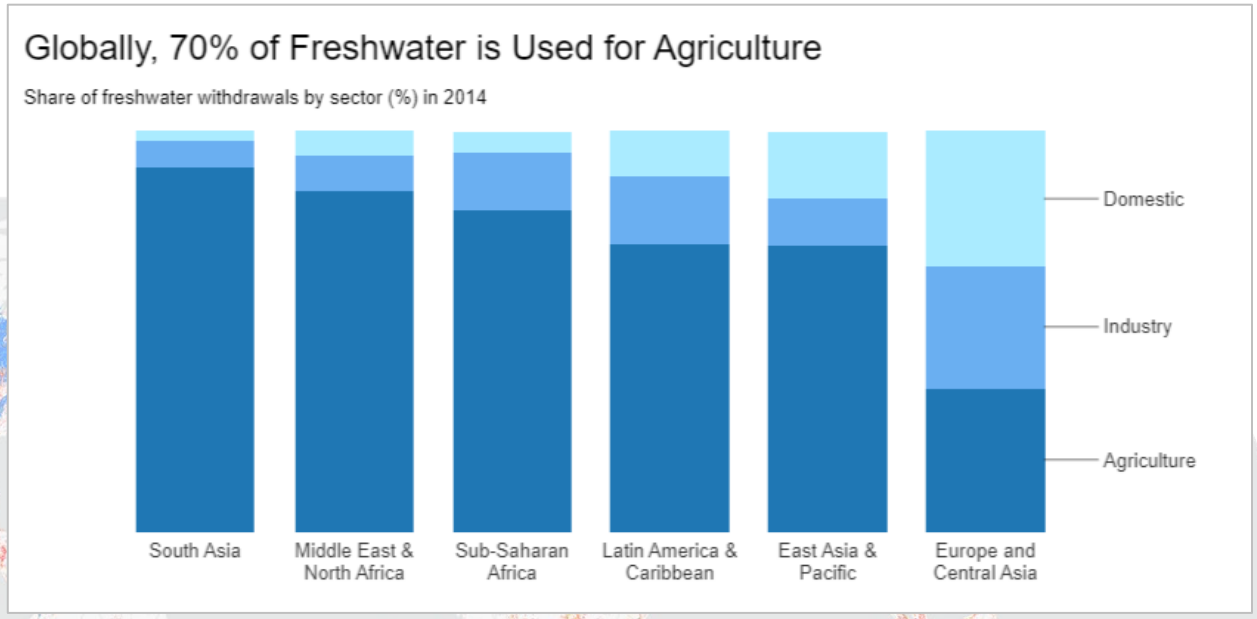
SWAT
Soil & Water Assessment Tool
26-30 JUNE 2023 AARHUS, DENMARK

VUB HYDR HYDROLOGY & HYDRAULIC ENGINEERING DEPARTMENT

Implications of Climate on crop water use in a tropical catchment. Nyando Catchment, Kenya

Katoria Lekarkar, Albert Nkwasa, Douglas Nyolei, Ann van Griensven

Context

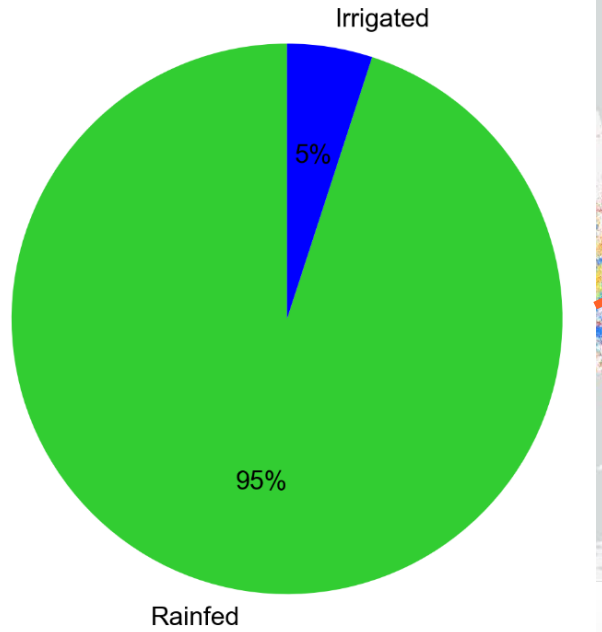

Globally, 70% of Freshwater is Used for Agriculture
Share of freshwater withdrawals by sector (%) in 2014
Domestic
Industry
Agriculture
South Asia
Middle East & North Africa
Sub-Saharan Africa
Latin America & Caribbean
East Asia & Pacific
Europe and Central Asia

Layers depicting cropland
1
2
3
4
5
6

Context

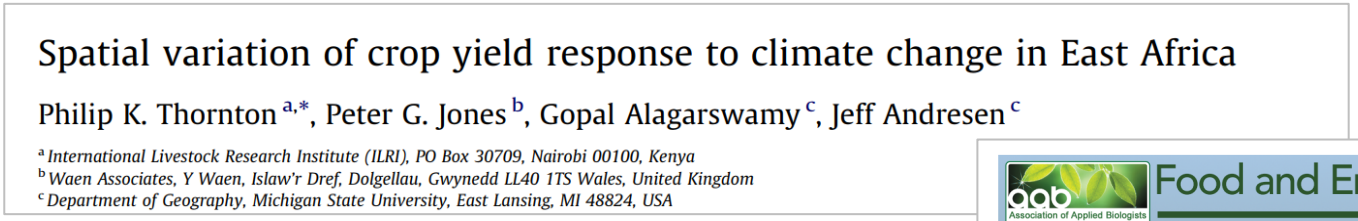
Tropical African catchments: High reliance on rainfall
→ 95% of agriculture is rainfed

Very sensitive to climate variability
+ low adaptive capacity hence highly susceptible to CC impacts



Context

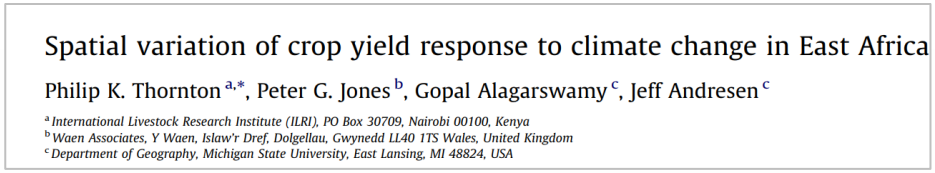
Studies overwhelmingly focused on impact on yields less CWU, despite its role as a resource for food production



Spatial variation of crop yield response to climate change in East Africa

Philip K. Thornton [a,*], Peter G. Jones [b], Gopal Alagarswamy [c], Jeff Andresen [c]

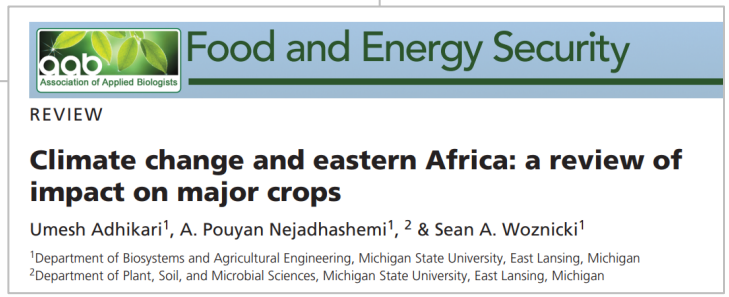
[a] International Livestock Research Institute (ILRI), PO Box 30709, Nairobi 00100, Kenya
[b] Waen Associates, Y Waen, Islaw'r Dref, Dolgellau, Gwynedd LL40 1TS Wales, United Kingdom
[c] Department of Geography, Michigan State University, East Lansing, MI 48824, USA



Spatial variation of crop yield response to climate change in East Africa

Philip K. Thornton [a,*], Peter G. Jones [b], Gopal Alagarswamy [c], Jeff Andresen [c]

[a] International Livestock Research Institute (ILRI), PO Box 30709, Nairobi 00100, Kenya
[b] Waen Associates, Y Waen, Islaw'r Dref, Dolgellau, Gwynedd LL40 1TS Wales, United Kingdom
[c] Department of Geography, Michigan State University, East Lansing, MI 48824, USA



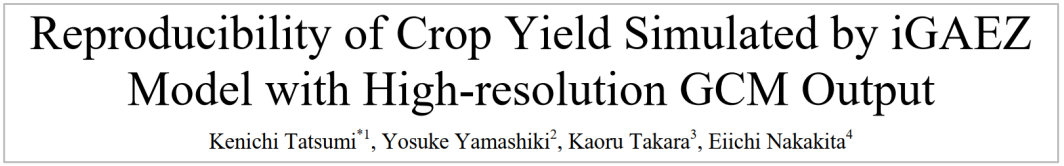
Food and Energy Security

REVIEW

Climate change and eastern Africa: a review of impact on major crops

Umesh Adhikari[1], A. Pouyan Nejadhashemi[1], [2] & Sean A. Woznicki[1]

[1]Department of Biosystems and Agricultural Engineering, Michigan State University, East Lansing, Michigan
[2]Department of Plant, Soil, and Microbial Sciences, Michigan State University, East Lansing, Michigan



Reproducibility of Crop Yield Simulated by iGAEZ Model with High-resolution GCM Output

Kenichi Tatsumi[*1], Yosuke Yamashiki[2], Kaoru Takara[3], Eiichi Nakakita[4]

Important to study impacts of CC on CWU to determine

- effects of shortages on agricultural
- Identify vulnerabilities and adapt agr to reduce Water stress, guarantee sustainable agr. and Water resources allocation

Objectives

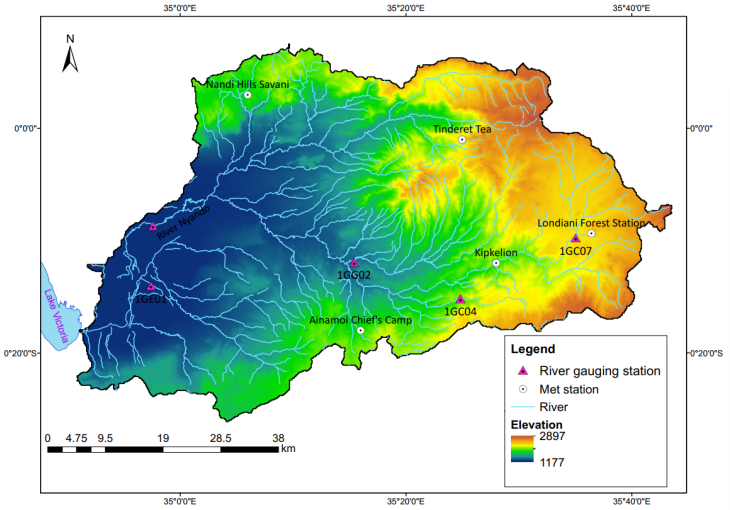
- Estimating agricultural uses in a tropical catchment: Nyando catchment
- Investigating climate change impacts on blue and green water consumption
    - Combined effects of future precipitation, temperature increase and CO_2 fertilization

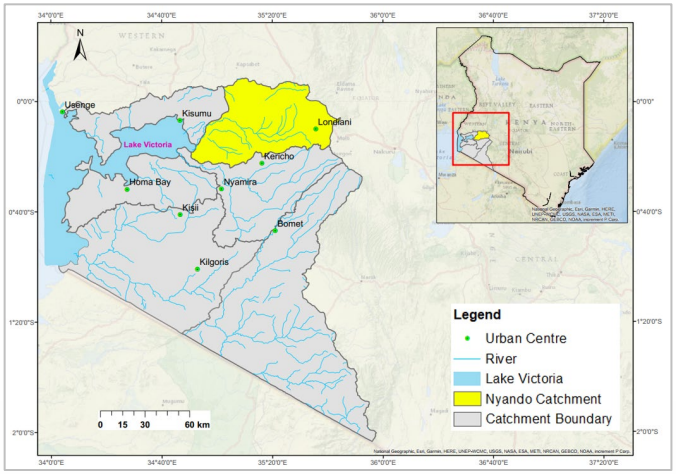
Nyando Catchment

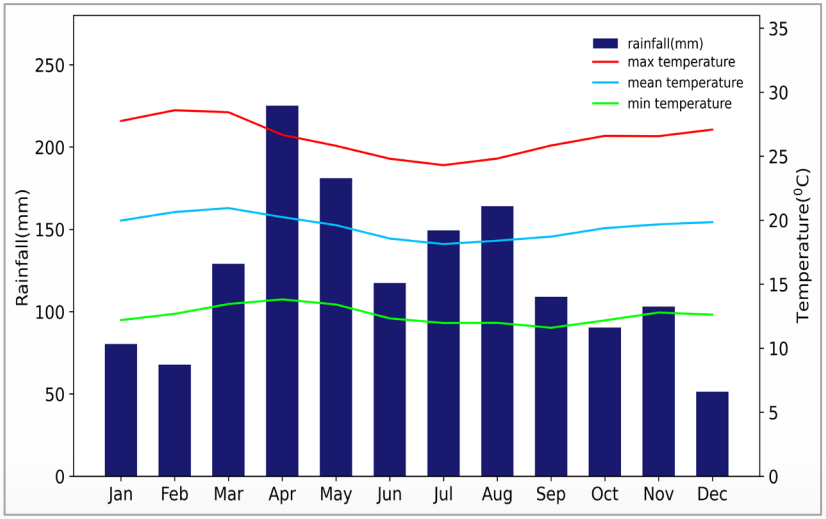
Location:

- Within Lake Victoria South Catchment Area
- 3,550 km^2

- Bimodal Rainfall: 1100-1700mm

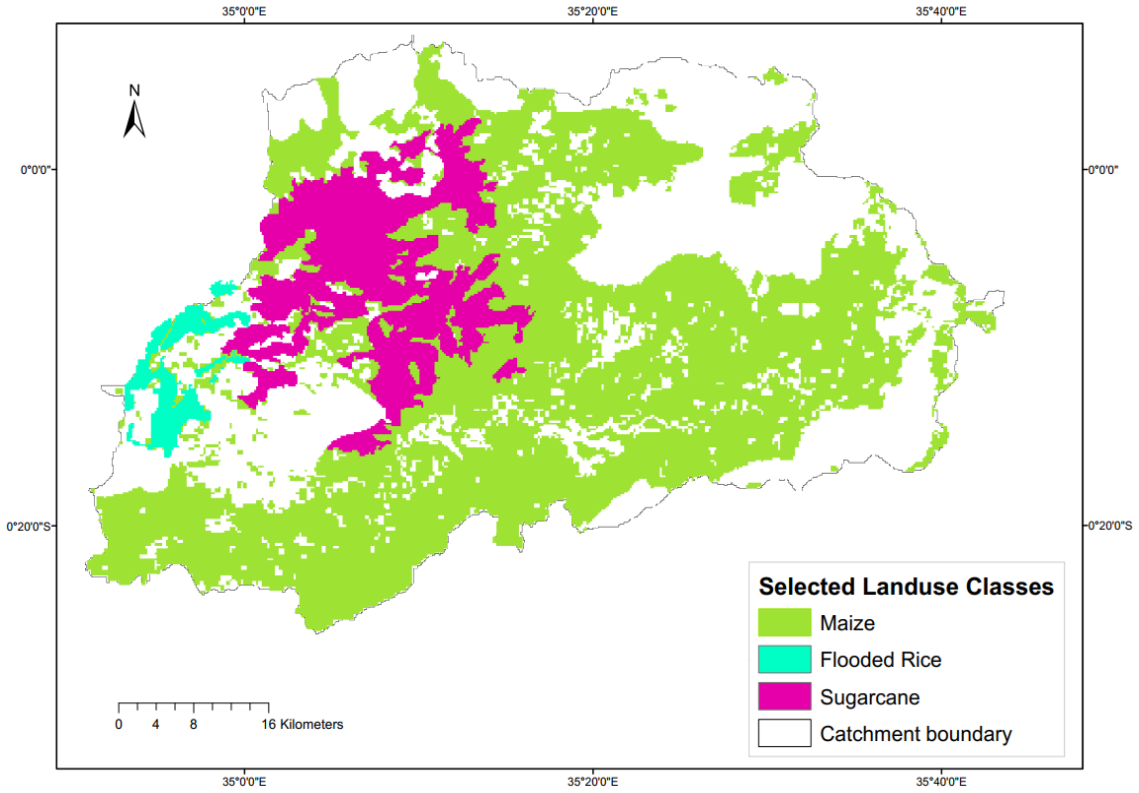






Land Use

- Dominant Land use: Agriculture ~70%
- Forests, rangelands, wetlands and bare areas 30%
- Focus Areas:
  - Sugarcane
  - Subsistence farming- maize
  - Flooded Rice: Irrigated: Ahero, West Kano



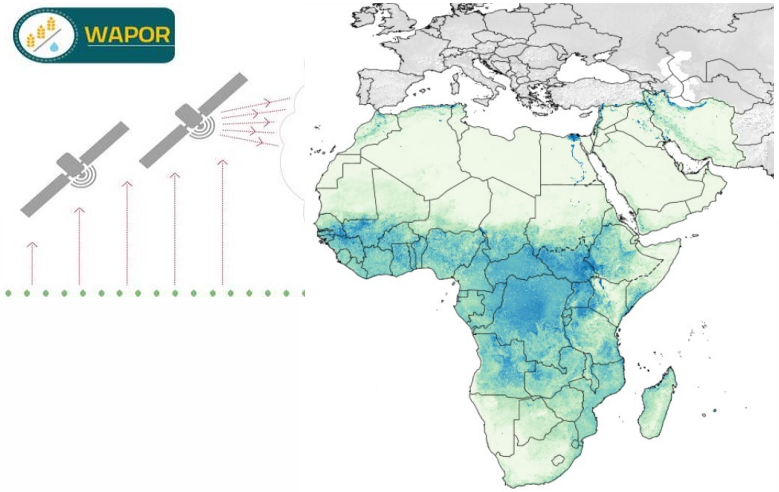
Estimating crop water use

ET as the indicator of crop water consumption

Datasets:

WaPOR-ET: Proxy observed ET dataset

- RS ET dataset,
- Developed by FAO and IHE Delft
- Data: 2009 onwards



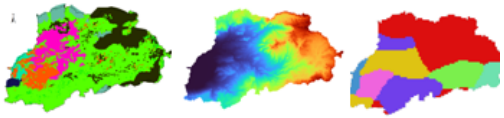
SWAT+

Physically-based, semi-distributed model

Impacts of land use management and climate change impacts on watersheds

SWAT+ Simulation

Geospatial data

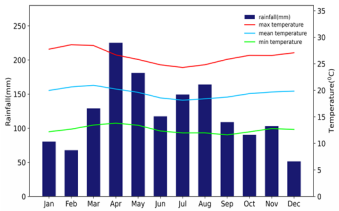


Land use Map: ESA, 2015

DEM: 90m SRTM

Soil Map: FAO

Climate data



Obs!

Raifall (CHIRPS), Tmax & Tmin (CHIRTS)

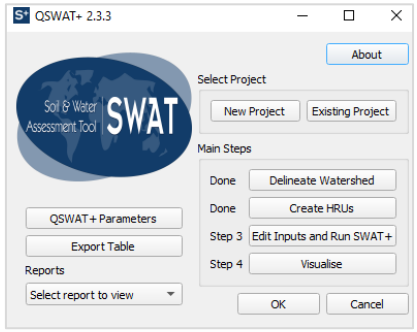
RHn, Wind speed and solar radiation: ISIMIP-EWEMBI

Cropping patterns and management operations

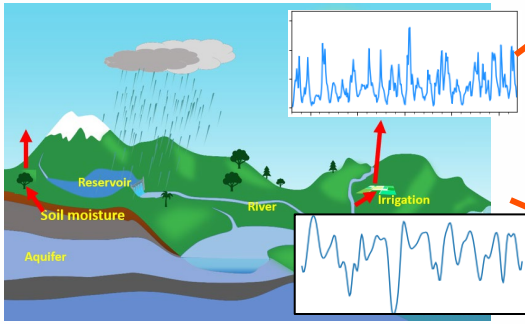
Calendar dates

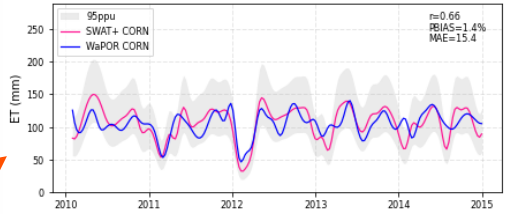
- Planting
- Irrigation
- Harvesting

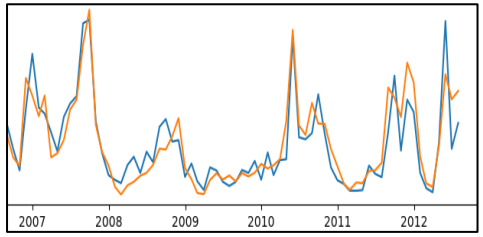
SWAT+: 1981-2014



SWAT+ Toolbox + DTs



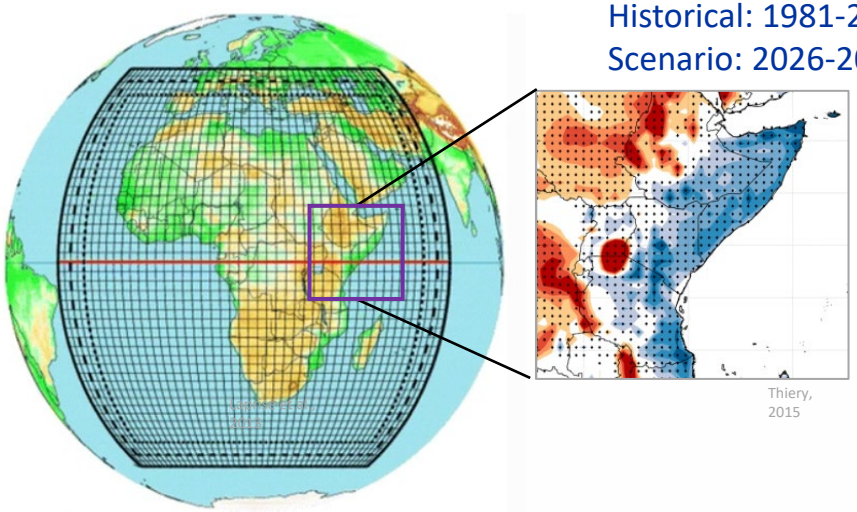




Rice: Irrigation for zero water stress

Changes in CWU under CC

5 RCMs CORDEX-AFR domain:
2 RCP scenarios: RCP4.5, RCP 8.5



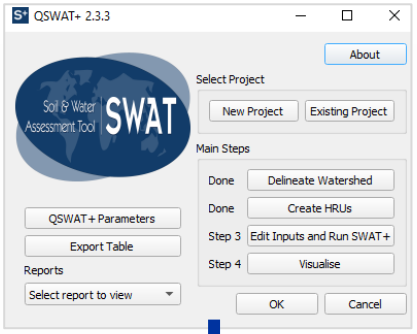
Climate variables
Historical: 1981-2005
Scenario: 2026-2050

Thiery, 2015

Bias-correct
Rainfall, Temp.

SWAT+ simulations for each RCM
Scenarios with and without CO2 fertilization
Current Land use conditions

SWAT+

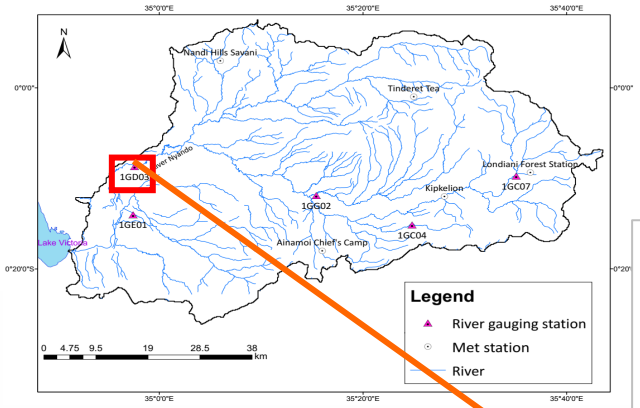


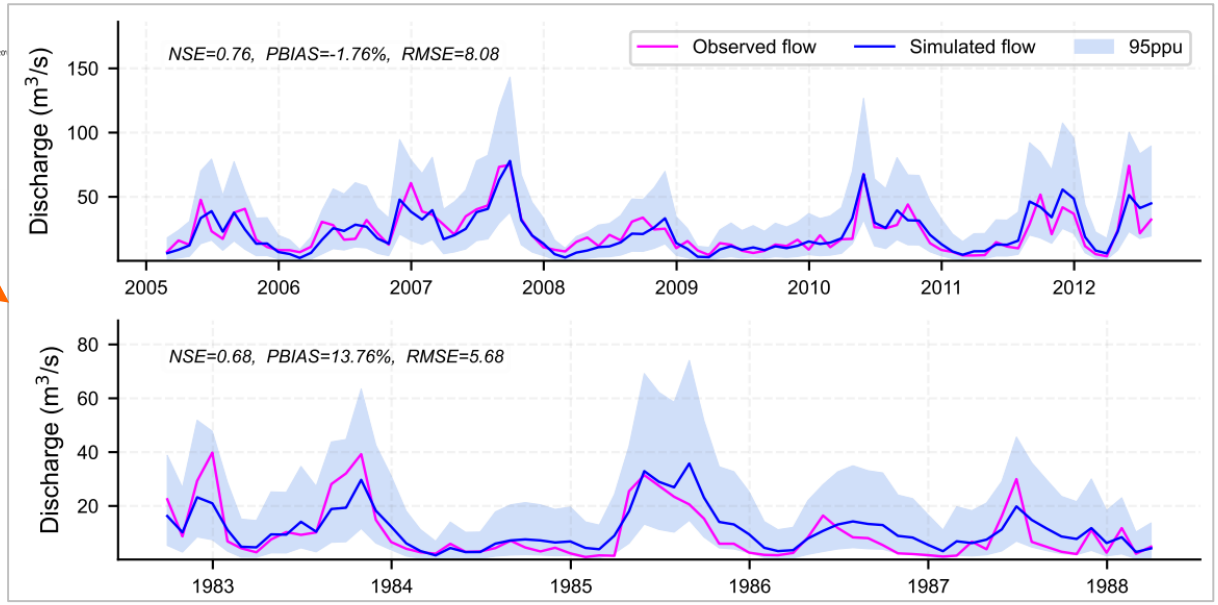
- Historical and projected ET for individual crops,
- Changes in crop WU: scenario-hist

Model Performance

Hydrological

Discharge at Nyando station 1GD03

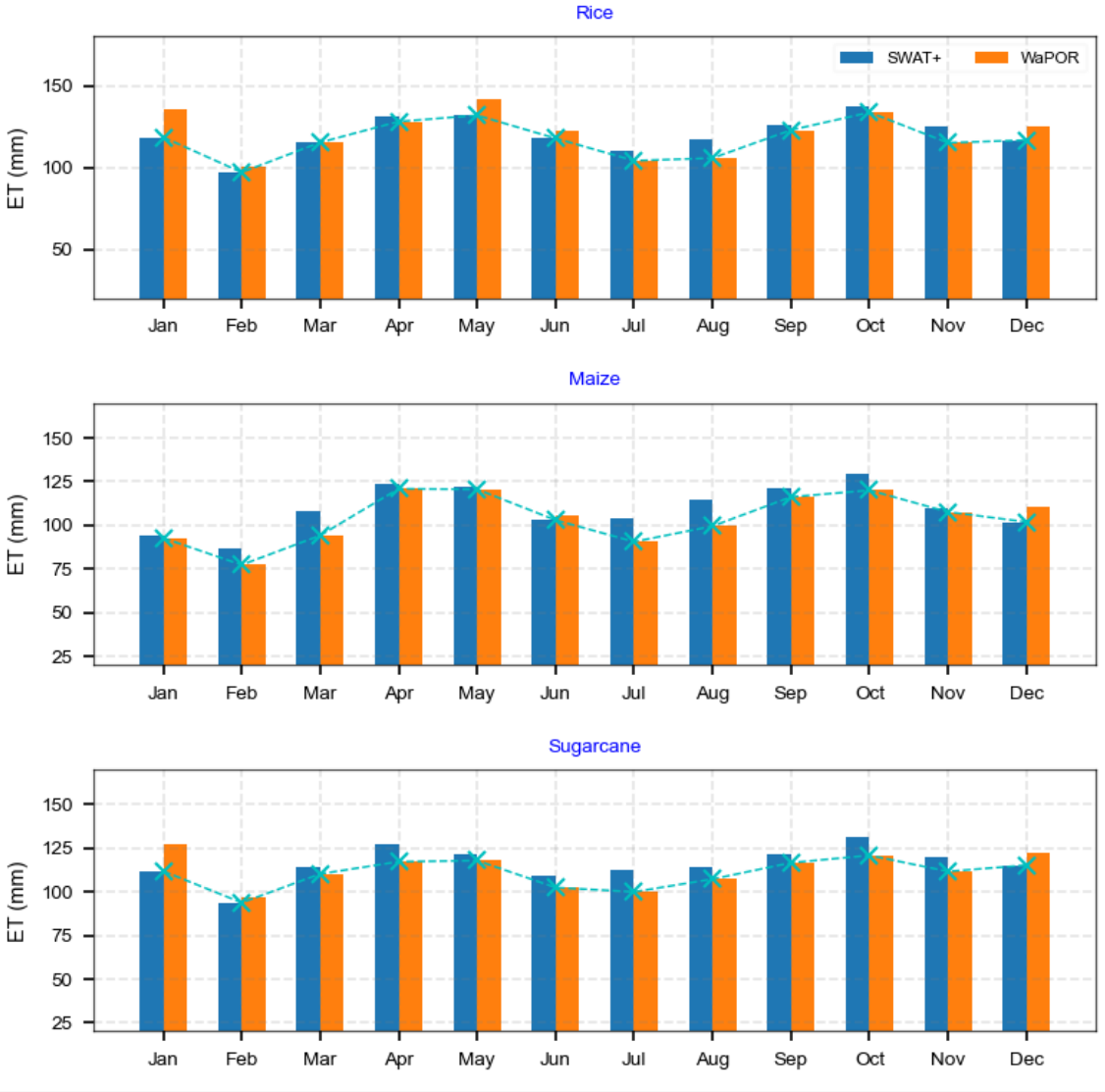




Model Performance
Crop water use: ET

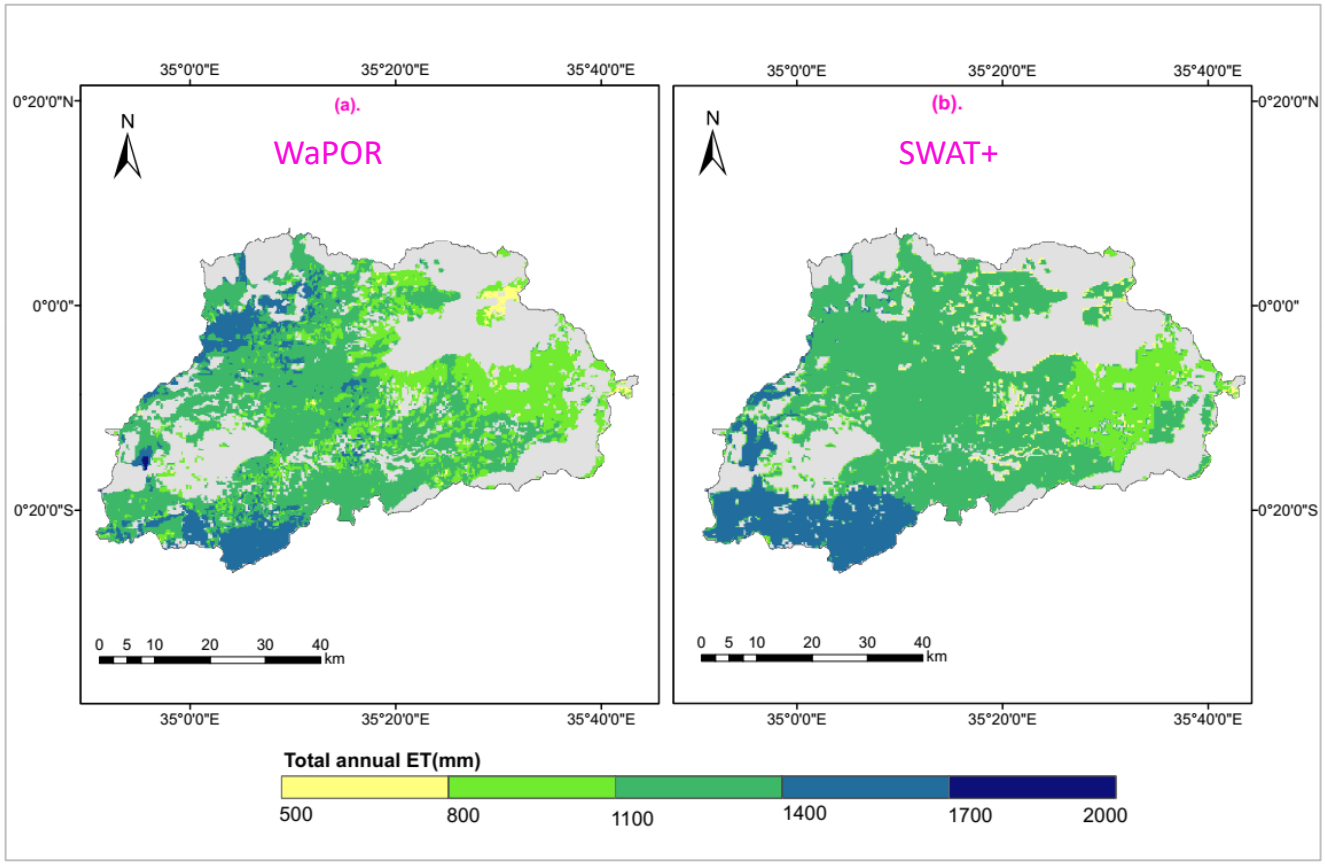
Evaluated against avg. monthly WaPOR ET for 2009-2014

Magnitude and temporal variation well represented



Spatial Representation: SWAT+ and RS ET

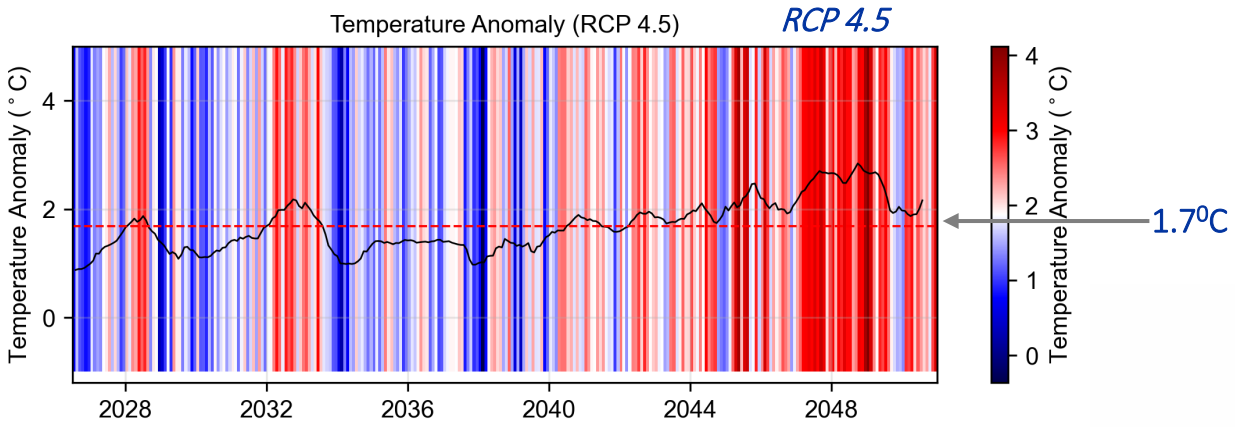
Similar spatial pattern of total ET

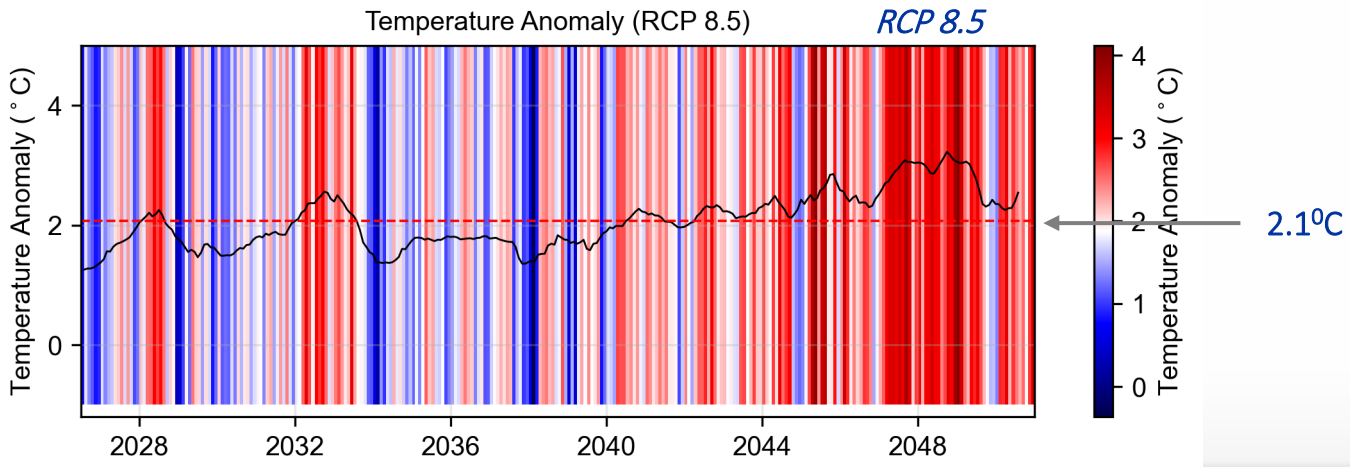


Slight inconsistencies due to model simplifications

CC outlook: 2026-2050

Temperature: Relative to historical period: 1981-2005



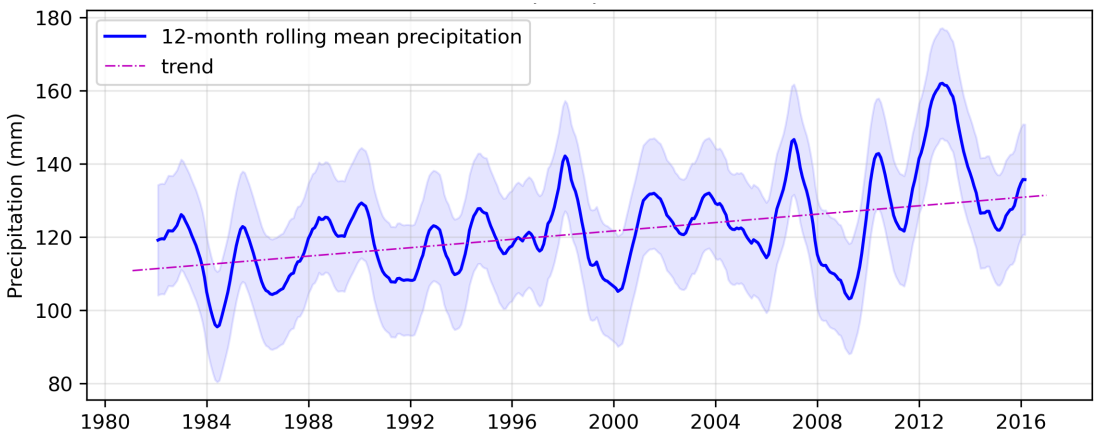


CC outlook: 2026-2050

Precipitation:

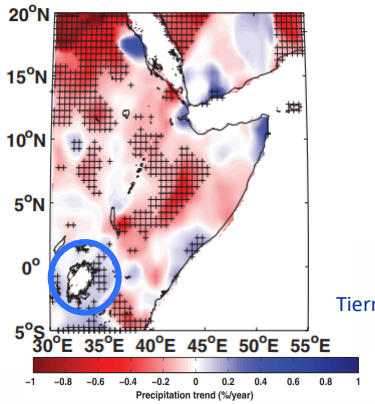
Historical precipitation: CHIRPS RS dataset: 1981-

MK Trend test: Wetting trend

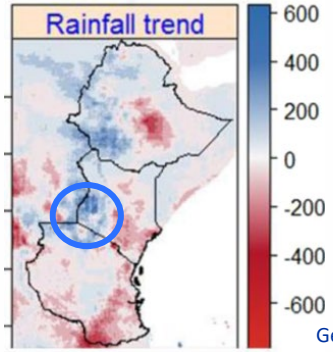


Consistent with trends observed in other studies in LVB

Annual pr trend: 1901-2010



Tierney et al. (2015)



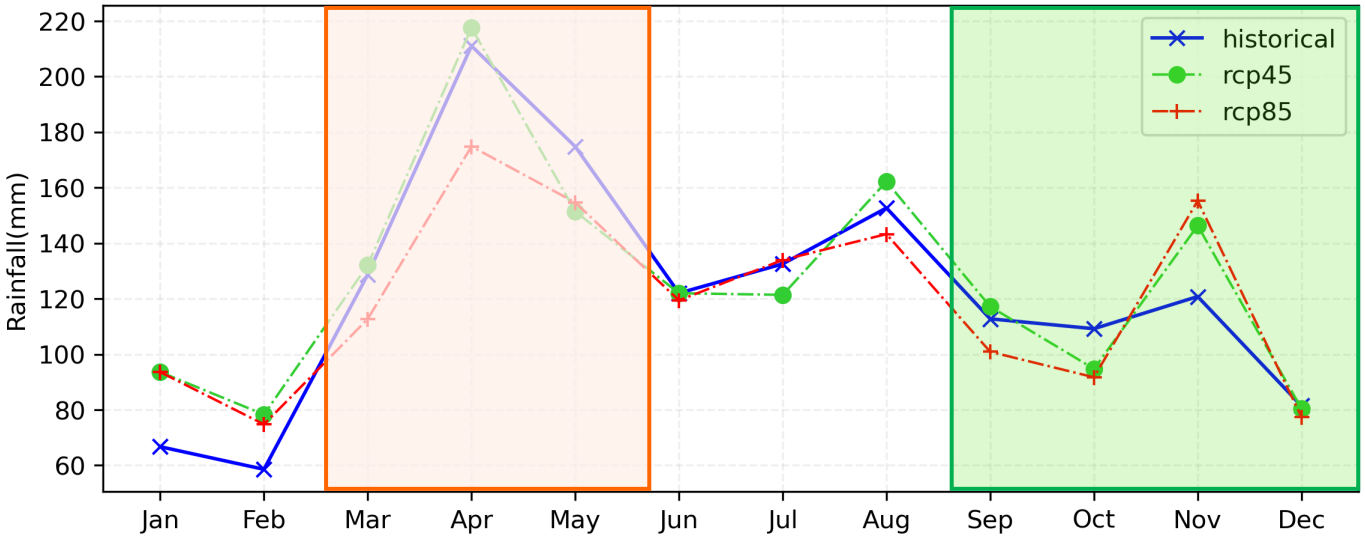
Gebrechorkos et al. (2019)

CC outlook: 2026-2050

Precipitation:

Main rainy season: Reduction with a stronger signal in RCP8.5

Short rainy season: Rainfall increases

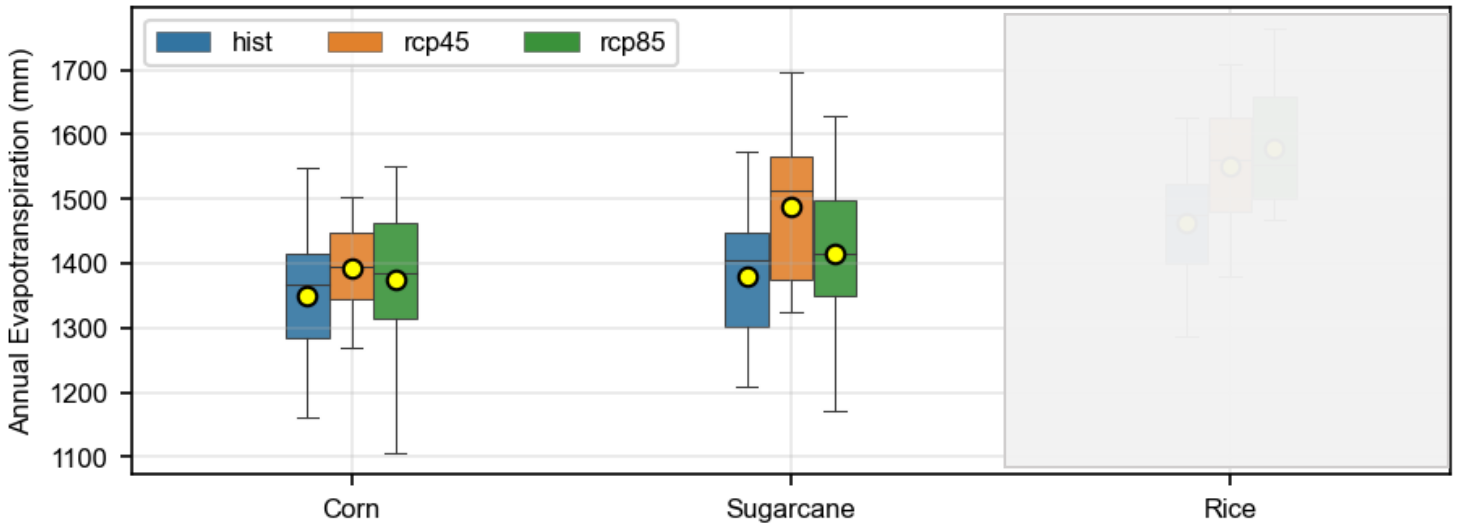


CC outlook: 2026-2050

CC impacts on crop water use

Increased Temp: Higher moisture holding capacity of the atmosphere: 7%/degree of warming

→ Increased evaporative demand: Higher ET,



→ For rainfed crops: Increase higher in RCP4.5

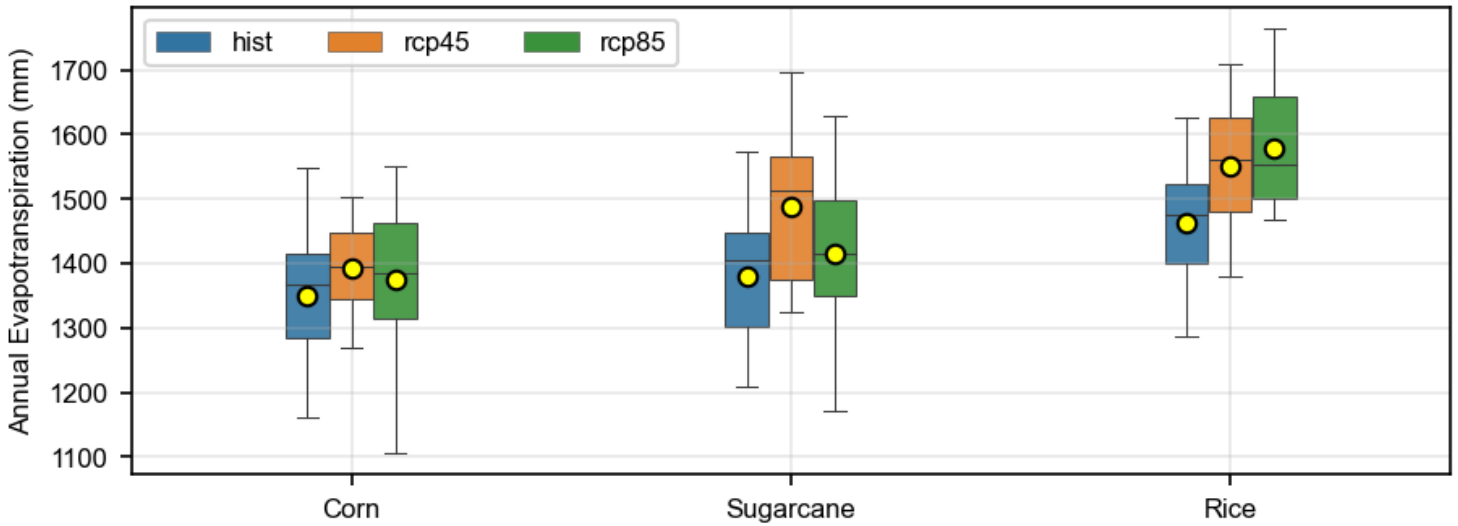
→ Although T+ higher under RCP8.5, water availability esp. in MAM limits ET increase

CC outlook: 2026-2050

CC impacts on crop water use

Increased Temp: Higher moisture holding capacity of the atmosphere: 7%/degree of warming

→ Increased evaporative demand: Higher ET,



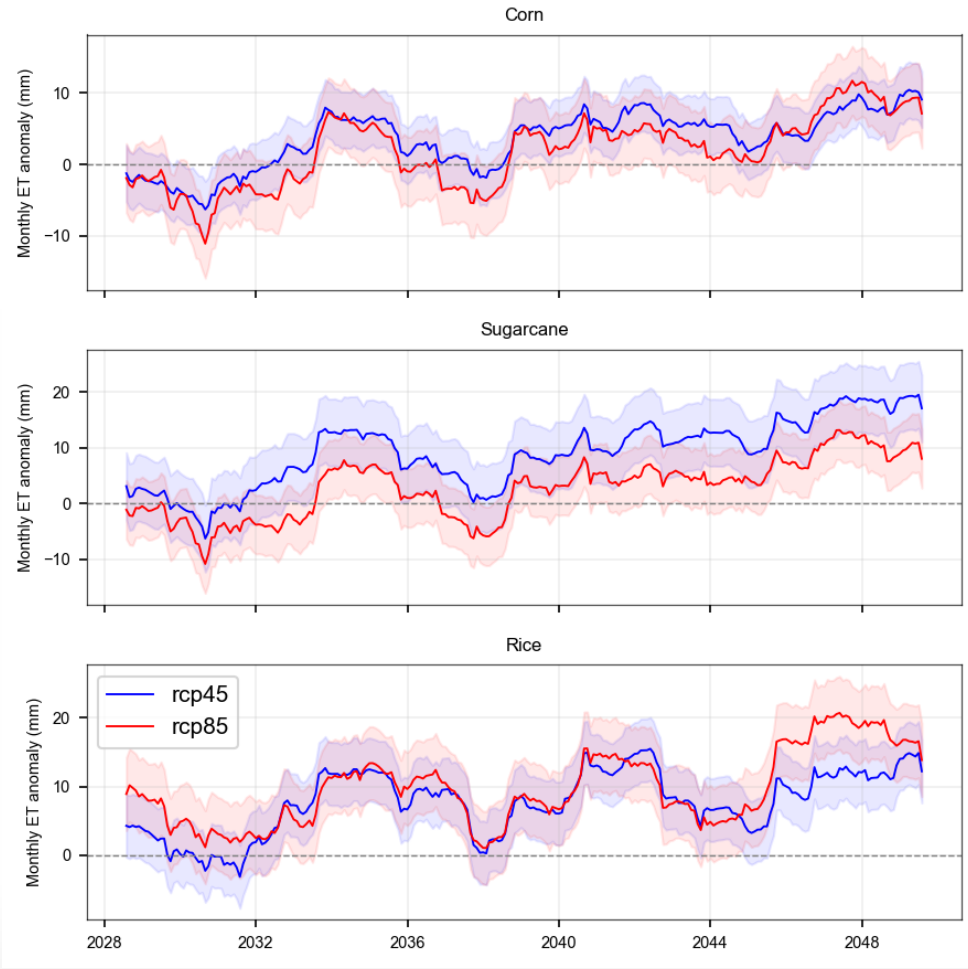
→ For rainfed crops: Increase higher in RCP4.5

→ Although T+ higher under RCP8.5, water availability esp. in MAM limits ET increase

→ With irrigation, WU higher under RCP8.5

CC outlook: 2026-2050

Anomalies in crop water use: all trends significant increase



Annual avg.increase

45, 24mm

109, 39mm

119, 89mm

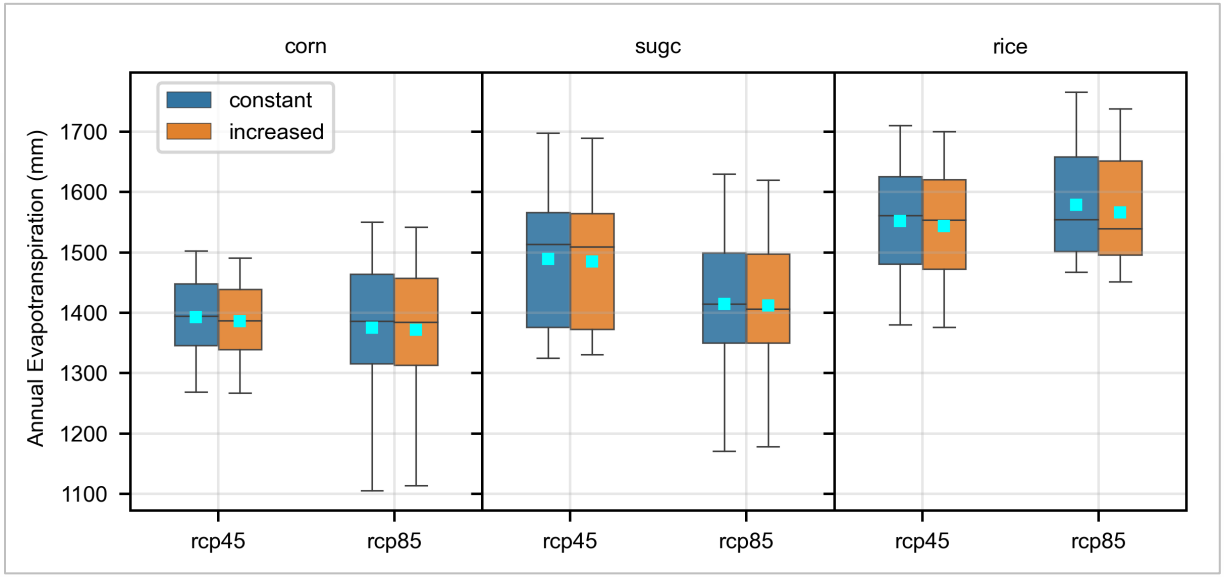
Increase in frequency of irr

CC outlook: 2026-2050

CO2 fertilization

Average emissions for each scenario: Hist: 400ppm, RCP4.5: 456ppm, RCP8.5: 481ppm: IPCC AR6

Implement in the parameters.bsn file



CO2 slightly offsets increase
Crops become photosynthetically efficient: Less time to open stomata
but signal is less than from T & pr changes

Consequences

- Enhanced ET increases depletion of soil moisture which can expose crops to agr. Drought
- Crop water stress, heat stress: Impacts on crop yields, (projected from other studies not analyzed)
- Irrigation demand to increase for rice

Measures:

- Investing in conservation agriculture to reduce consumption
- Invest in irrigation (?)
- Drought-resistant crops and diversification

Conclusions

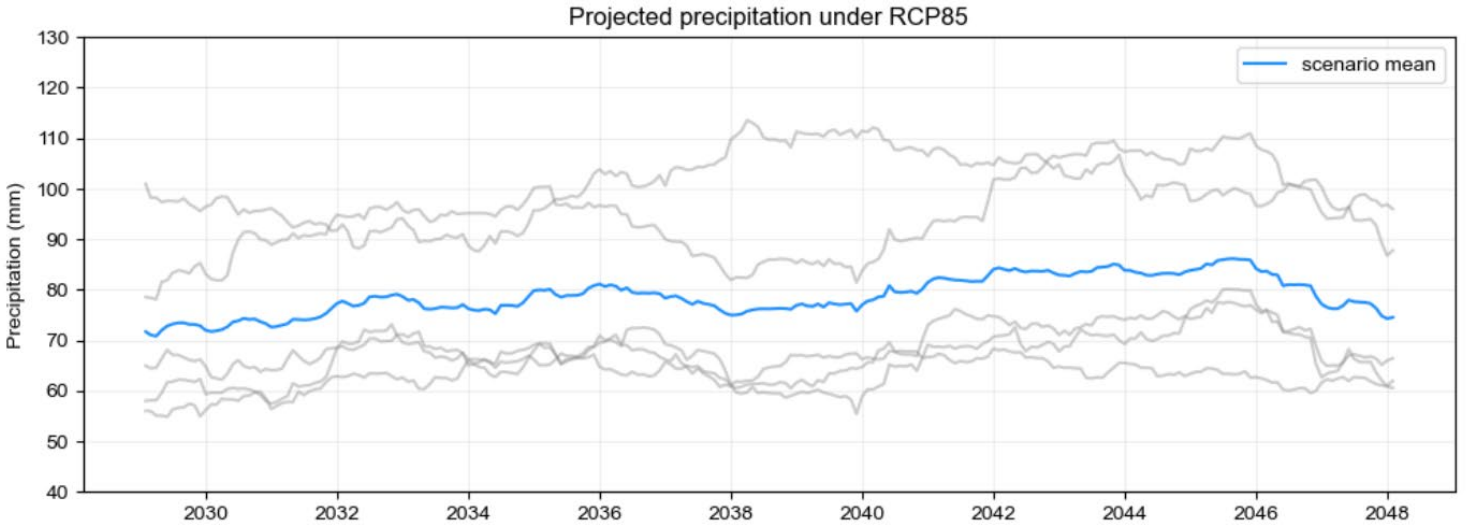
- Increase in water demand although rainfall reduces particularly under RCP8.5
- RCP 8.5 is warmer but drier in the main rainy season which limits availability
- Atm. CO2 reduces CWU but CC signal is dominated by increased CWU due to T+ and P- during the main growing season, which erode benefits from CO2
- Need to adapt to these conditions to sustain production

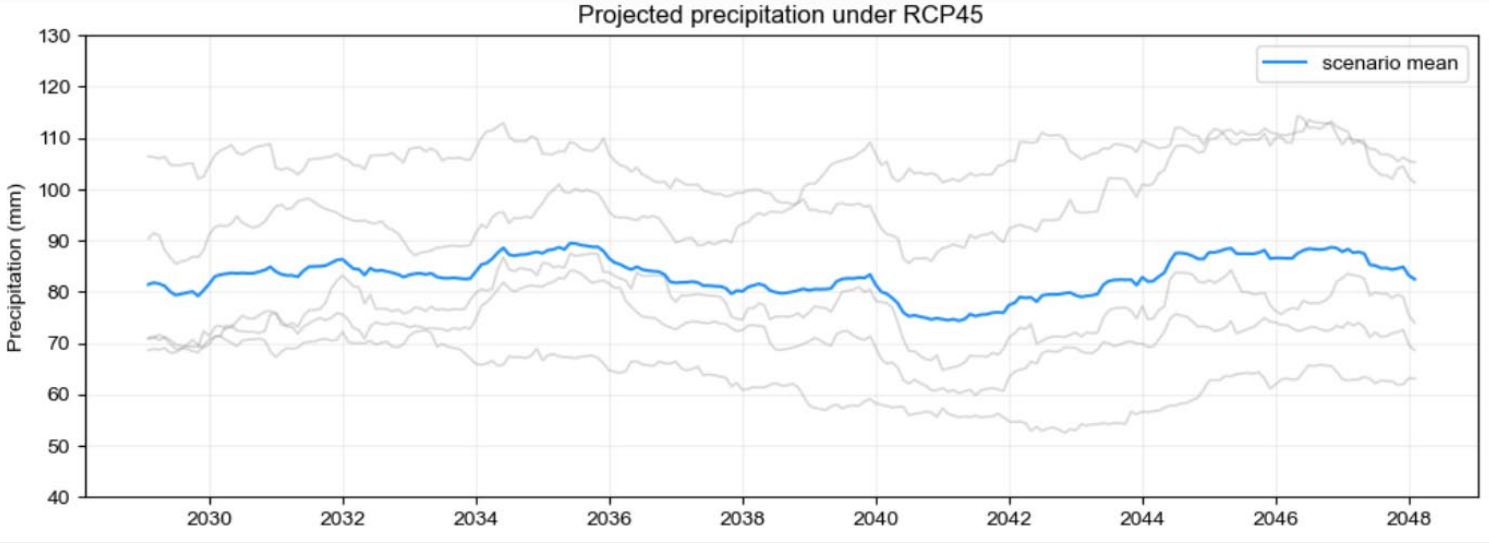
SWAT
Soil & Water Assessment Tool
26-30 JUNE 2023 AARHUS, DENMARK

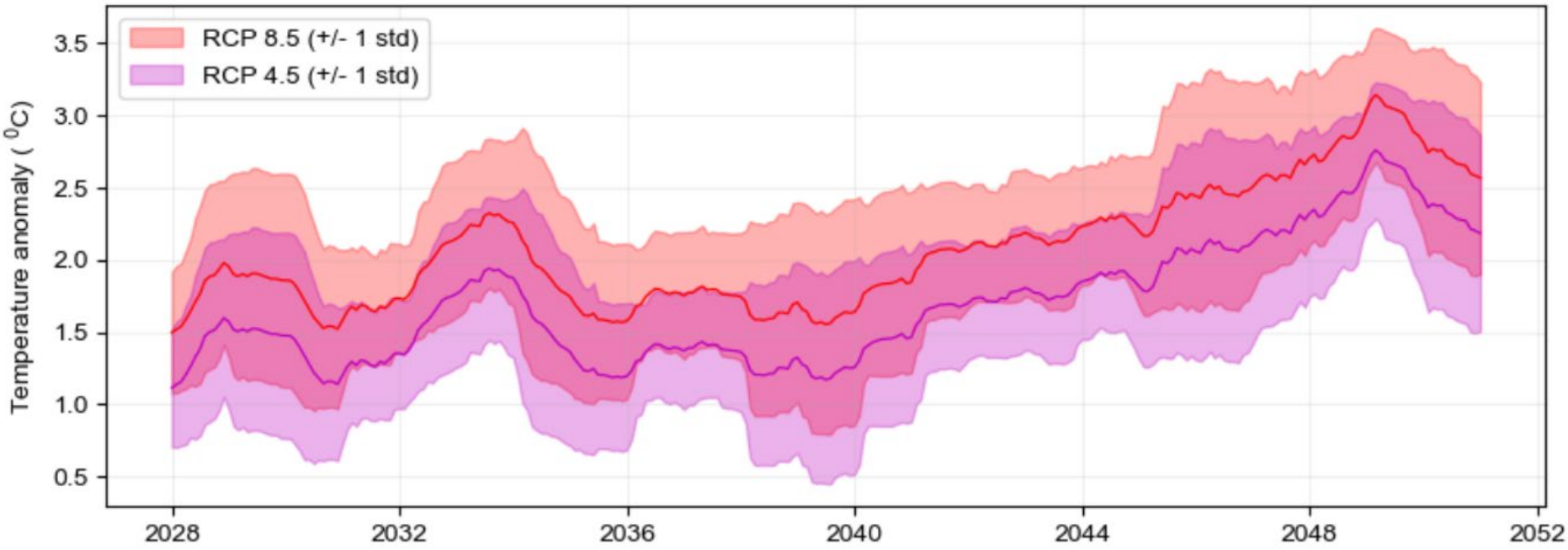
VUB HYDR HYDROLOGY & HYDRAULIC ENGINEERING DEPARTMENT

Implications of Climate on crop water use in a tropical catchment. Nyando Catchment, Kenya

Katoria Lekarkar, Albert Nkwasa, Douglas Nyolei, Ann van Griensven


Projected precipitation under RCP85
scenario mean
Precipitation (mm)
130
120
110
100
90
80
70
60
50
40
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048


Projected precipitation under RCP45
scenario mean
Precipitation (mm)
130
120
110
100
90
80
70
60
50
40
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048

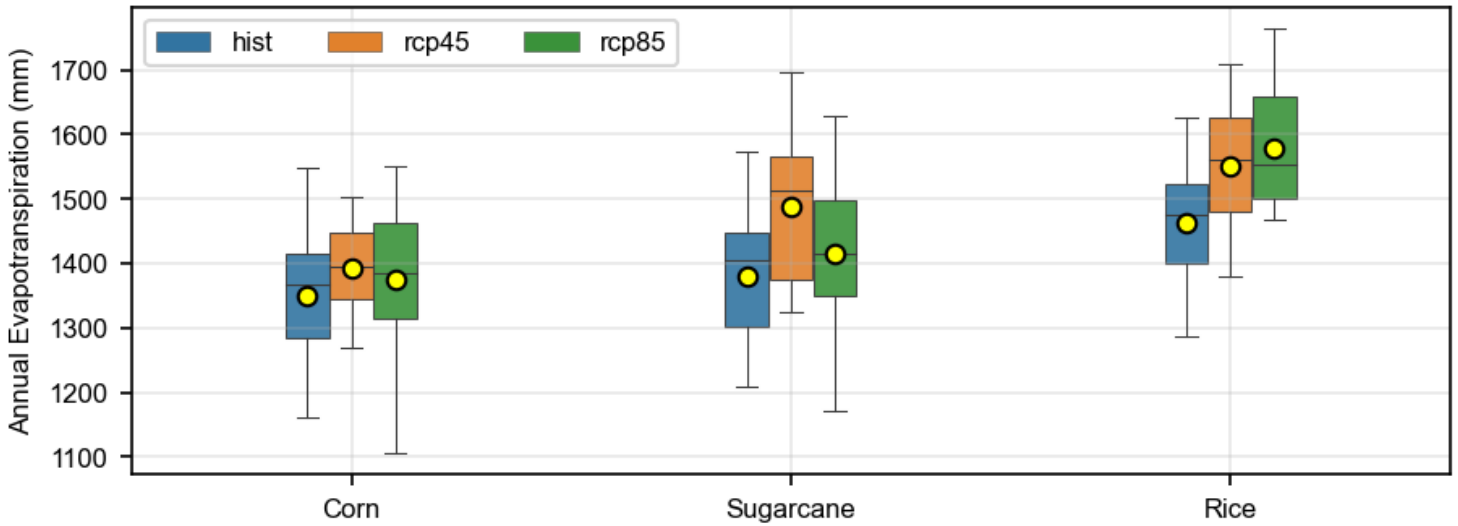

RCP 8.5 (+/- 1 std)
RCP 4.5 (+/- 1 std)
Temperature anomaly (^{0}C)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2028
2032
2036
2040
2044
2048
2052

CC outlook: 2026-2050

CC impacts on crop water use

Increased Temp: Higher moisture holding capacity of the atmosphere: 7%/degree of warming

→ Increased evaporative demand: Higher ET,



→ Increase highest in RCP4.5

→ Water availability limitations under RCP8.5