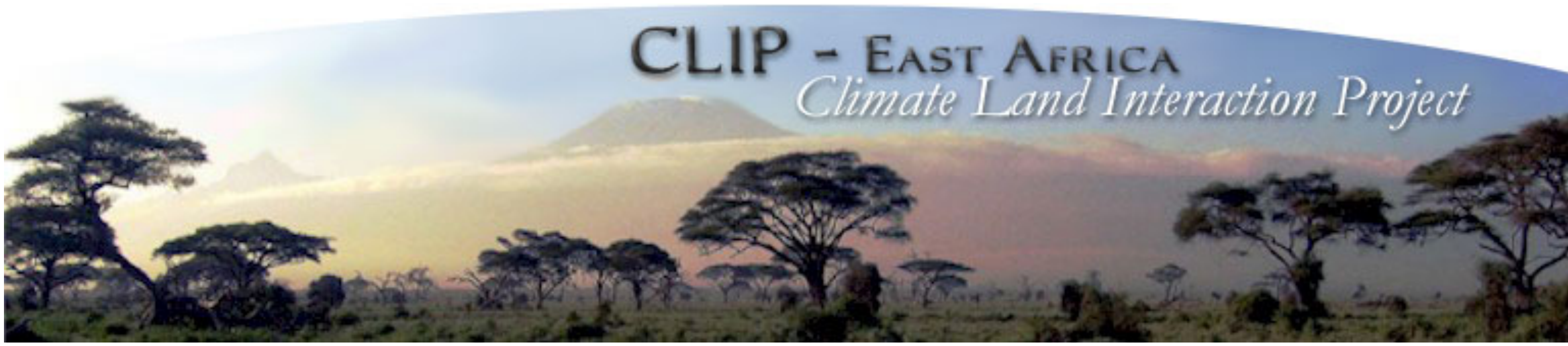

Impact of Climate Change and Adaptation Technologies on Crops in the Rufiji Basin, Tanzania

Institute of Resources Assessment,
University of Dar es Salaam, November 9, 2015

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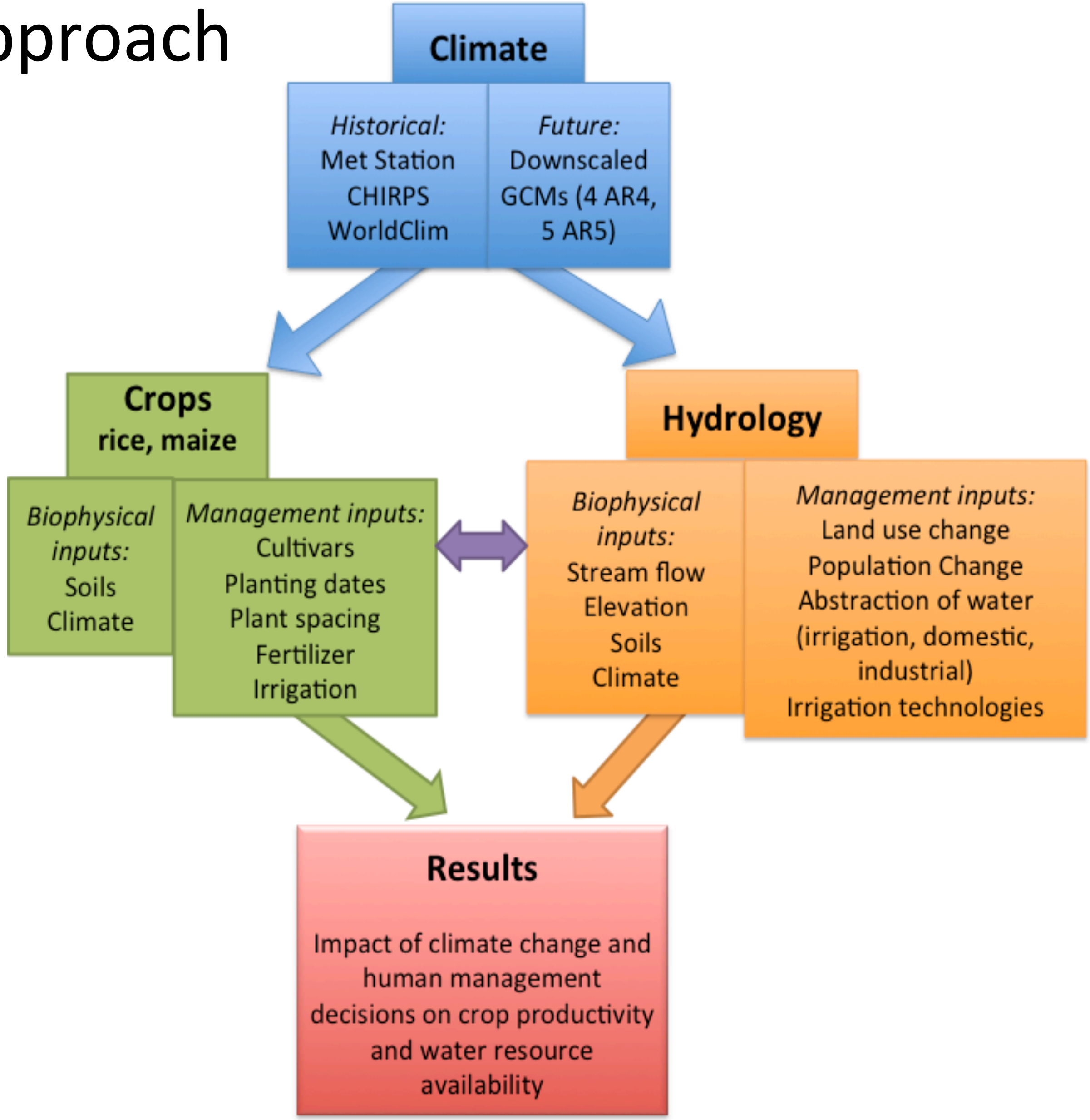
Study Approach



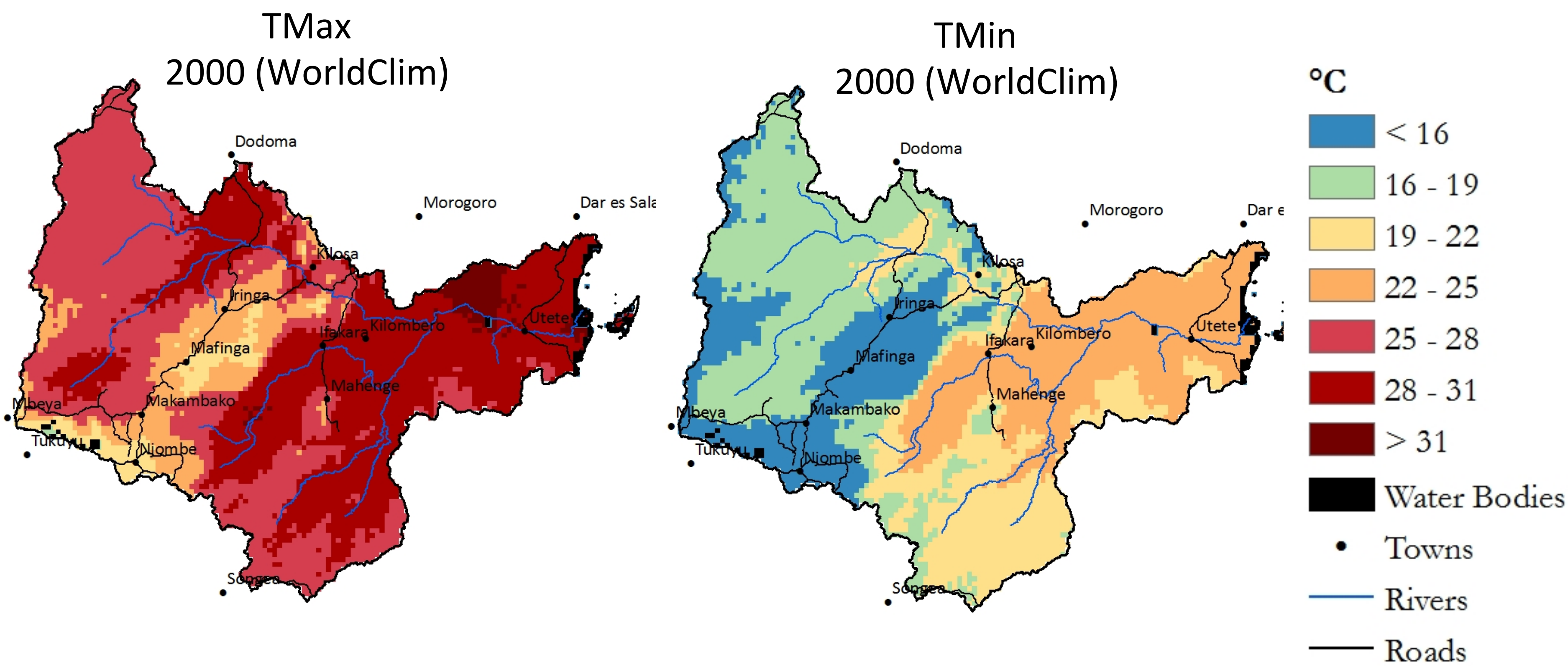
Crop Modeling Methodology

- Climate data: Historical (TMA, CHIRPS, WorldClim), and 2050 (4 AR4 SRES A1B, and 5 AR5 RCP 8.5 GCMs downscaled to 6 km)
- Process-based crop simulation modeling, CERES Maize and Rice models embedded in DSSAT v4.0.
- Crop model calibration for Rufiji Basin:
  - Soils from FAO soils map calibrated with soil profiles from WISE database (ISRIC).
  - Local crop varieties validated against observed data (Rice: Pussa 33, Kilombero, TXD-85; Maize: Katumani, H-614).
  - Agronomic practices similar to farmer practices (surveys).
  - Climate models (GCMs) downscaled using local data.
- Ag practices:
  - Short- and long-duration rice and maize cultivars
  - Low and moderate Nitrogen fertilizer levels
  - Rainfed and irrigated.

How does climate change affect crop growth?

1. Rising temperatures:
   a. Higher evapotranspiration and water demand
   b. Faster maturity and so lower yields
   c. Hot temperatures (>35°C) inhibit growth, reproduction.
2. Changing precipitation
   a. Declining rainfall causing water deficits
   b. Fewer, more intense storms cause higher runoff, less water available in soil, erosion
   c. Variable onset and ending of rainy seasons, possible shorter rainy seasons, and dry spells within rainy seasons, cause water stress.

Current Tmax and Tmin Temperatures Dec-May



Rice and Warming Temperature

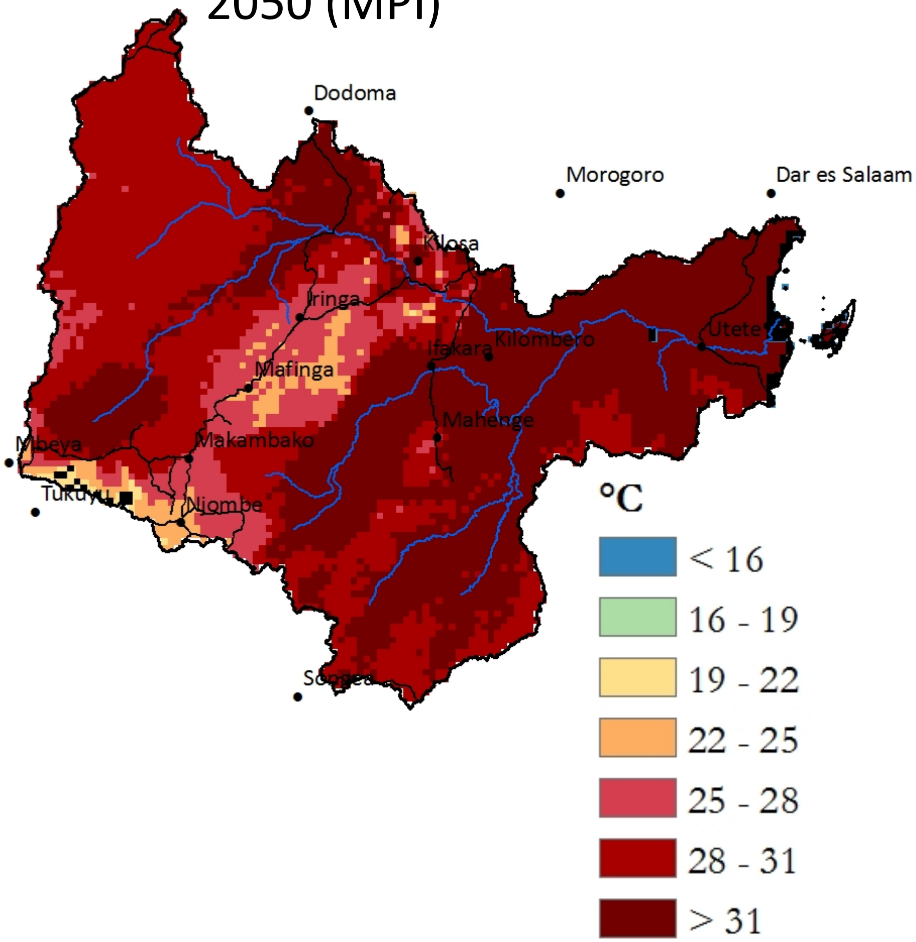
1. Rice grows best in warm daytime temperatures (Tmax), but extreme heat events over 35°C for even a few hours can damage plant processes and lead to lower yields and sterility.
2. Warmer nighttime (TMin) temperatures reduces yields; yields decline 10% for every 1°C rise in minimum temperatures.
3. Rice is sensitive to cold temperatures, which slows growth and damages the plant causing smaller or failed harvests.
4. Our simulated yields in Rufiji were highest when TMax ranged from 28°C to 30°C and TMin ranged from 20°C to 23°C.
5. In the Rufiji Basin, hot temperatures over 35°C are more frequent, and minimum temperatures are rising faster than maximum.
6. Higher zones are warming rapidly and may become favorable. The zone of highest yield will move up the elevation gradient.
7. The lowest zones can be expected to become too warm for optimal yields.

Maize and Warming Temperatures

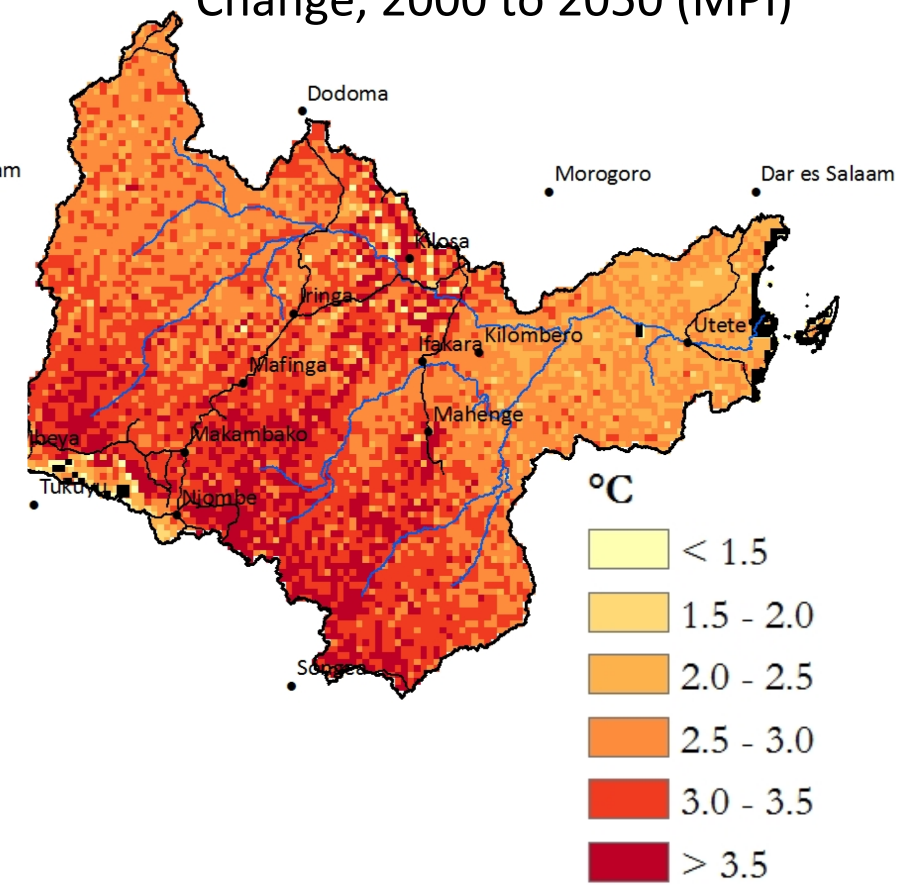
1. Maize temperature range is greater than for rice, especially its ability to withstand cooler temperatures.
2. Temperatures above 35°C are considered inhibitory at whatever stage of growth.
3. The warmer the temperature, the faster the plant matures (phenology). In Rufiji Basin, the more rapid phenology leads to lower yield as the plant matures rapidly before grains are large.
4. Warmer nighttime temperatures reduce its yield while increasing its water demand.
5. Recent temperature trends in Rufiji—more frequent hot days, warmer nighttime temperatures, and generally warmer temperatures—negatively affects maize growth and reduce maize yields.

Tmax in 2050, and Change 2000 to 2050 MPI GCM, Dec-May

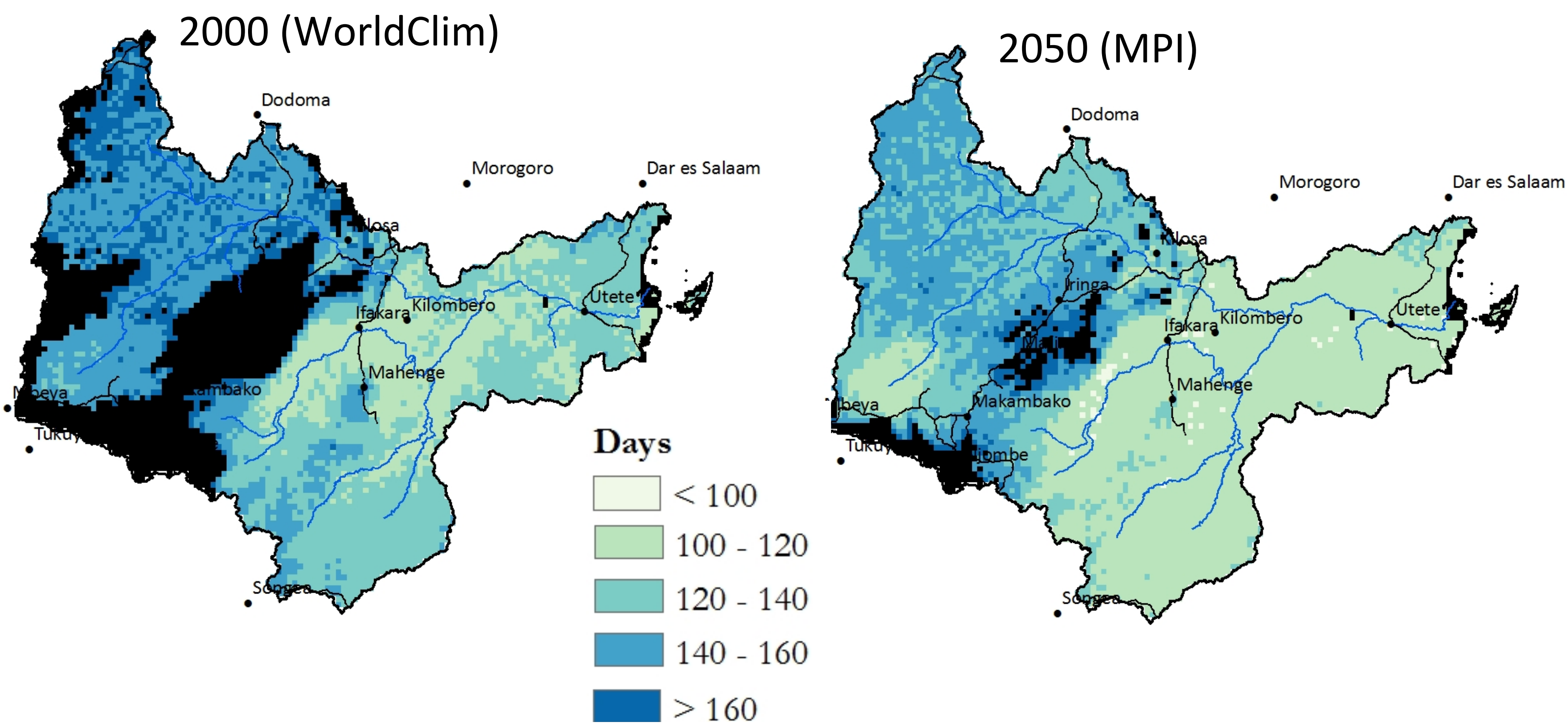
2050 (MPI)



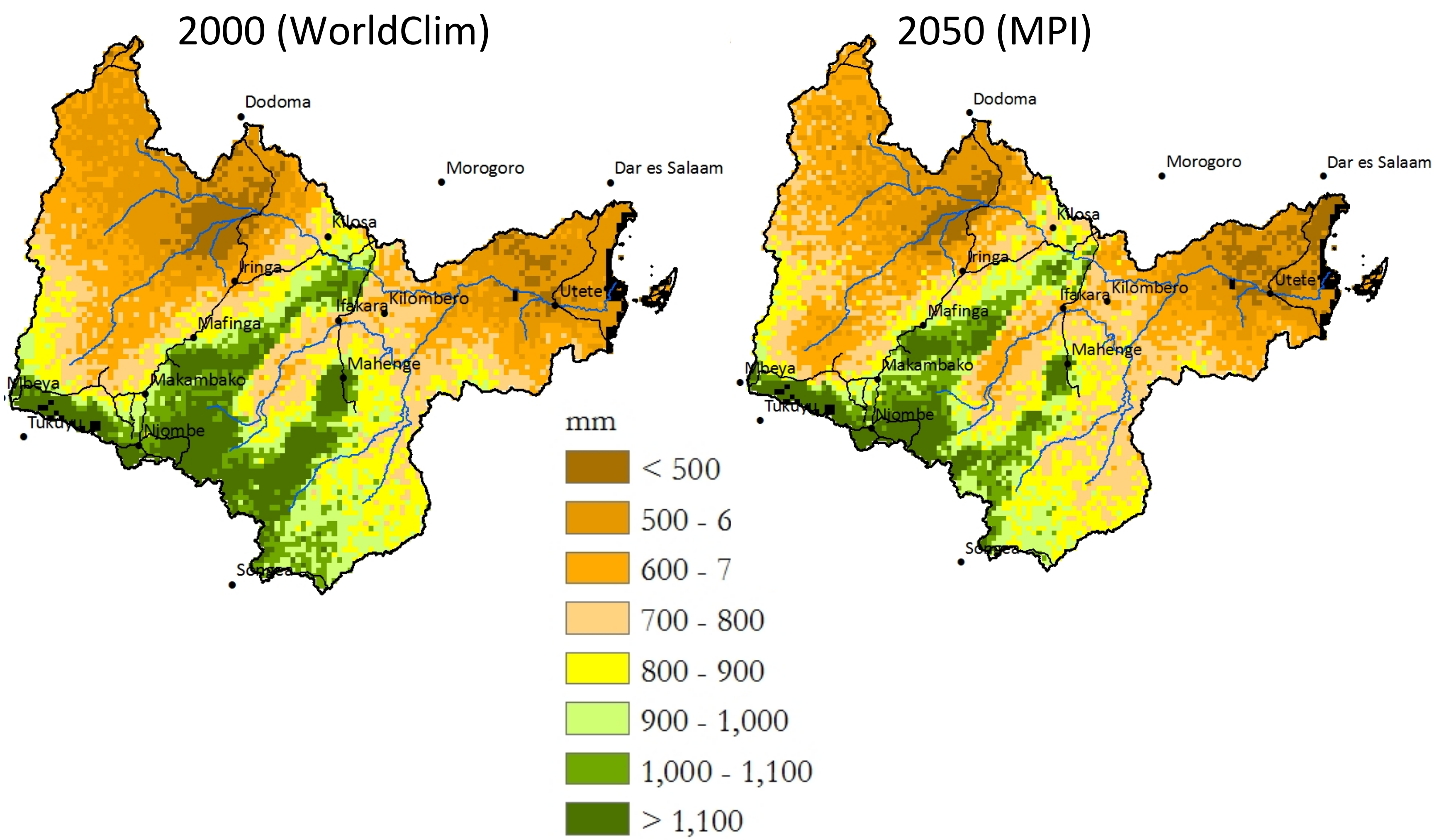
Change, 2000 to 2050 (MPI)

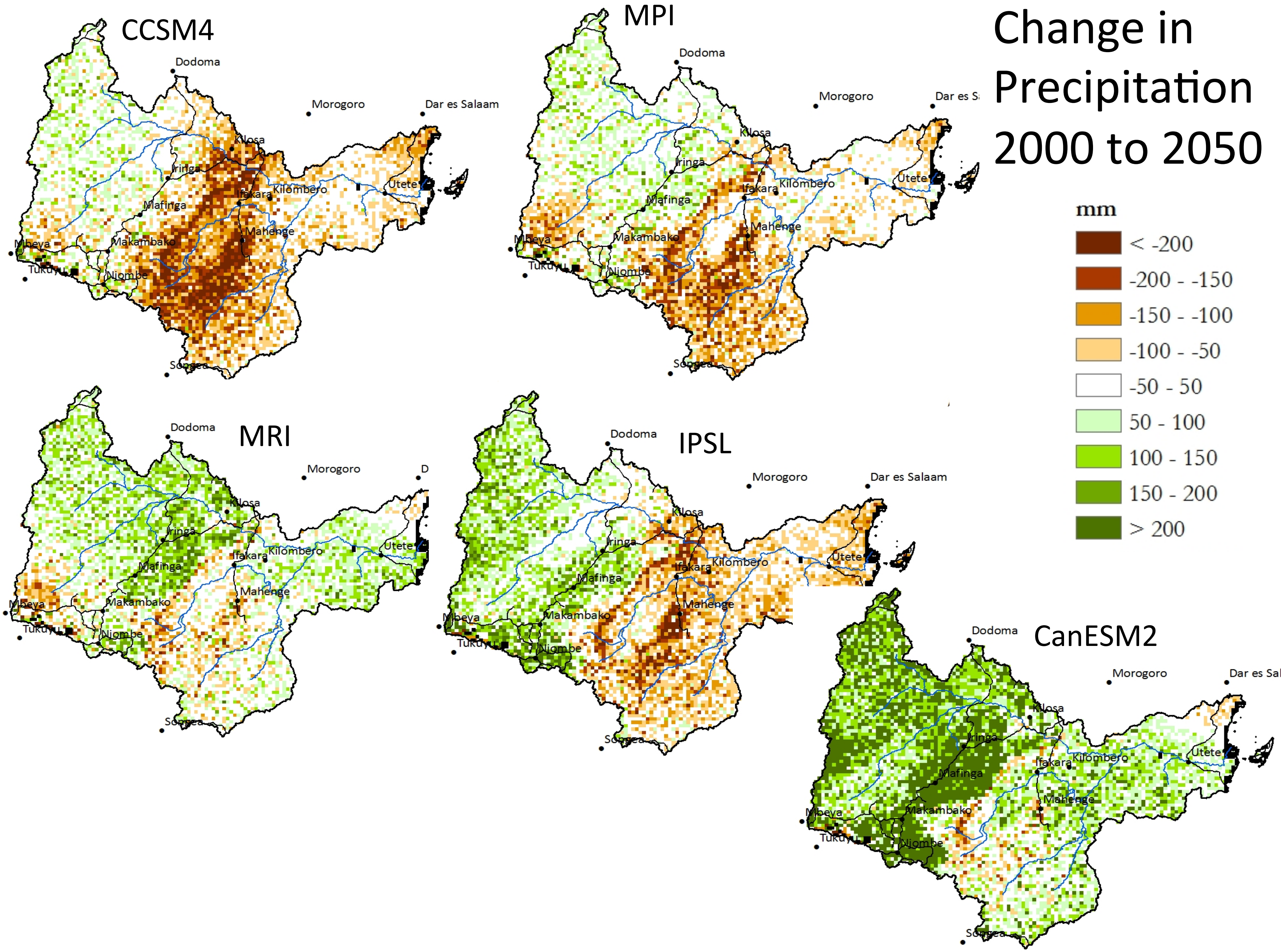


Days to Maturity of Rice (Dec. planting): 2000 & 2050



Precipitation Dec-June, 2000 & 2050 (MPI)





Change in Precipitation 2000 to 2050
mm
< -200
-200 - -150
-150 - -100
-100 - -50
-50 - 50
50 - 100
100 - 150
150 - 200
> 200
CCSM4
MPI
MRI
IPSL
CanESM2
Dodoma
Morogoro
Dar es Salaam
Kilosa
Iringa
Kilombero
Ifakara
Utete
Mafinga
Mahenge
Mbeya
Makambako
Tukuyu
Njombe
Songea

Impact of Climate Change on Rice and Maize? Potential of Irrigation & Nitrogen to Mitigate Impacts

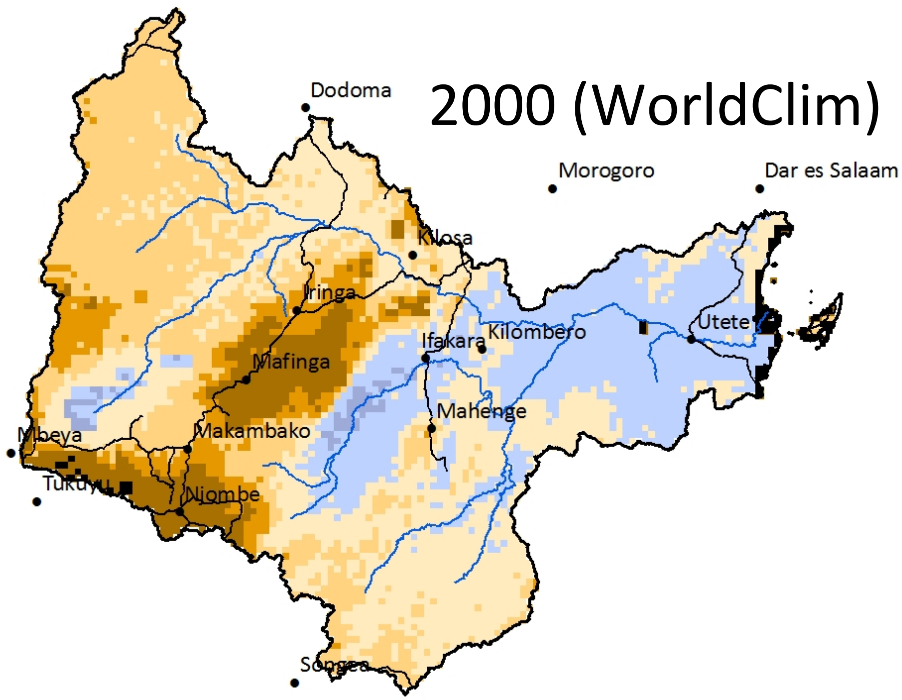
Rice Modeling

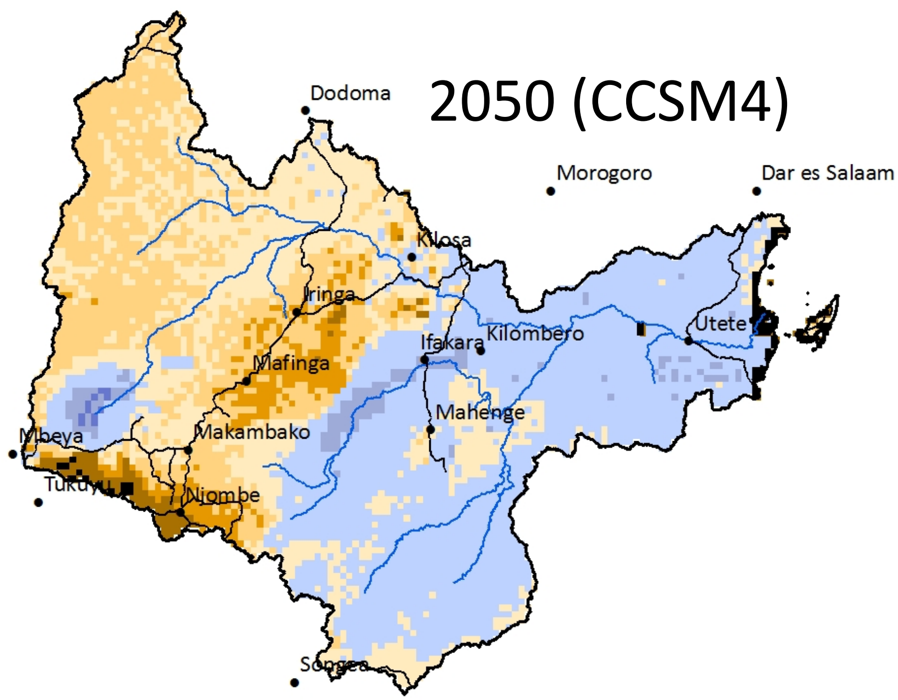
- Simulated rainfed rice grown during the rainy season (December transplanting) for current and 2050 climate conditions.
- Also simulated irrigated rice, transplanted in June, using same climates and varieties.
- Shown are results from GCMs MPI and CCSM4 of variety TXD-85 with 100 kg N

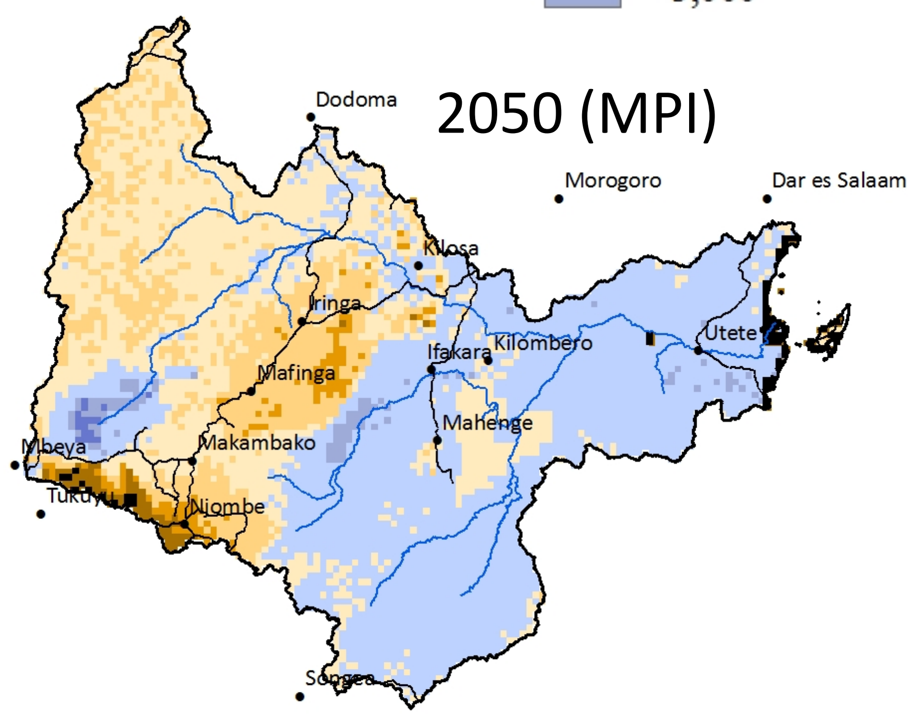
Rainfed Rice Yield
2000 and 2050

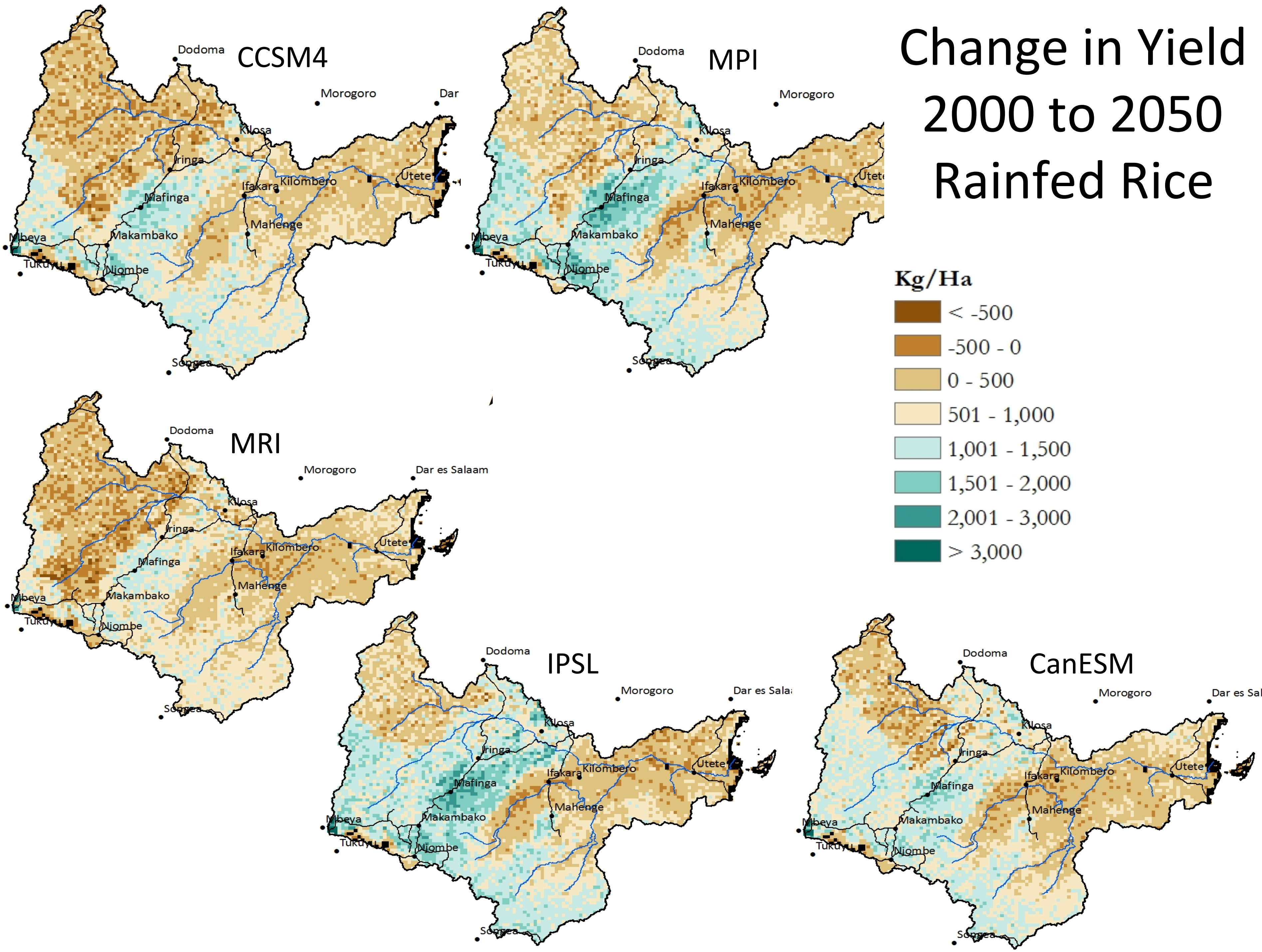
Kg/Ha

- 1 - 1,000
- 1,001 - 2,000
- 2,001 - 3,000
- 3,001 - 4,000
- 4,001 - 5,000
- > 5,000

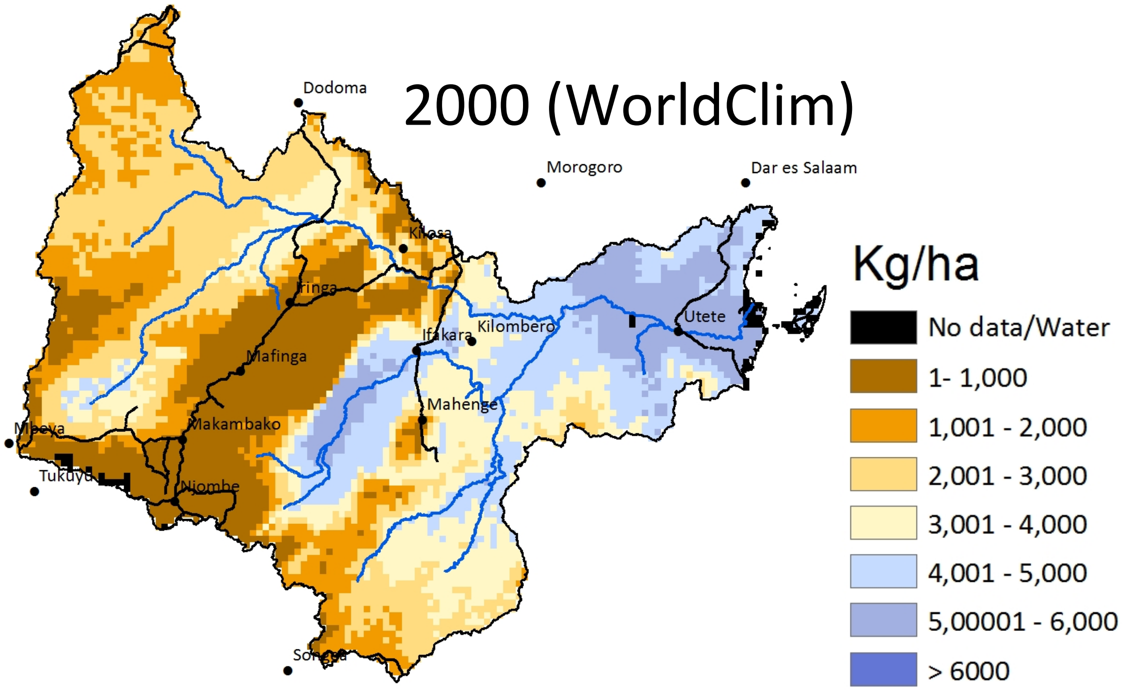


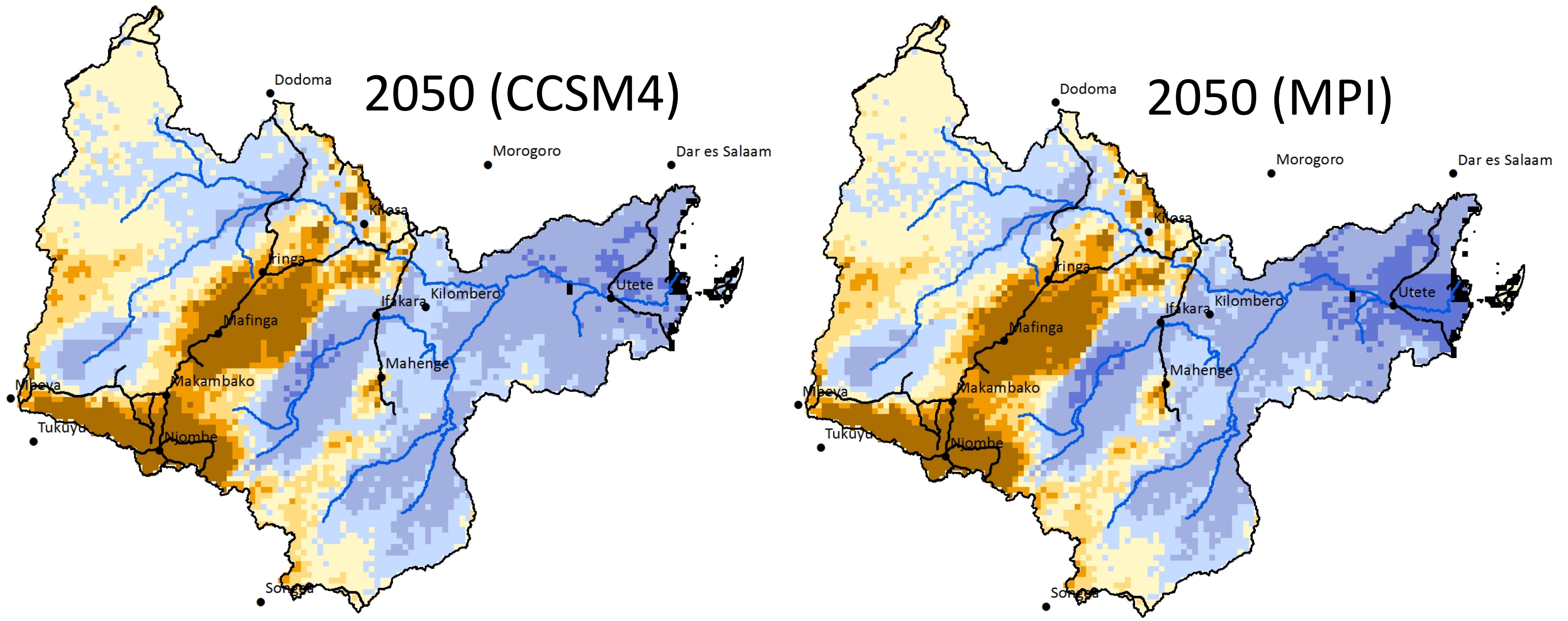




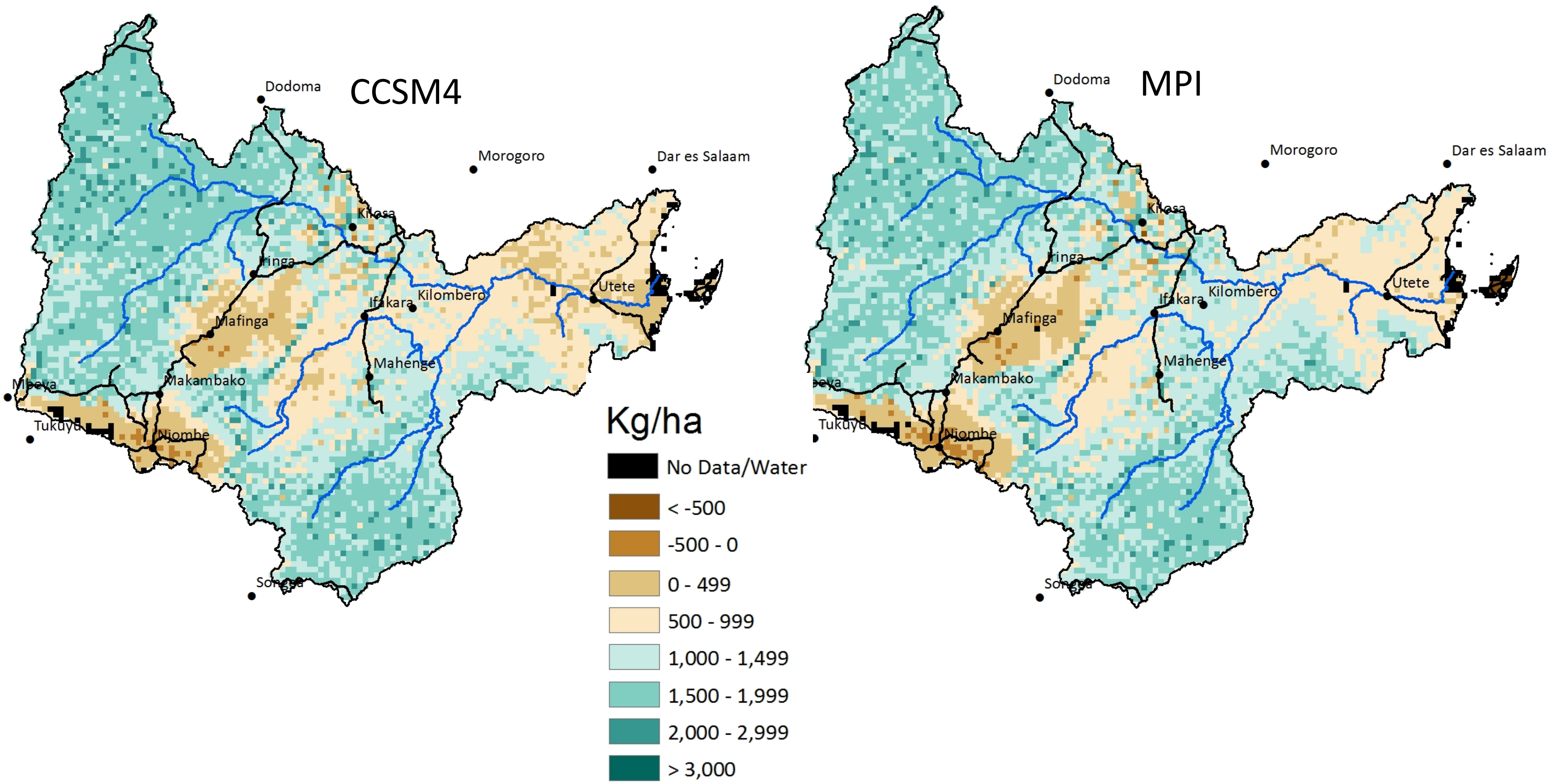

Change in Yield
2000 to 2050
Rainfed Rice
CCSM4
MPI
MRI
IPSL
CanESM
Dodoma
Morogoro
Dar
Dar es Salaam
Kilosa
Iringa
Ifakara
Kilombero
Utete
Mafinga
Mahenge
Makambako
Mbeya
Tukuyu
Njombe
Songea
Kg/Ha
< -500
-500 - 0
0 - 500
501 - 1,000
1,001 - 1,500
1,501 - 2,000
2,001 - 3,000
> 3,000

Irrigated Rice Yields June transplanting 2000 and 2050





Change in Irrigated Rice Yield, 2000 to 2050 (June transplanting)



Adaptation Implications for Rice

- Rice yields greatly benefit from N applications, but the benefits are lower in the very warm or drier areas. Benefits will decline in future.
- In the future, yields will improve in the Highlands, but the highest yields will remain in the lowlands.
- However, rainfed rice yields are expected decline in the future in the lowlands because of the impacts of hot temperatures on plant growth and, in some areas, worsening water deficits. Without supplemental irrigation during the rainy season, yields may decline.
- During the winter (June) planting, if the rice plants have sufficient irrigation and nutrients, yields will remain the same or even rise in the future in most areas.

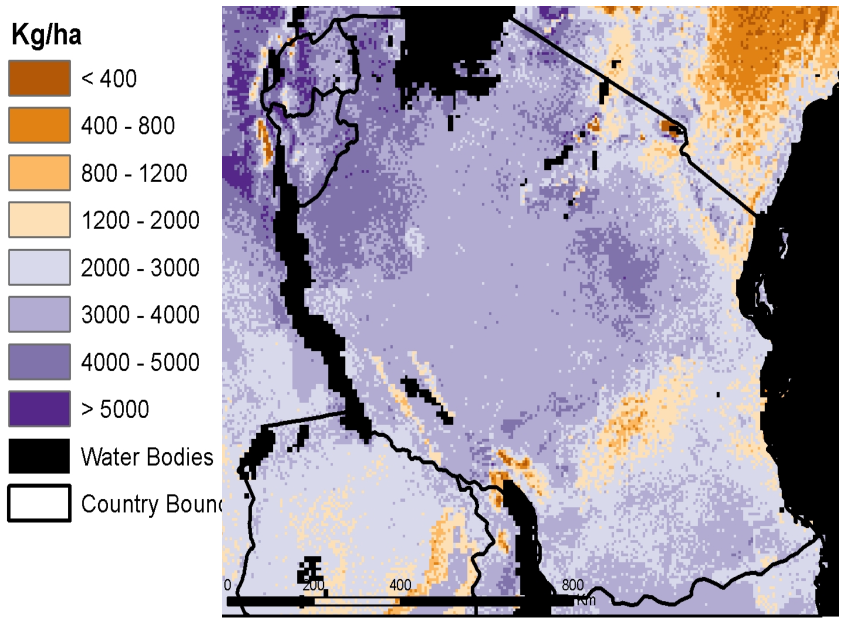
Maize Modeling

- Simulated rainfed maize in CERES Maize and the CERES maize model embedded in DSSAT.
- Would adaptation practices reduce impact of climate change? Examined climate change impact on benefits of irrigation during the rainy season, and Nitrogen fertilizer.

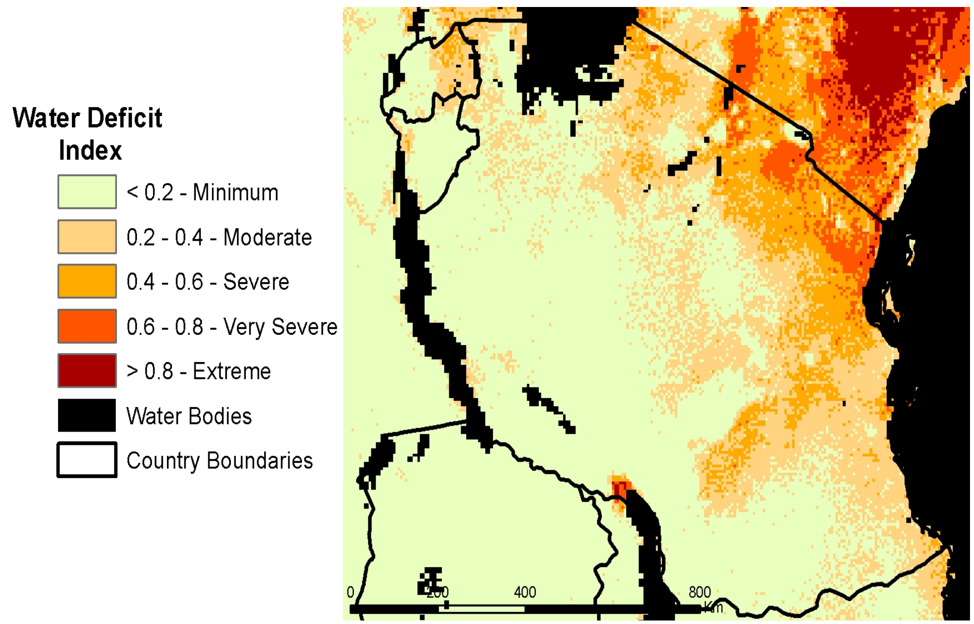
- Shown here are results of GCM HadCM3, variety H614, 85 kg/ha N in order to highlight effects of climate change.

Maize Yield and Water Deficit, 2000

Rainfed Yield, 2000

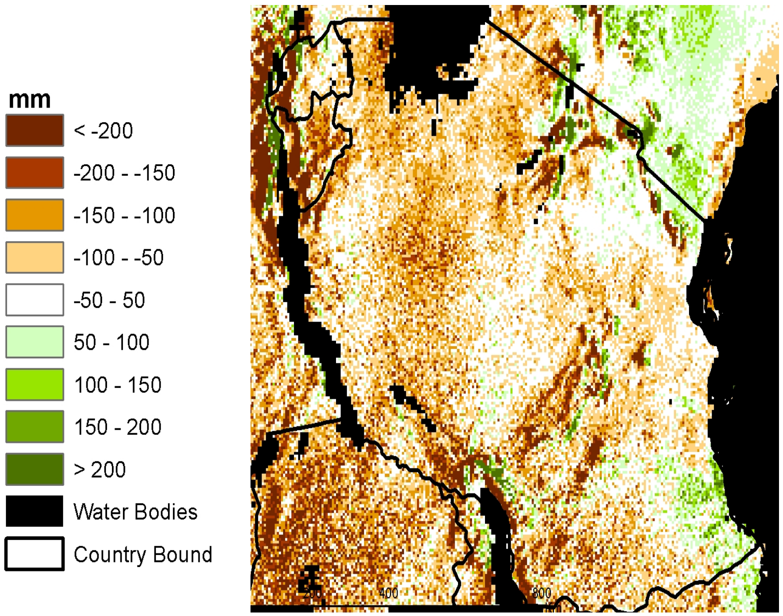


Water Deficit, 2000

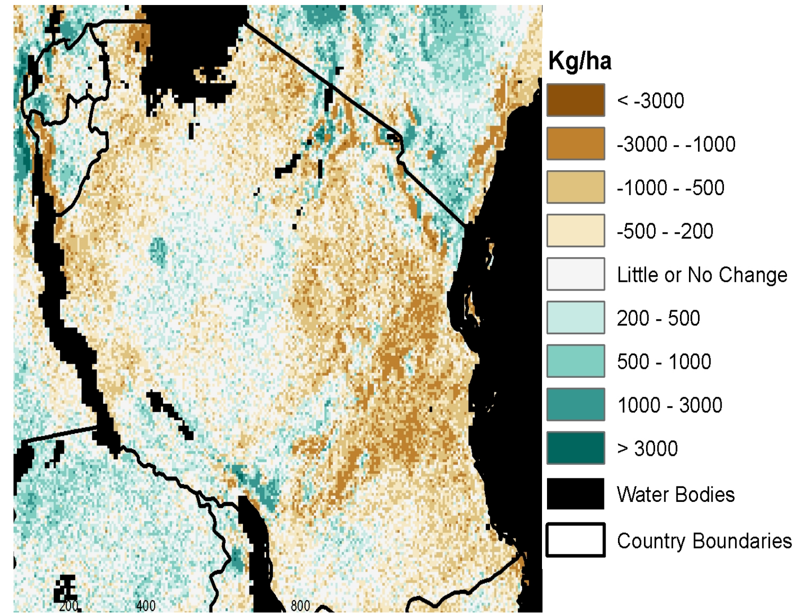


Perhaps the most important yield limiting factor in the region is water. Water deficits mostly mirror yields, confirming the critical nature of water. The Highlands have sufficient water but are too cool for maize.

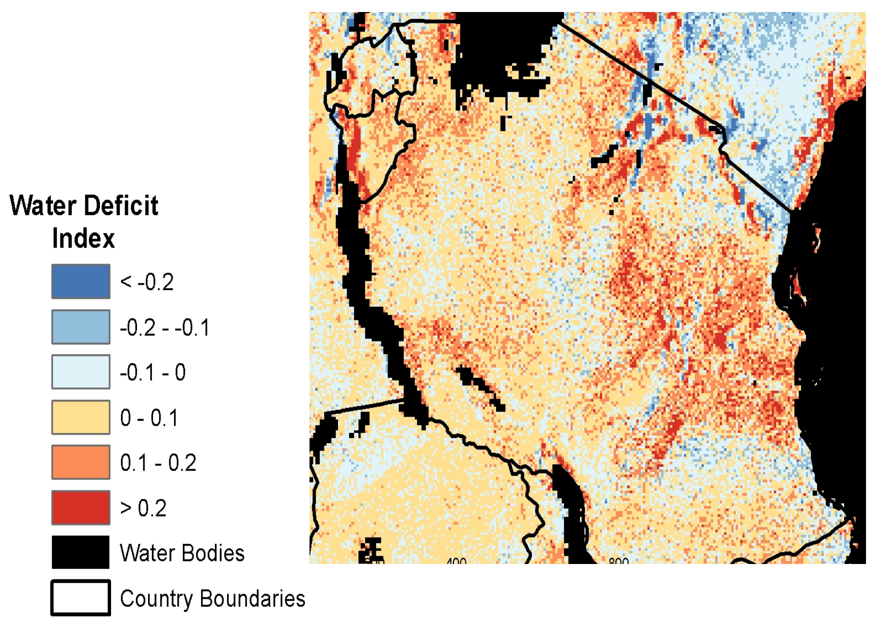
Change in Precipitation



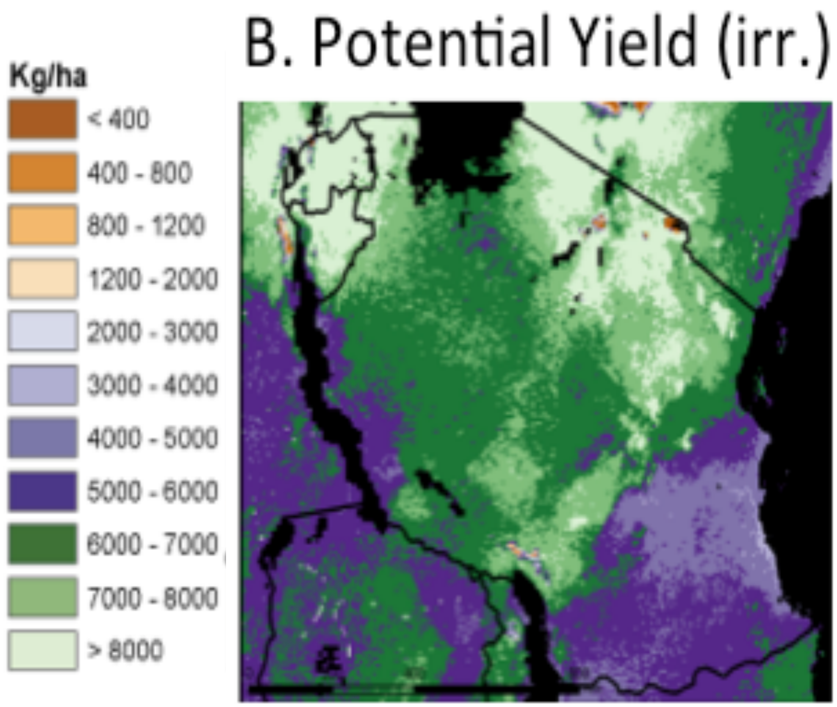
Change in Rainfed Yield

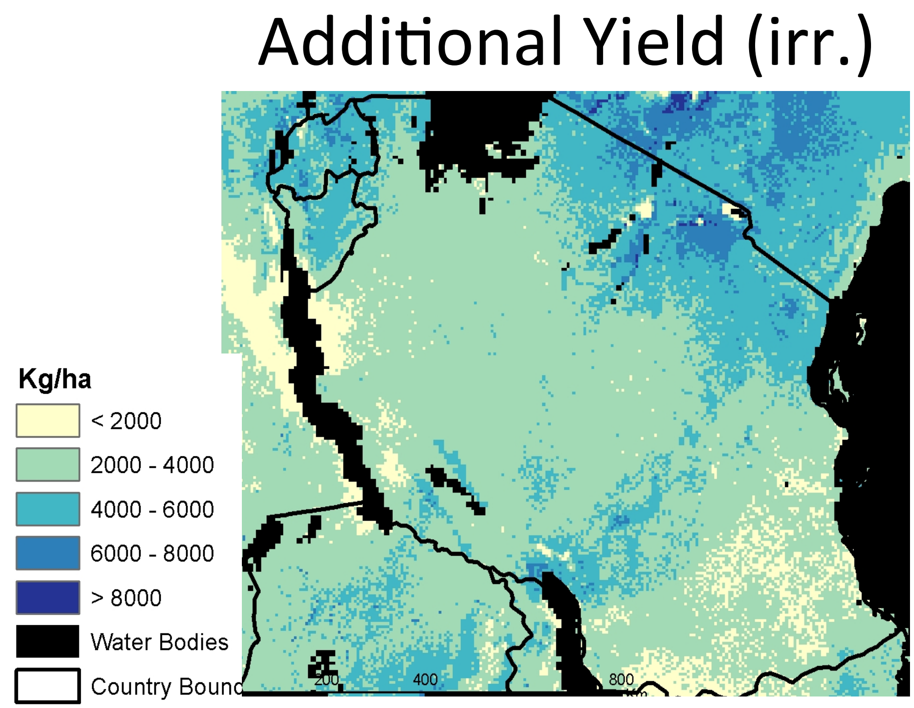


Change in Water Deficit



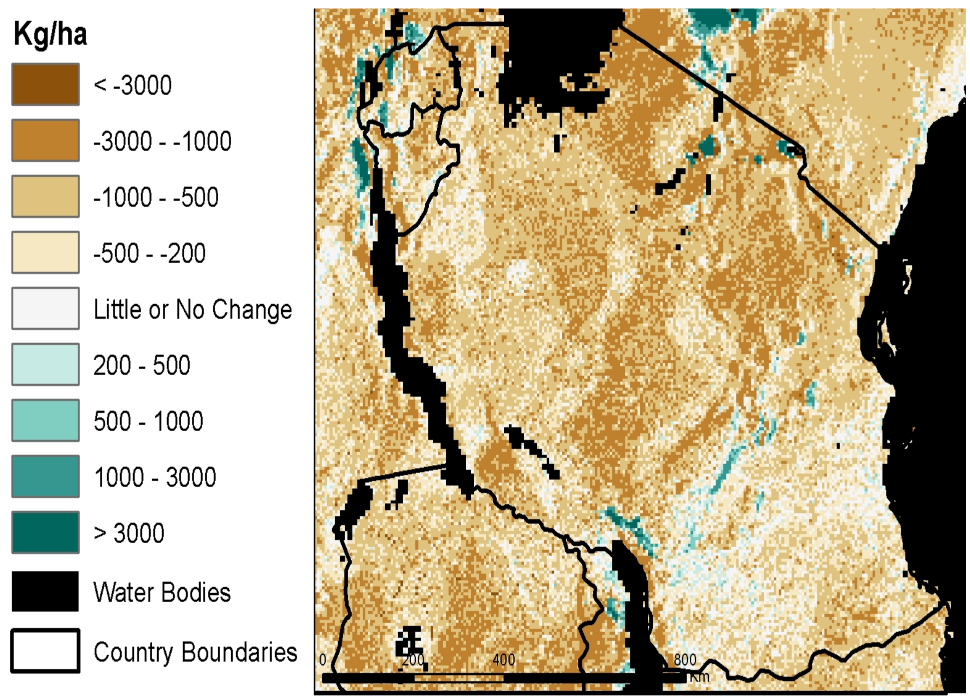
Maize Yield Benefits of Irrigation--2000





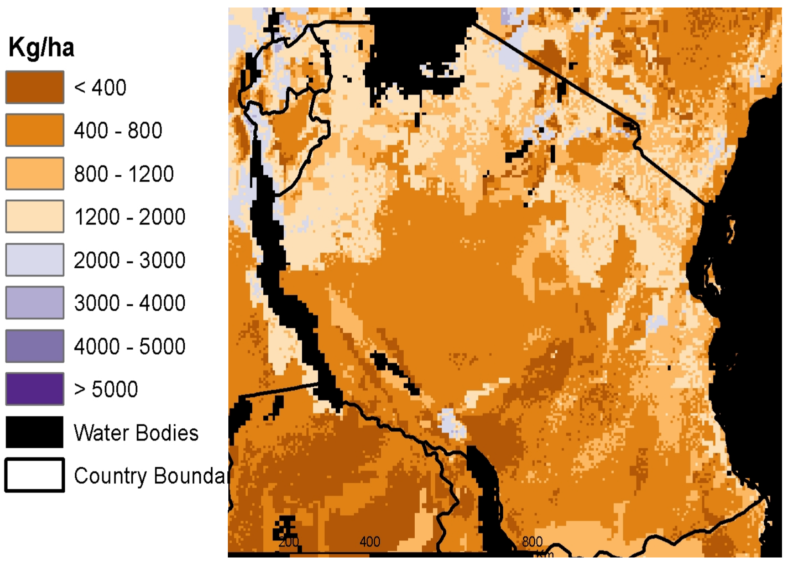
Impact of Climate Change on Potential (Irrigated) Maize Yields

Change in <u>Potential</u> Yield
2050-2000

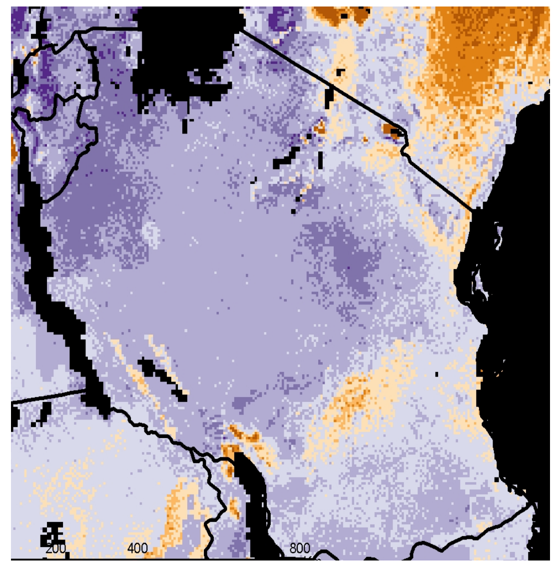


Nitrogen Benefits, 2000

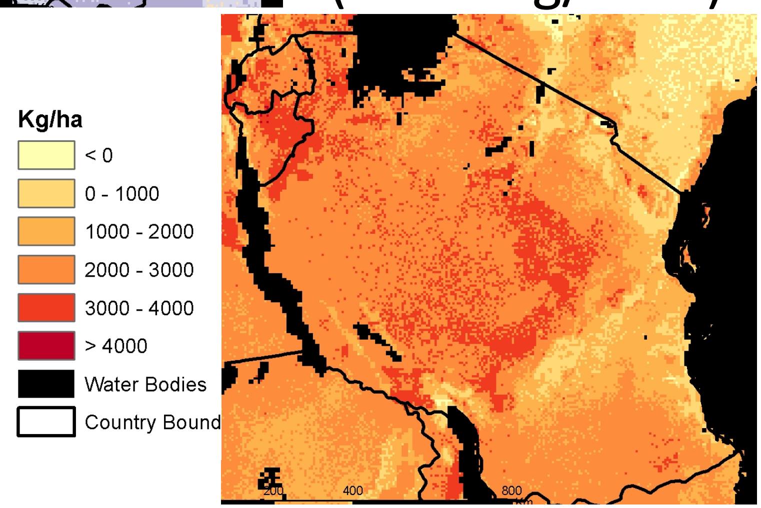
5kg/ha N



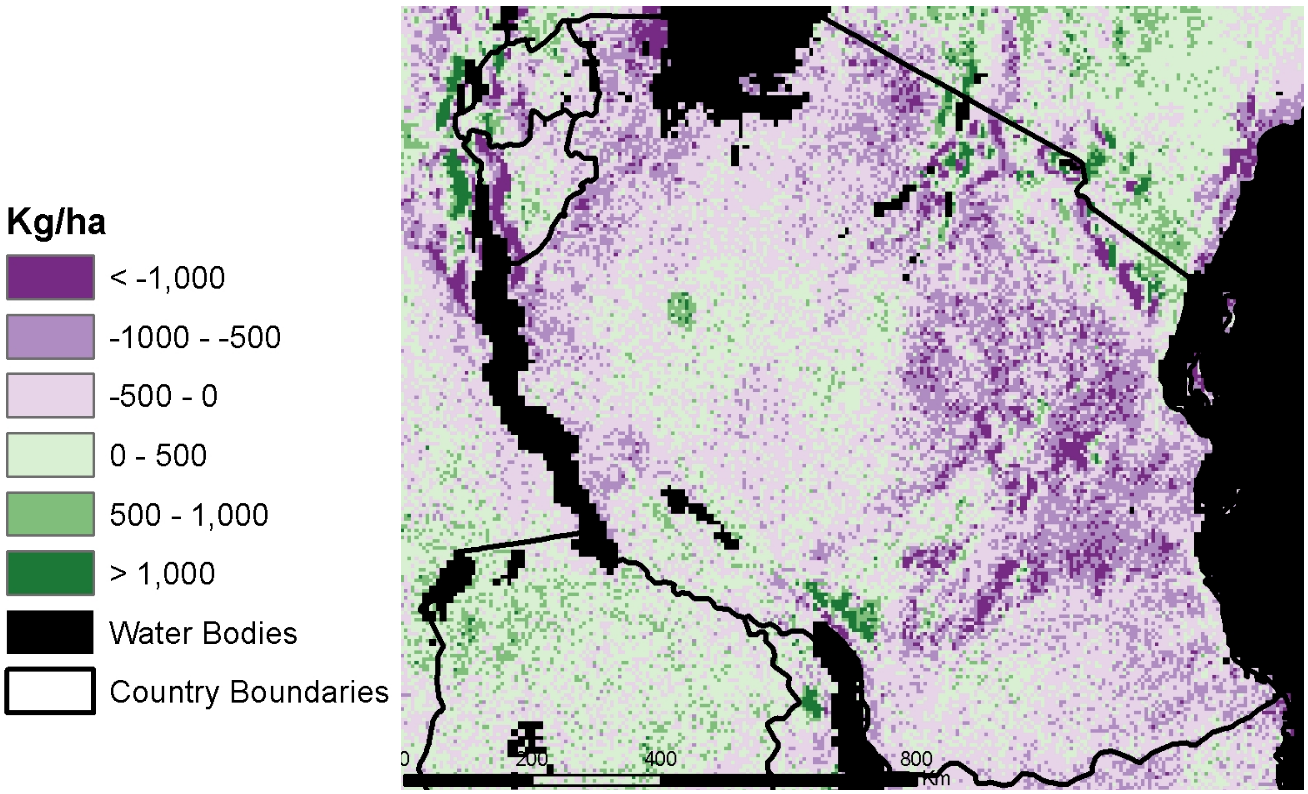
85kg/ha N



Nitrogen Benefit (85 – 5kg/ha N)



Impact of Climate Change on Benefits to Nitrogen, 2000 to 2050



Adaptation Implications for Maize

Implications for nutrient management

- Low fertilizer levels significantly limit current yields. With climate change, the benefits of fertilizer will decline, since its ability to increase yields diminishes with water deficits. Fertilizer will remain a critical management practice, however, especially in medium and high potential areas.
- In humid areas, using small multiple doses rather than single doses of nitrogen fertilizer is as important as the amount applied.

Implications for irrigation

- Irrigation in moderate temperature areas of would generate very large benefits
- Hot areas, and of course wetter areas, would benefit much less from irrigation.
- Benefits from irrigation will decline in the future due to hotter temperatures.

Implications for crop choice and crop breeding

- Maize, rice, bean and other crop varieties will need to be tolerant of warmer temperatures and extreme heat. Grains in particular will need to be resistant to the acceleration of plant maturity due to warmer temperatures.
- Some (not all) areas should move towards shorter-duration varieties for rainfed conditions.
- In areas of low and declining precipitation, varieties and crops resistant to within-growing season dry spells, especially during flowering, will produce more reliably.

Thank you!