Dynamical Vegetation Model

Eighth ICTP Workshop on the Theory and Use of Regional Climate Models
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•**IAFES-CMCC - Division on Impacts on Agriculture, Forests and Ecosystem**

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Centro Euro-Mediterraneo
sui Cambiamenti Climatici

ICTP
The Abdus Salam
International Centre
for Theoretical Physics

LUC and Climate
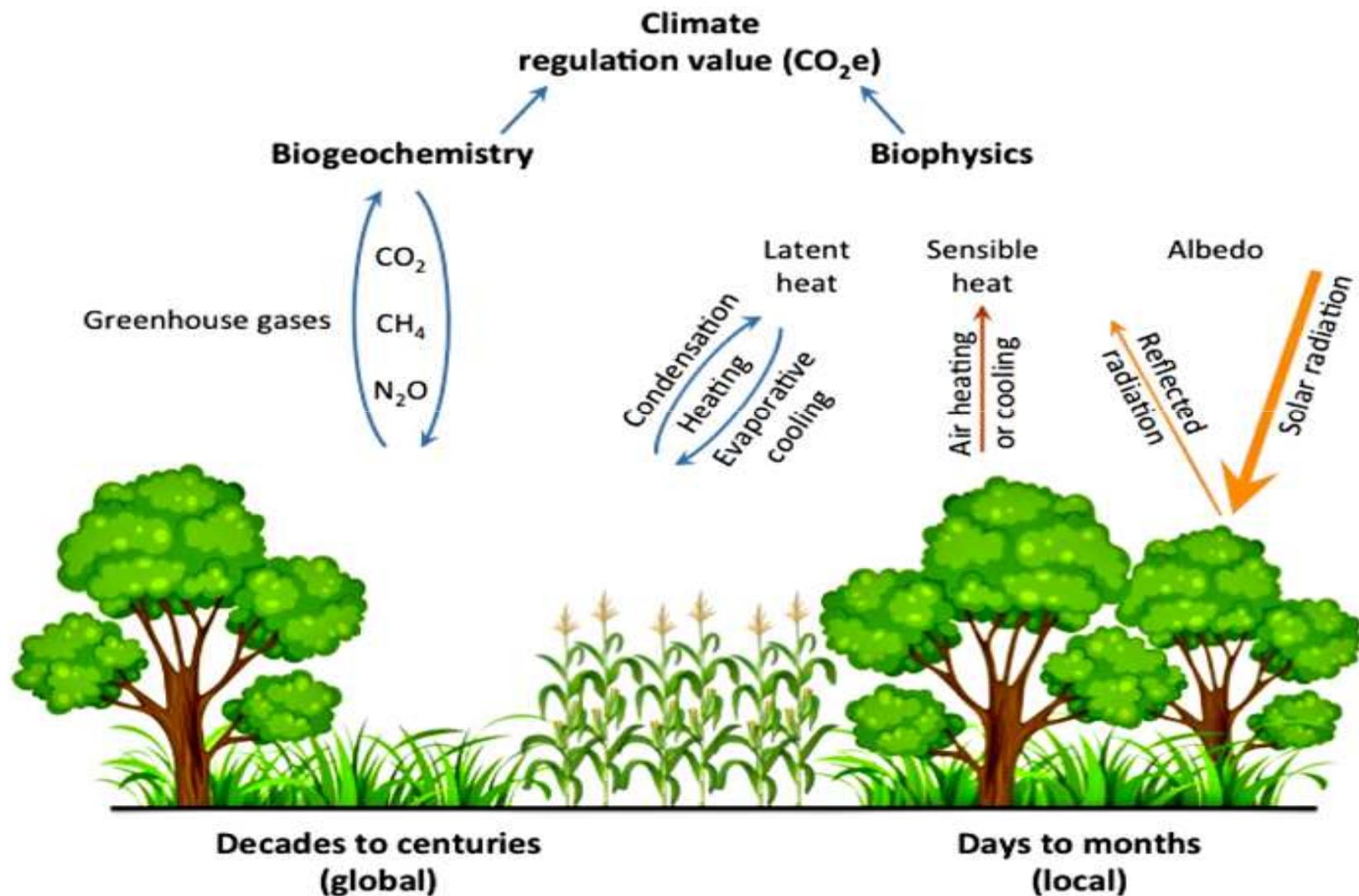
LUC and RF

**LUC RADIATIVE EFFECTS**

+1.68 W/m²

BGC Impact ~ 33% tot anthropogenic emissions [1]

BPH Impacts

LUC NON RADIATIVE EFFECTS

Surface roughness, LE , River Runoff

Hard to quantify the LULLC Non linear processes → Change in circulation [3]

| Emitted compound	Resulting atmospheric drivers	Radiative forcing by emissions and drivers		Level of confidence
CO₂	CO₂		1.68 [1.33 to 2.03]	VH
CH₄	CO₂ H₂Oˢᵗʳ O₃ CO		0.97 [0.74 to 1.20]	H
Halo-carbons	O₃ CFCs HCFCs		0.18 [0.01 to 0.35]	H
N₂O	N₂O		0.17 [0.13 to 0.21]	VH
CO	CO₂ CH₄ O₃		0.23 [0.16 to 0.30]	M
NMVOC	CO₂ CH₄ O₃		0.10 [0.05 to 0.15]	M
NOₓ	Nitrate CH₄ O₃		-0.15 [-0.34 to 0.03]	M
Aerosols and precursors (Mineral dust, SO₂, NH₃, Organic carbon and Black carbon)	Mineral dust Sulphate Nitrate Organic carbon Black carbon		-0.27 [-0.77 to 0.23]	H
	Cloud adjustments due to aerosols		-0.55 [-1.33 to -0.06]	L
	Albedo change due to land use	**-0.15 W/m²**	-0.15 [-0.25 to -0.05]	M
	Changes in solar irradiance		0.05 [0.00 to 0.10]	M
	2011		2.29 [1.13 to 3.33]	H
Total anthropogenic RF relative to 1750	1980		1.25 [0.64 to 1.86]	H
	1950		0.57 [0.29 to 0.85]	M

Radiative forcing relative to 1750 (W m⁻²)

IPCC AR5 REPORT

(1)   Houghton, R. A. et al. *Biogeosciences* 9, 5125-5142 (2012);
(2)   Rounsevell, M. D. A.. Et al. *Earth System Dynamics* 5, 117-137 (2014)
(3)   Pielke et al . Phil. Trans. 360, 1705-1719 (2002)

Biophysical vs Biogeochemical Magnitude

Experiment: Afforesting 50% of the regional crop area until 2060
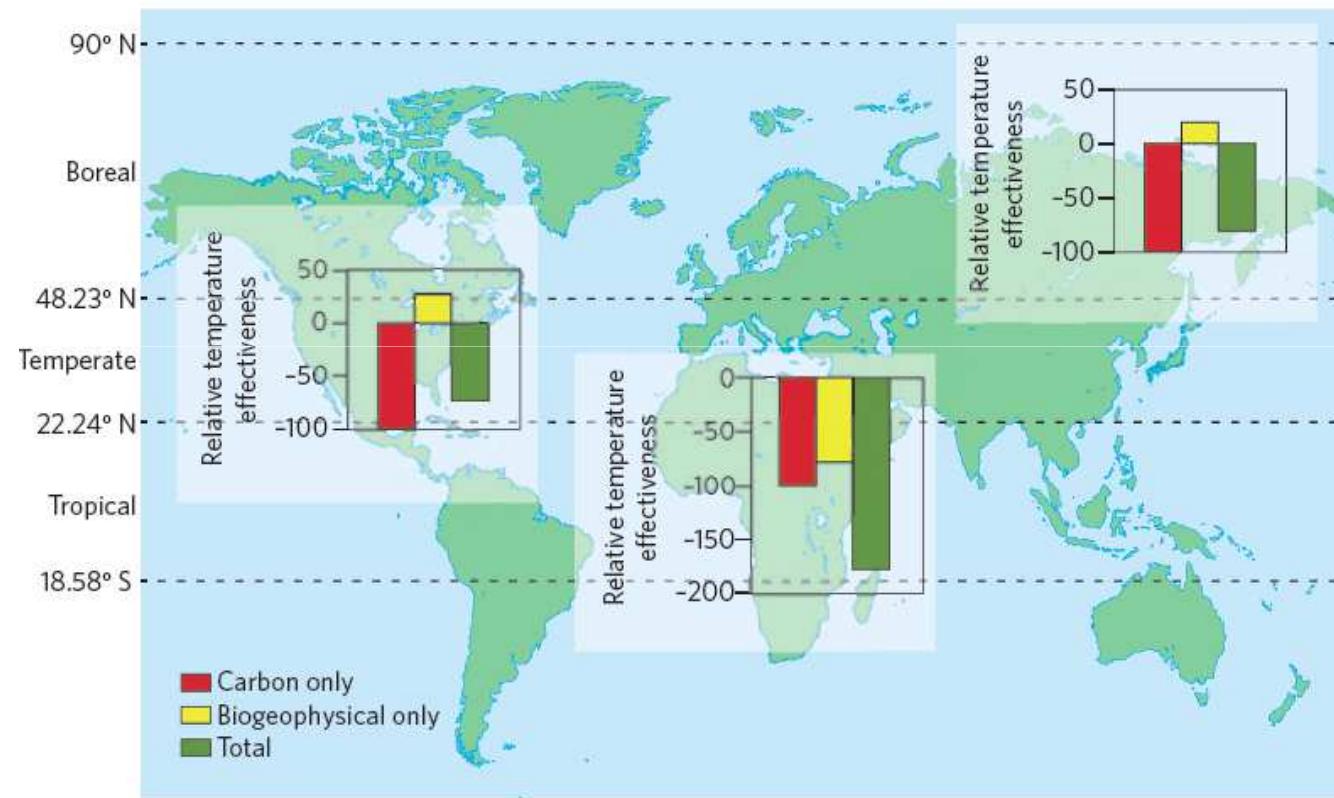
Biophysical climate effects have regionally different magnitude and signs

Arora & Montenegro, Nat. Geosc. 2011

Systematic Review Biophysical LULCC

Luc4c

- • **Only recent studies (January 2000)**
- • **Explicit transition in LULCC (e.g. 100% deforestation/reforestation**

- • **2 m air Temperature / Precipitation**
- • **Annual Average**

- • **No site specific**
- • **No Biogeochemical effects**
- • **Main ecological zones**

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Systematic Review Biophysical LULCC

LUC4C

Tropical Regional LUC Transitions

From	To	Mean	Stdev	Max	Min	Entries
MODELED						
Shrubland	*Bare land*	0.55	0.62	1.20	-0.40	**5**[6]
Shrubland	*Cropland*	0.50	~	~	~	**1**[5]
Forest	*Cropland*	1.02	0.71	2.00	0.29	**5**[5,11,12]
Forest	*Grassland*	0.33	0.76	2.50	-0.30	**21**[2,4,9,13,14,15,16,17]
Forest	*Bare land*	1.06	0.23	1.50	0.80	**8**[6,18]
Grassland	*Forest*	-0.17	0.12	-0.10	-0.40	6[1,9]
Deforestation		0.60	0.74	2.5	0.3	**34**[2,4,5,6,11 to 18]
Forestation		-0.17	0.12	-0.10	-0.40	**6**[1]
OBSERVED						
Deforestation		0.41	0.57	1.06	-0.23	**4**[7,8,9]
Forestation		-0.87	~	-0.67	-1.06	**2**[8,9]

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LULCC induces changes in Temperature

REGIONAL IMPACTS
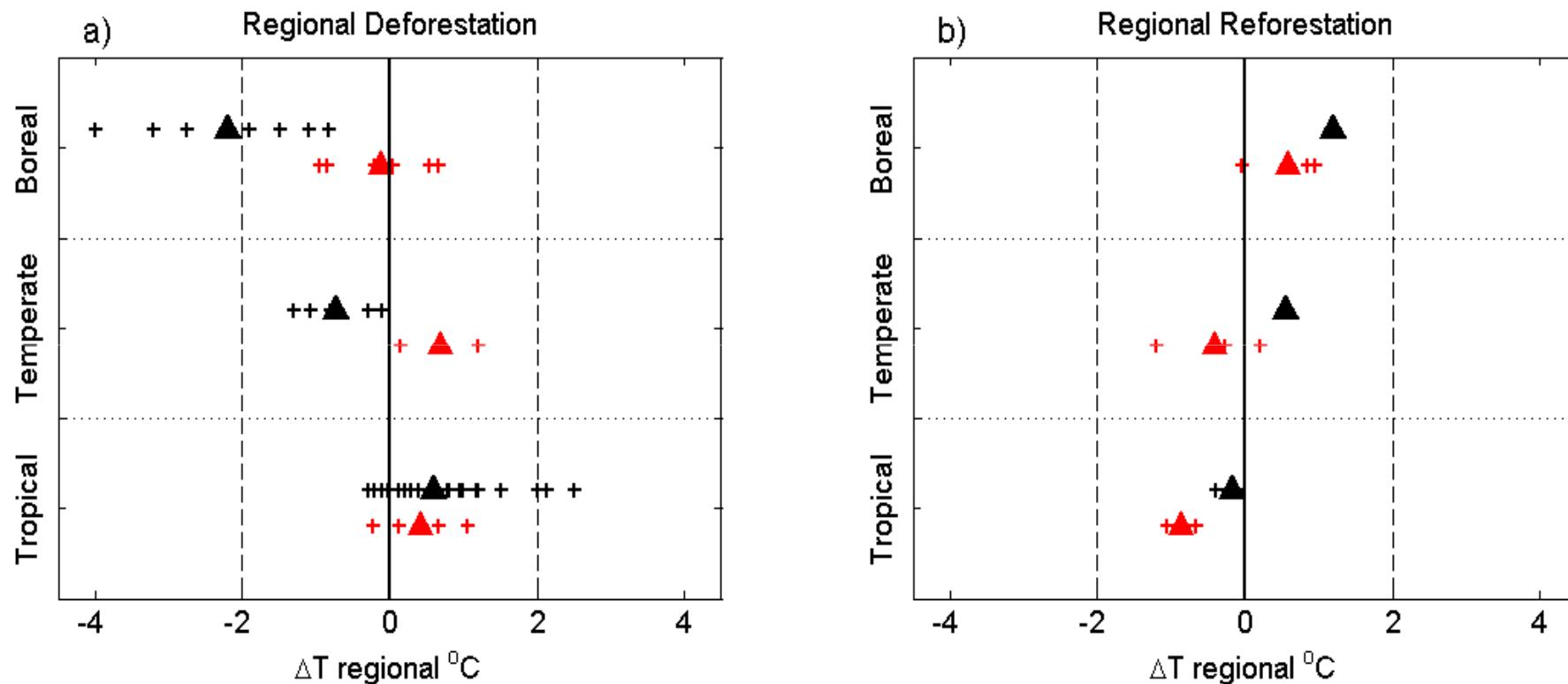
OBSERVATIONS ≠ MODELS → NOT DIRECTLY COMPARABLE (SCALE ISSUE*)

Deforestation >> Forestation

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LULCC induces changes in Temperature

GLOBAL IMPACTS

Paucity of Data

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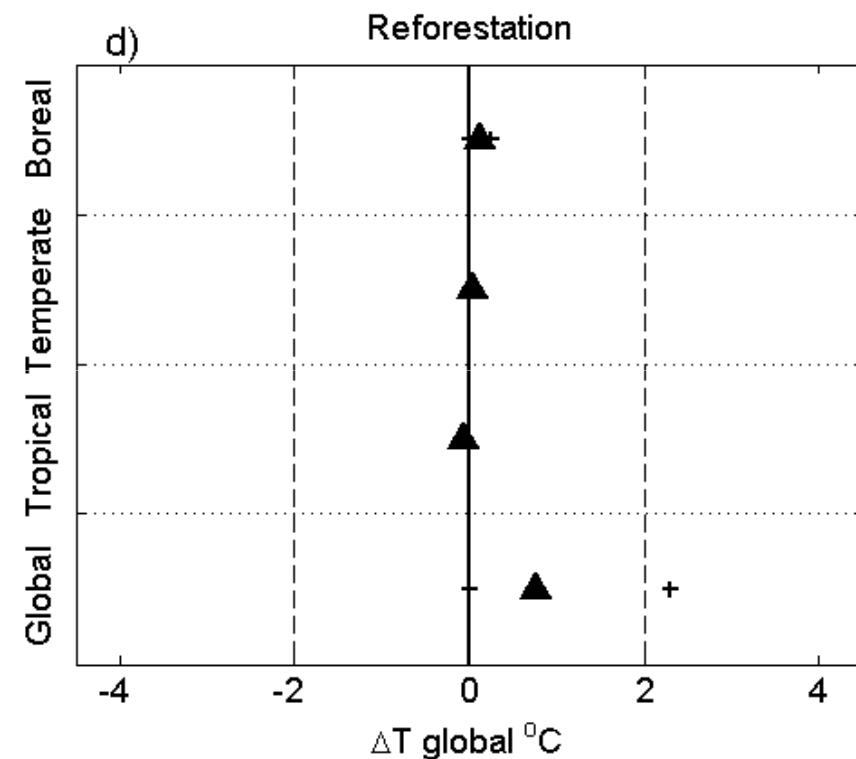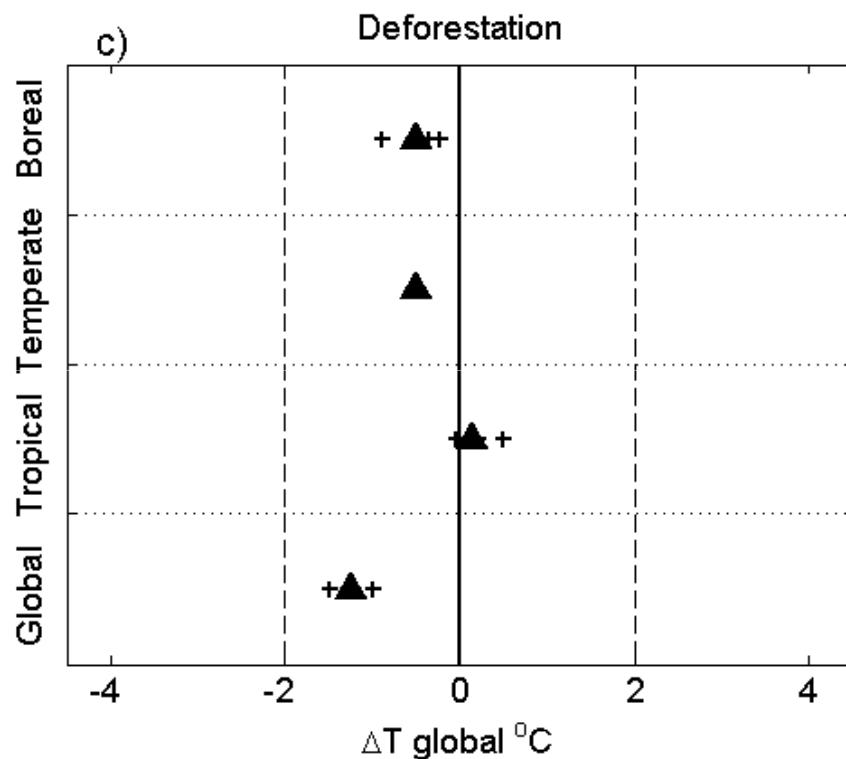
… Observed also from Satellite

- ❖ **MODIS 2001-2012**
- ❖ **5 Km Resolution**
- ❖ **> 5500 tiles**
- ❖ **BHP = 18% BGC**

Alkama and Cescatti, Science 2016
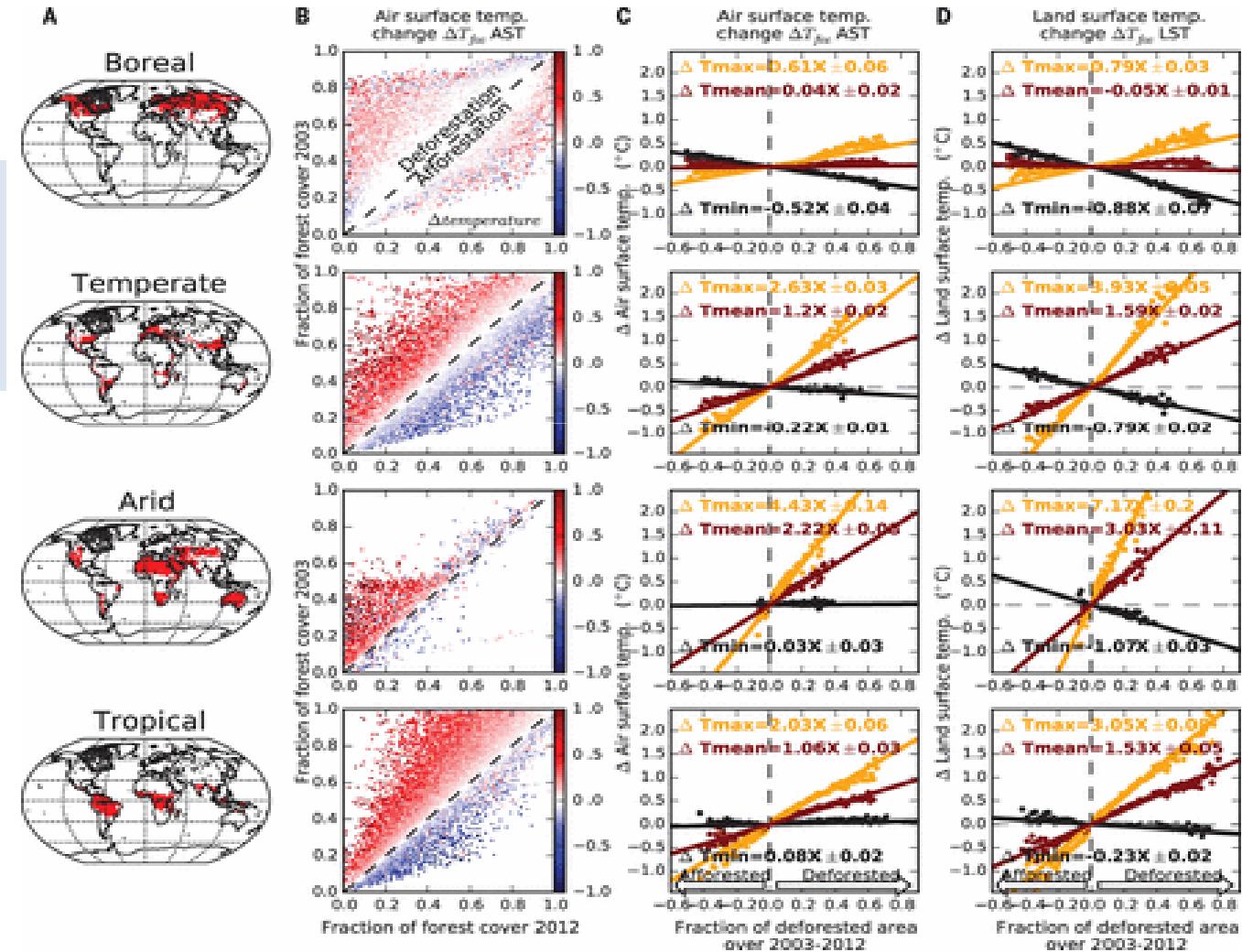
LULCC induces changes in Precipitation

Luc4c

The effect of deforestation across different biomes, which leads to a decrease of precipitation in all cases (n=86)

-220 ± 265 mm yr-1

-470±100 mm yr-1

Deforestation

LATITUDINAL GRADIENT

ΔP mm $^{yr-1}$
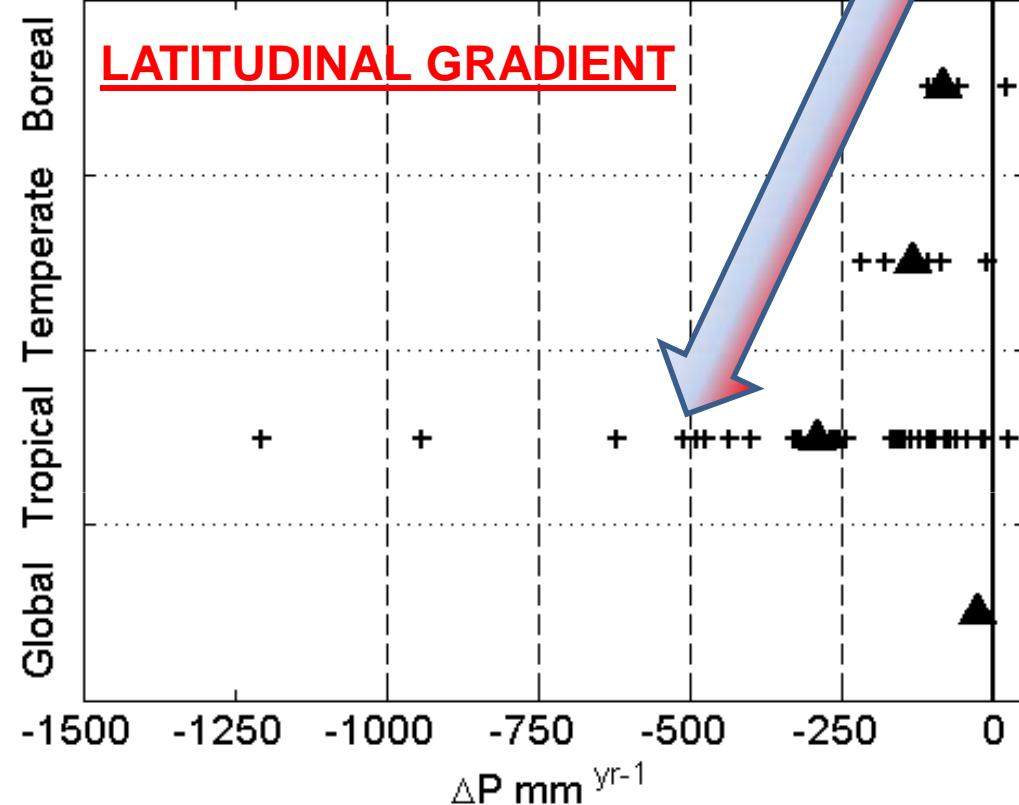
When forests are substituted with herbaceous plant types, the decrease of precipitation is reduced if compared with bare soils transition

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IAM and HYDE 3.1

CMIP5-LUCID and IPCC AR5

Hyde 3.1

- **Harmonization of land-use hystorical data with future IAMs scenarios**
- **0.5 deg res**

Major Shortcomings

- **Consider just few categories of LU:(eg pasture, cropland, primary forest) with some internal inconsistencies**
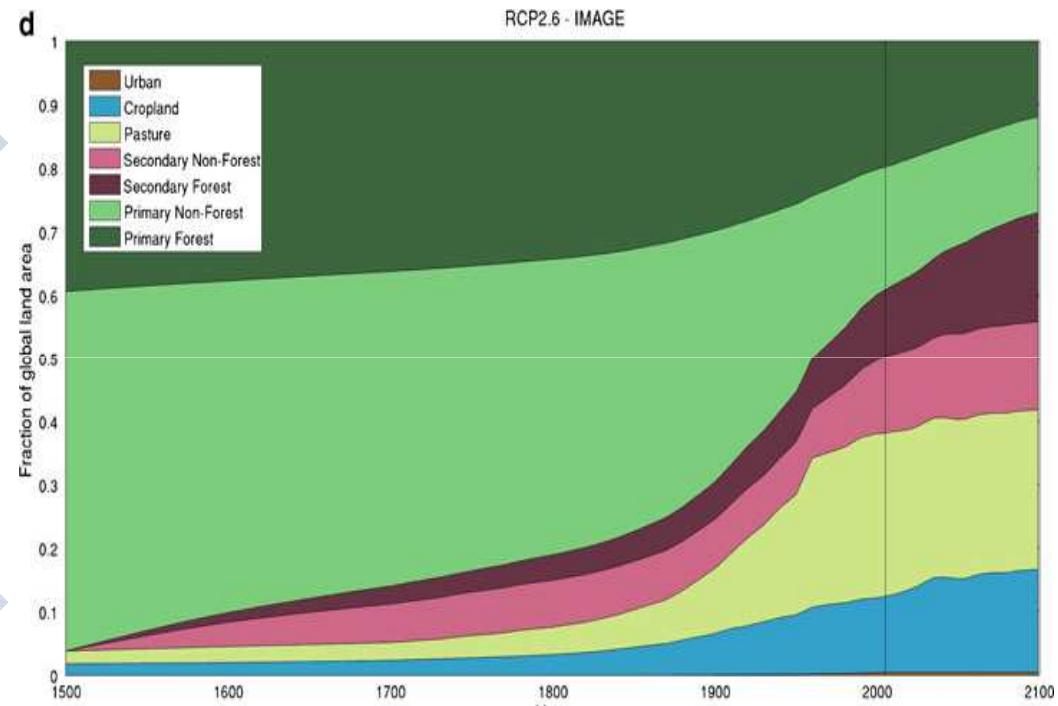
The (RCPs) are associated with a story-line for future anthropogenic LUC

Van Vuuren et al., Climatic Change 2011
Moss et al. Nature 463:747-756 2010
Pitman et al. 2009
Brovkin et al. 2013

HYDE 3.1 and CMIP5 SCENARIOS

The land use classifications and their spatial resolutions mean that for the use in ESM integrations, a harmonisation process was required (HYDE v3.1)
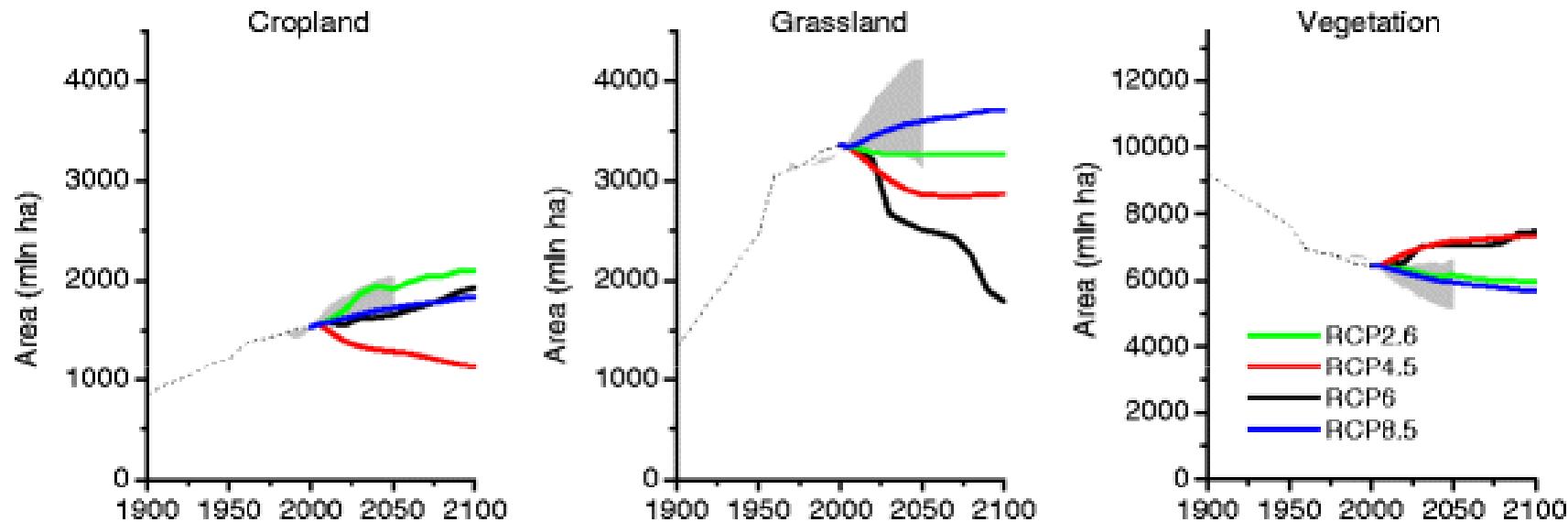
Although the ESMs use the same harmonized land-use scenarios, the method employed to convert HYDE categories into land categories and PFTs used by ESMs differs between the models

UNCERTAINTIES !!!!

Van Vuuren et al., Climatic Change 2011
Moss et al. Nature 463:747-756 2010

CMIP5 LUC UNCERTAINTIES

Different decisions on land-transitions
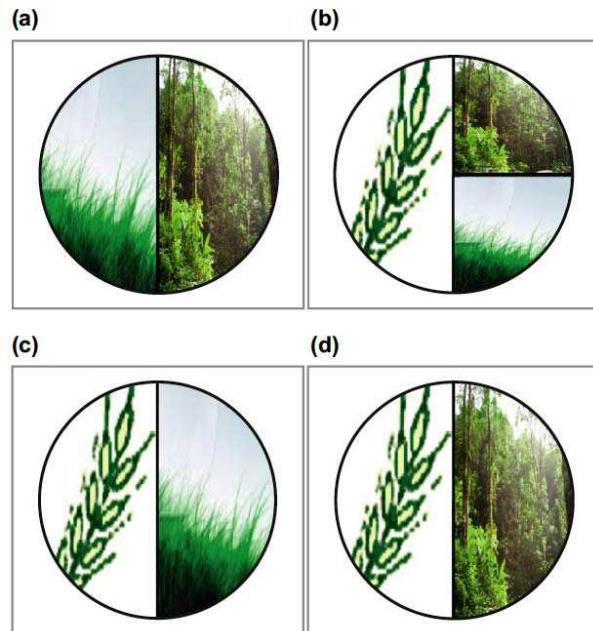
AR5 ESMs represented croplands as grasslands
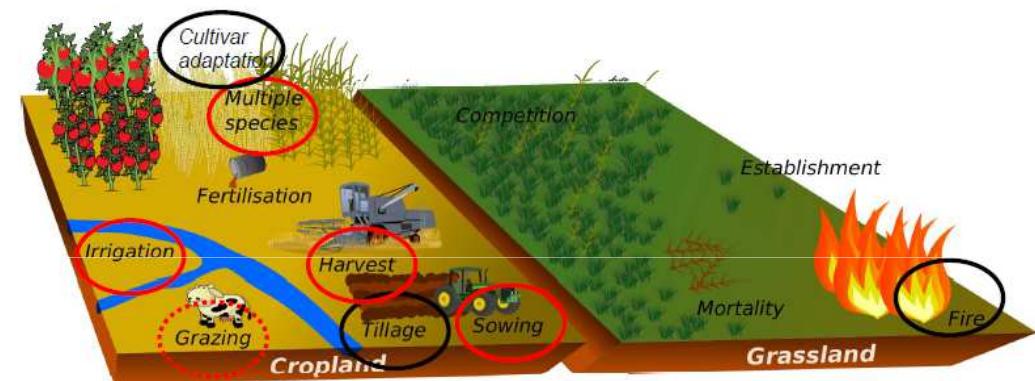
Courtesy of Almut Arneth

Users often ignore the fact that HYDE 3.1 is not observation data but merely modeling results

De Noblet et al . GAP 2014
Kees Klein Goldewijk • Peter H. Ecology Landscape ecology 28, 861-877 (2013)

CMIP5 LUC SCENARIOS

HYDE 3.1 INPUT

- **CROP**
- **RCP 2.6/8.5**

GCMs

- **??**
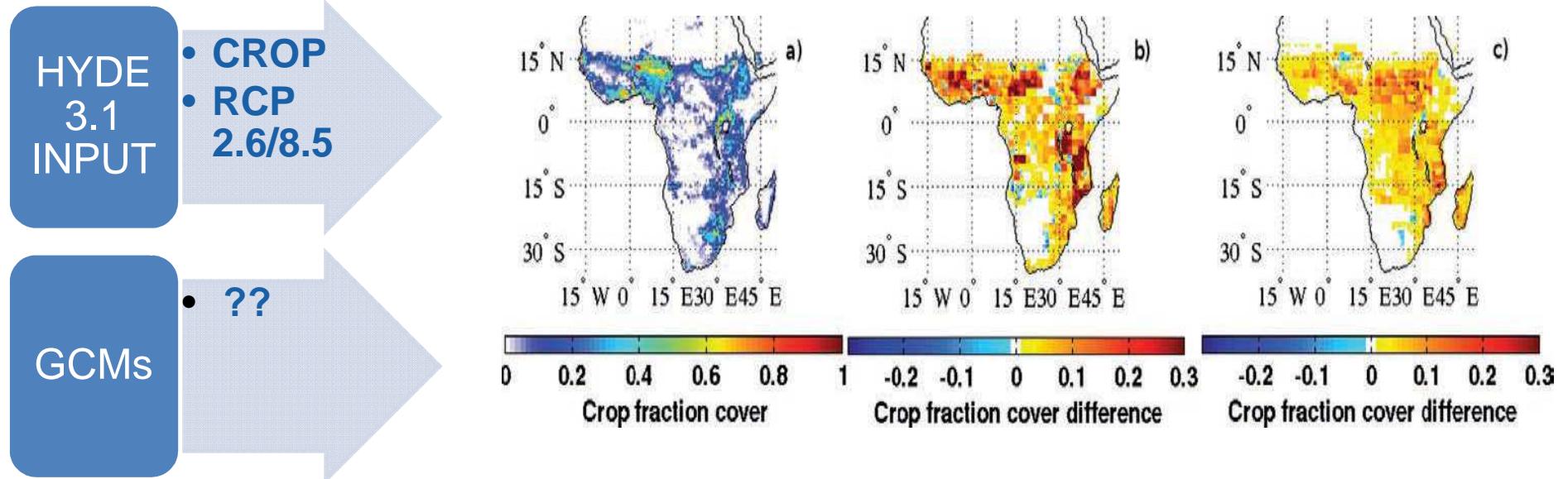
Present day crop fraction in Africa and the changes projected to occur by 2099 under (B) RCP2.6 and (C) RCP8.5.

Table 1. Summary of the key land surface details relevant for the History Database of the Global Environment 3.1 conversion.

| ESM	CanESM2	IPSL-CM5A-LR	MIROC-ESM	MPI-ESM-LR
Land model	CTEM	ORCHIDEE	SEIB-DGVM	JSBACH
Reference	Arora and Boer (2010)	Krinner *et al.* (2005)	Sato *et al.* (2007)	Raddatz *et al.* (2007)
PFTs classes	9	13	13	12
DVM	No	No	Yes	Yes
HYDE output	Absolute values	Absolute values	Transition matrix	Transition matrix
HYDE conversion	Woody + herbaceous = natural	Woody + herbaceous = natural	Primary + secondary = natural	Primary + secondary = natural

Tompkins A.M and Caporaso L.Geospatial Health 2016

CURRENT LUC-GCM IMPLEMENTATION

DVM

Climate model

HYDE

coupling

LUC

LUC from HYDE needs to be merged with DVM output to form surface tiles for climate model. Each modelling centre applies rules to convert to land cover allocation and to deal with inconsistencies.

DVG ntegration coupled to climate model

Offline HYDE integration

A. M. Tompkins, L. Caporaso, R. Biondi, J.P. Bell PLoS ONE 10(9): e0136154
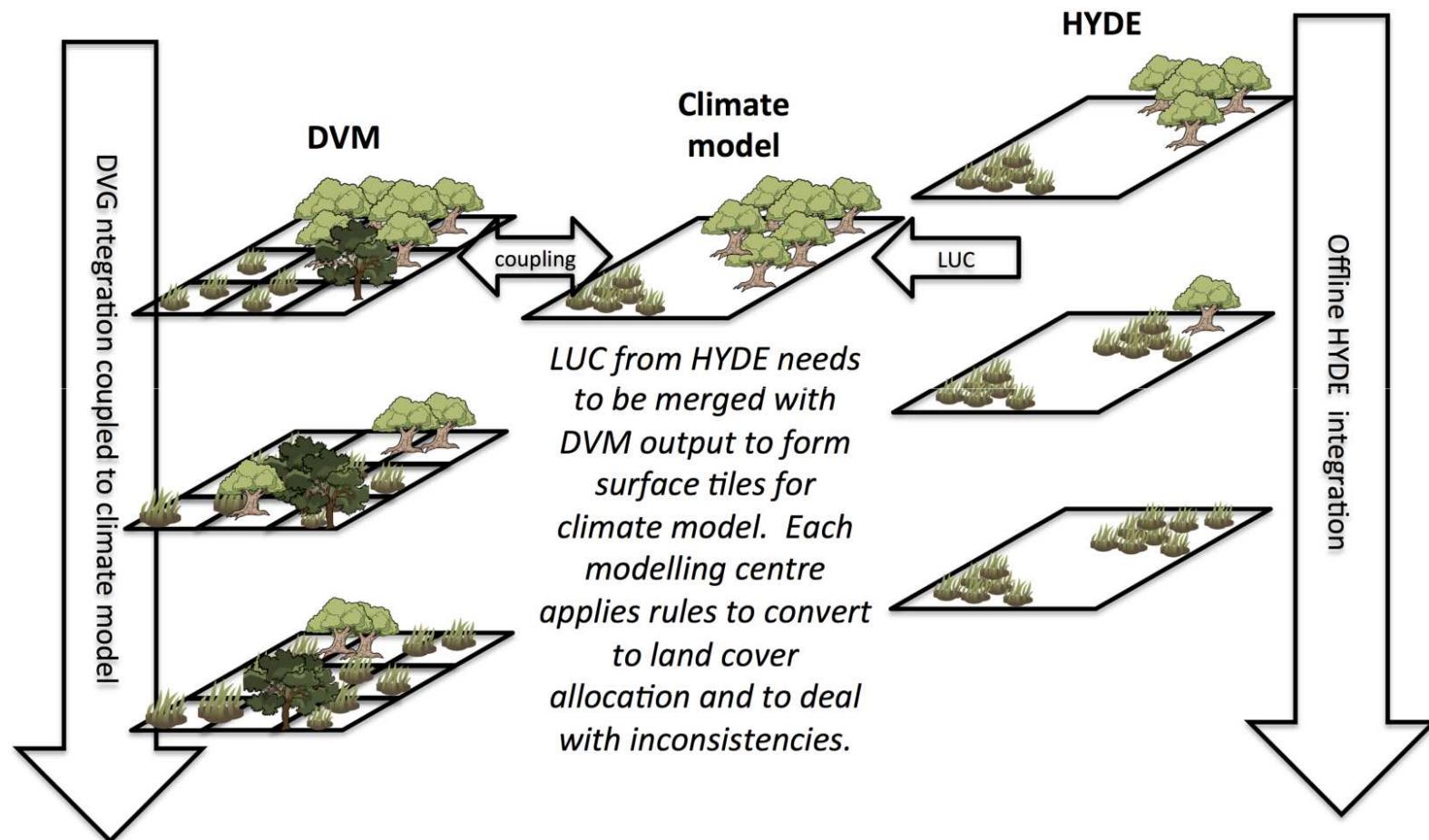
FOREST-SAGE: Deforestation and land-use change scenario generator model

✓ **FOREST-SAGE translates global anthropogenic land-use scenarios to ESMs grid-scale land cover on-line in a fully coupled way**

A. M. Tompkins, L. Caporaso, R. Biondi, J.P. Bell PLoS ONE 10(9): e0136154
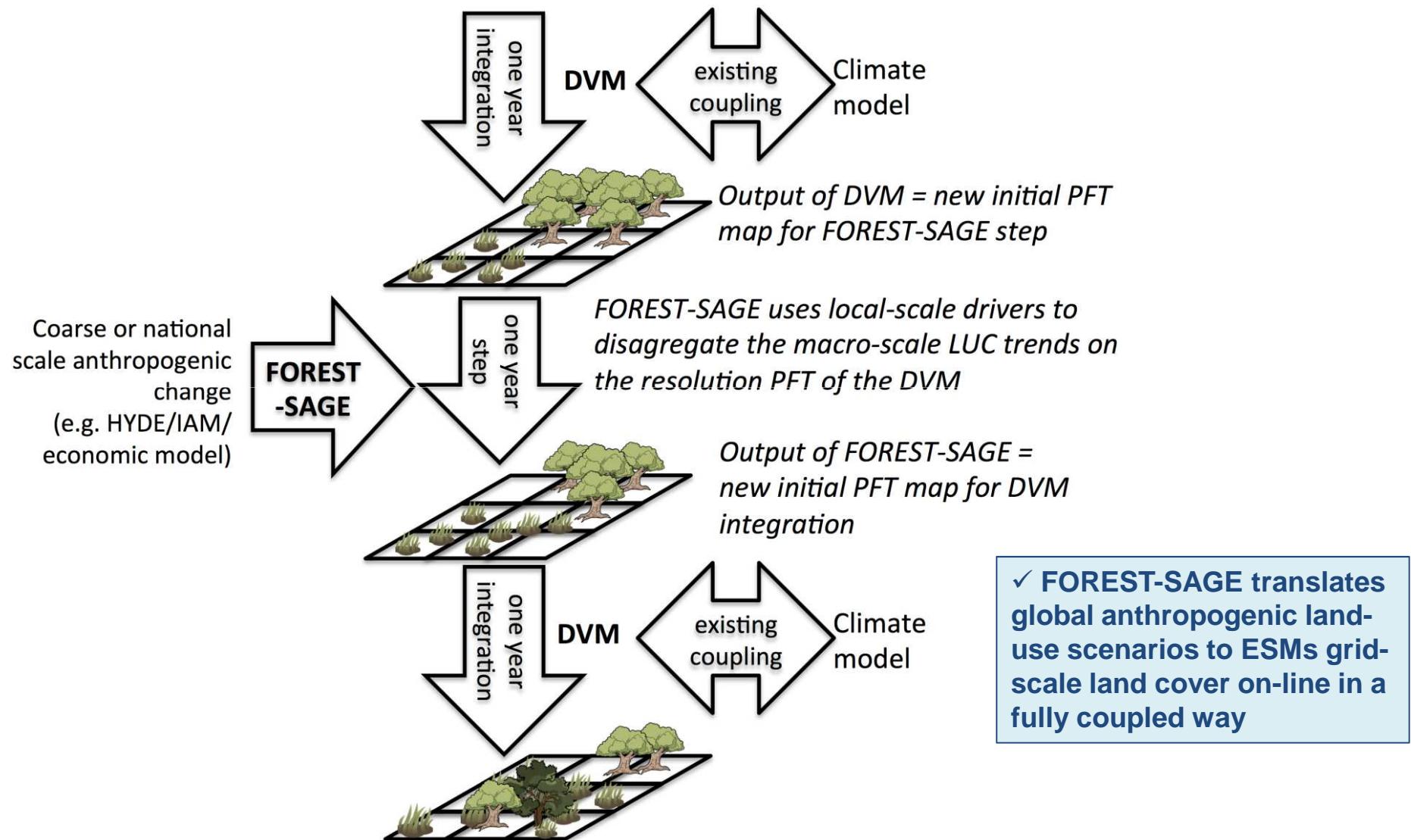
FOREST-SAGE over Congo Basin

- **FS Off Line Simulations**
- **MODIS VCF 10yr**
- **Reasonable Results!!!!**
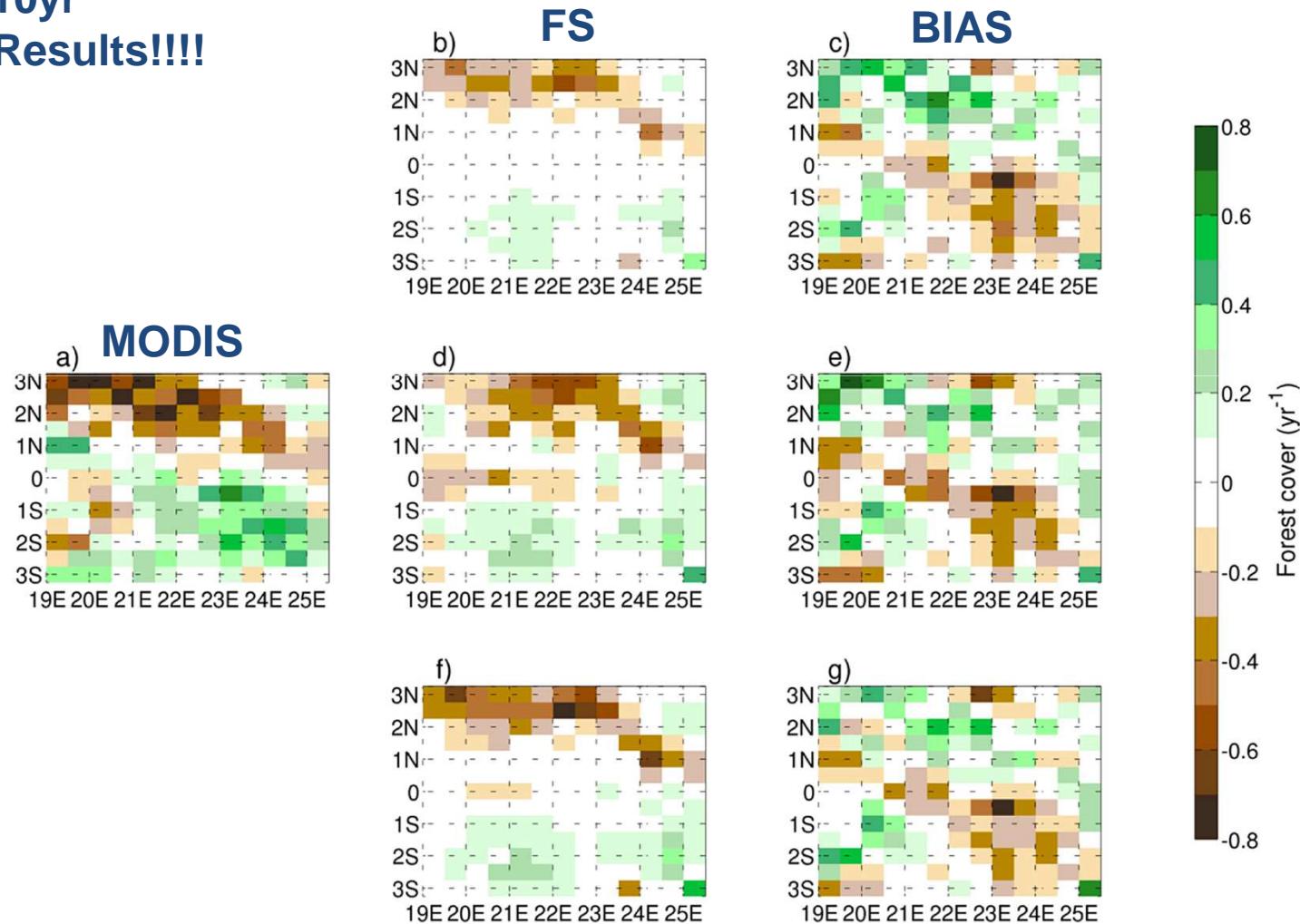
HYDE 3.1 over Congo Basin

- ➤ **MODIS trend 2001-2010 vs Hyde 3.1**
- ➤ **Hyde 3.1 Scenarios cannot capture spatial variability!!!**

A. M. Tompkins, L. Caporaso, R. Biondi, J.P. Bell PLoS ONE 10(9): e0136154

RegCM 4.5 CLM 4.5 CN-CNDV 1/2

DGVM
- Dynamic global vegetation models (DGVMs) are powerful tools to project past, current and future vegetation patterns and associated biogeochemical cycles.

DGVM
- Derived from LPJ
- CLM-DGVM represents vegetation as pfts

PFTs
- pfts list shorter than CLM → no crops and shrub + merged boreal forest
- pfts located in the same grid compete for soil water

RegCM 4.5 CLM 4.5 CN-CNDV 2/2

DGVM
- Compile RegCM with the clm 45 option
- Open makeinc and uncomment
- a. CPPFLAGS+= $(DEFINE)CN
- b. CPPFLAGS+= $(DEFINE)CNDV
- c. CPPFLAGS+= $(DEFINE)VICHYDRO (optional)

Compile
- Make install
- It will create an esecutable with the CN_CNDV option
- e.g. regcmMPICLM45_CN_CNDV_VICHYDRO

RUN
- You need to add in the namelist under CLM 4.5 parameter stanza the option Create_crop_landunit = .false.,
- Note 1: CLM 4.5 DGVM cannot run with the PFTdynamic option (HYDE 3.1)
- Note 2: The crop model cannot be activated

Experiment Preliminary Results

Africa Cordex domain

AFRICA + KE

100 Km + ERA

30 yr + CLM hv

**POTENTIAL VEGETATION
VS
STATIC MAP**

Experiment Preliminary Results
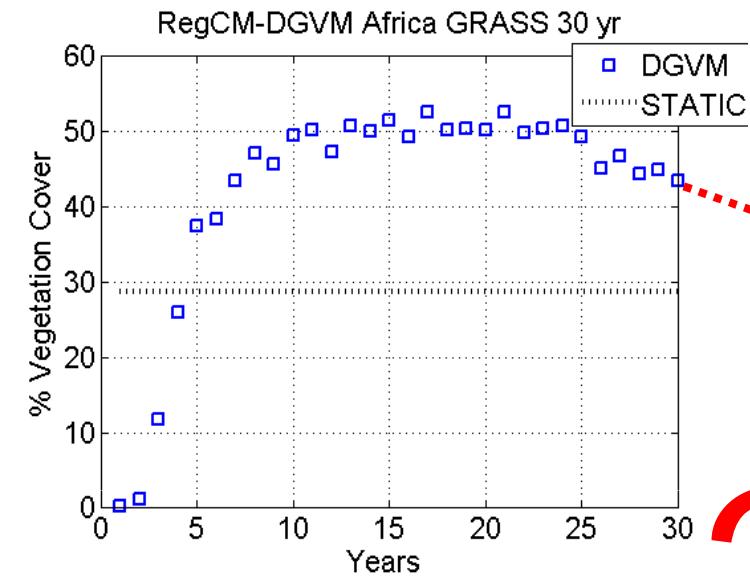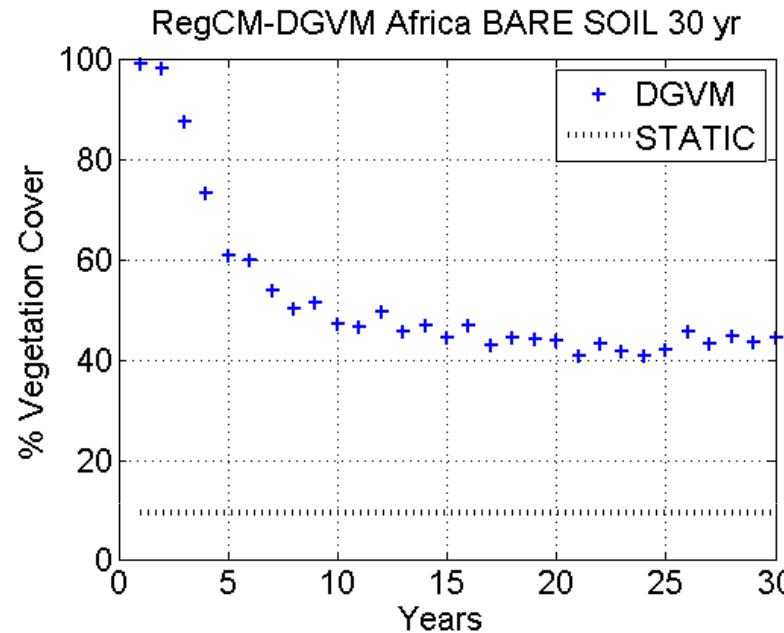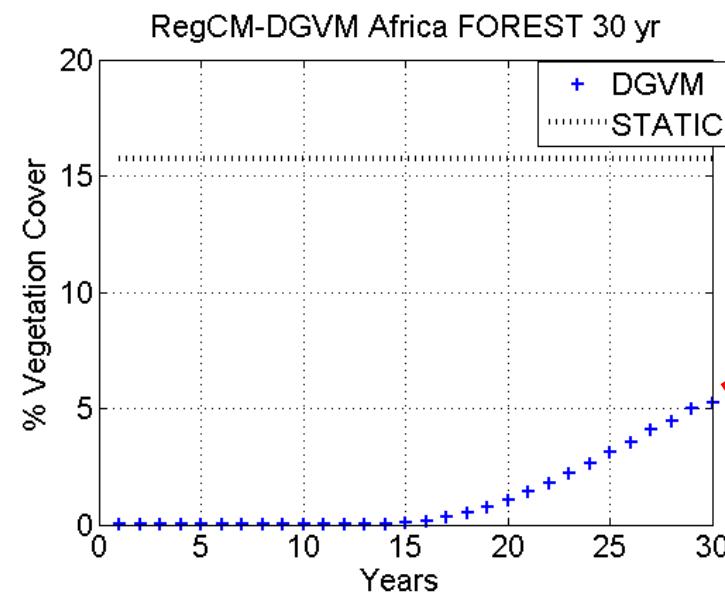
Experiment Setting:

Experiment setup: Africa Cordex domain/100 km/ERA –INTERIM
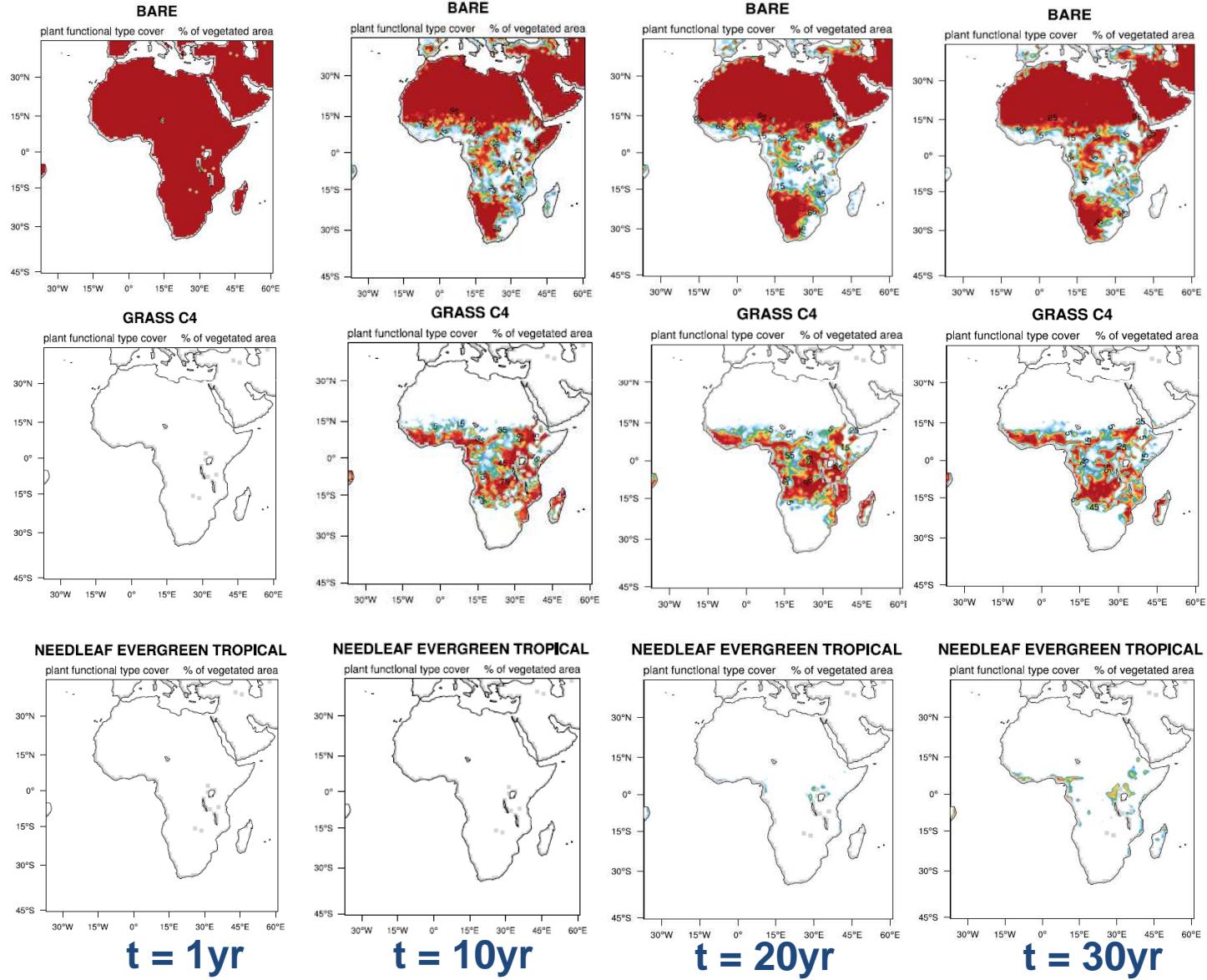
✓CLM_hv file
✓ Yearly
✓1d → 2d

t = 1yr   t = 10yr   t = 20yr   t = 30yr
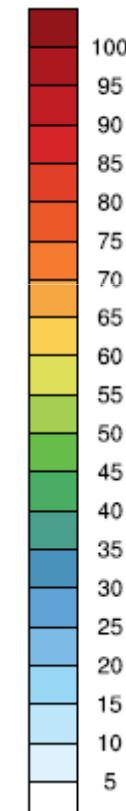
Conclusions/Future Work:

✓ **LUC and Climate**

✓ **RegCM 4.5-CLM 4.5 → static land use map**

✓ **RegCM 4.5-CLM 4.5 anthropogenic LUC map → HYDE 3.1**

✓ **RegCM 4.5 CLM-DGVM → Preliminary Results**

✓ **Several experiments ongoing (Parallel with/without DGVM)**

✓ **Coupling FOREST-SAGE with CLM4.5-DGVM**

Thanks