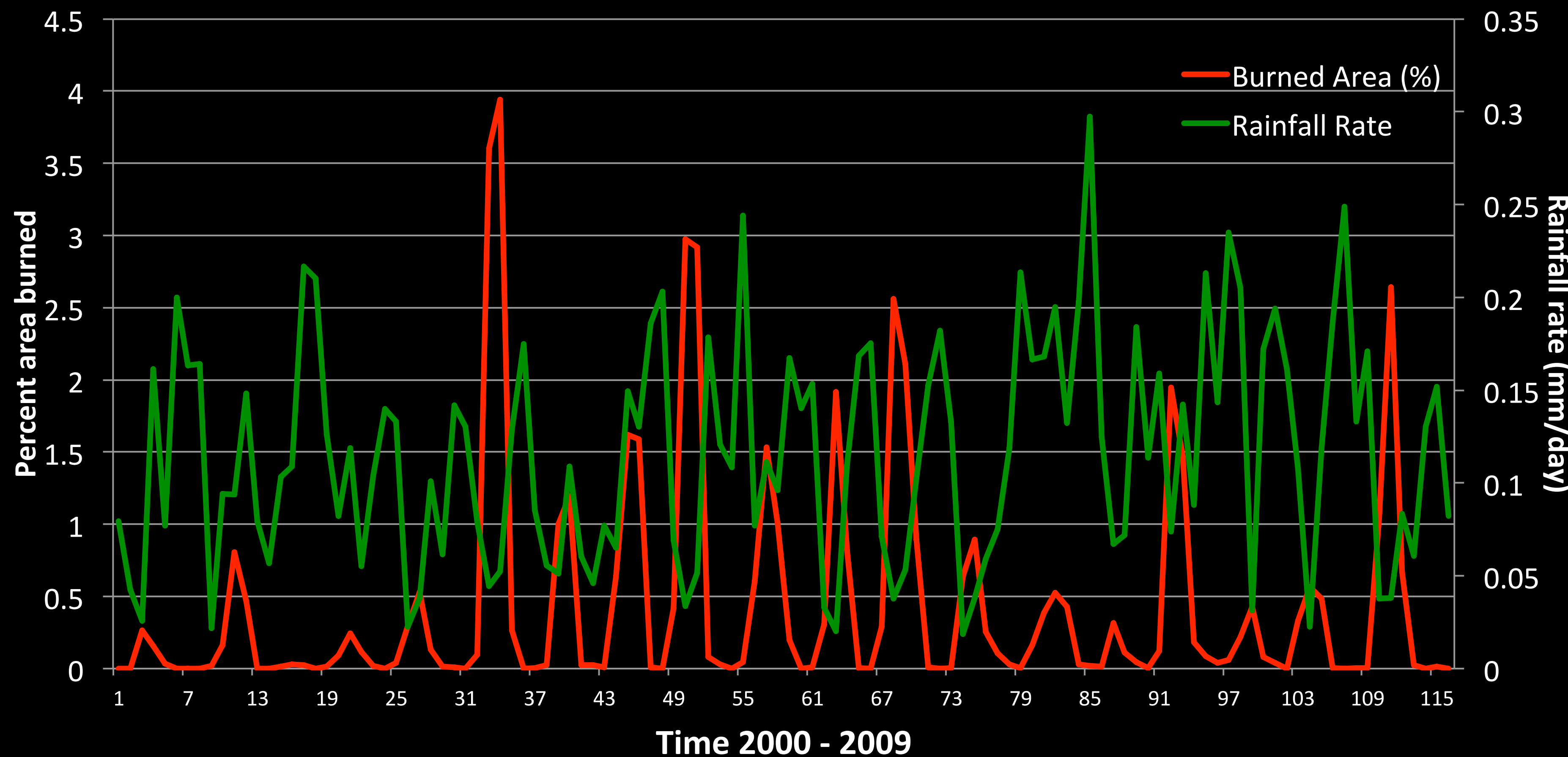
Mean annual rainfall rates for each landscape (TRMM t3b43, 2000 - 2009)



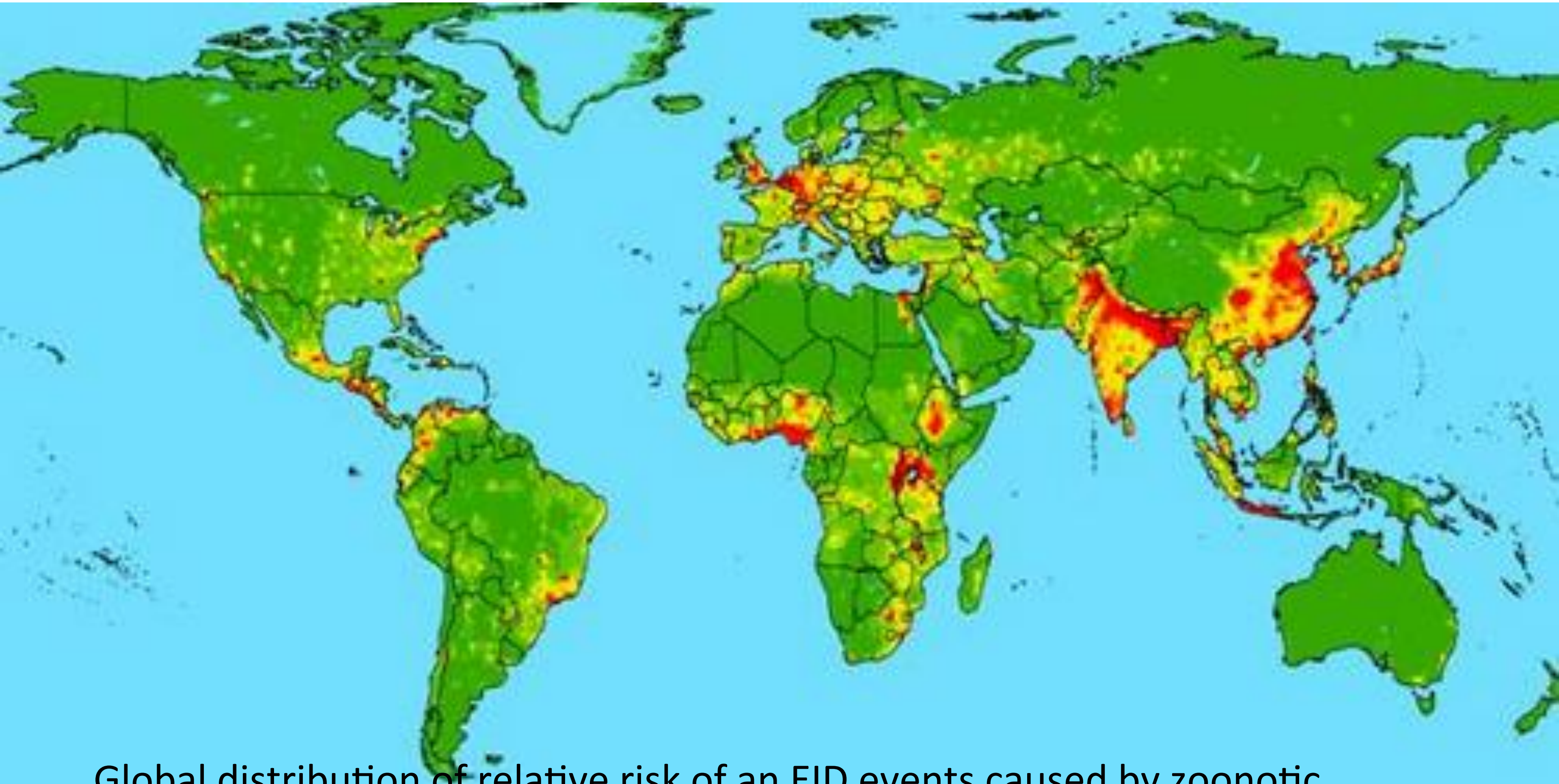
Fire response

- Analysis will evaluate relationship between rainfall and burning on a monthly basis. Statistical evaluation yet to be conducted,
- Plan to conduct an evaluation of burning according to elevation and landcover types for each landscape
- Given the majority of fires in the region are anthropogenic in origin, it may be that this dataset can be analysed further to reveal patterns of human activity

Greater Virunga landscape monthly burning and rainfall rate 2000 - 2009



Emerging Infectious Disease origin regions



Global distribution of relative risk of an EID events caused by zoonotic pathogens. The relative risk is mapped on a linear scale from green (lower values) to red (higher values)

Source: Dr. Kate Jones, Zoological Society of London

Key summary points

Albertine Rift highland protected areas are among best-hope locations for Africa wildlife conservation

Must increase efforts to measure and monitor climate, ecology and species

Direct climate change induced impacts will be significant, with major horizontal and vertical range reconfigurations of habitats, species distributions, agriculture, human livelihoods, etc.

Human response likely to create pressure for highland forest conversion to cultivation far greater than present

Disease threat is largely unknown, research critically needed

Thank you!
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