COUNTING THE TRUE COSTS OF CLIMATE CHANGE

THE INTERNATIONAL CONFERENCE ON CLIMATE-CHANGE IMPACTS FOR SCIENTISTS & STAKEHOLDERS

11-13 OCTOBER 2017
POTSDAM, GERMANY

THE INTERPLAY OF WATER, FOOD AND ENERGY IN THE SUDAN

Climate change impact until 2050 and nexus interventions

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THE ECONOMY OF THE SUDAN

Sources of vulnerability

CLIMATE IN THE SUDAN

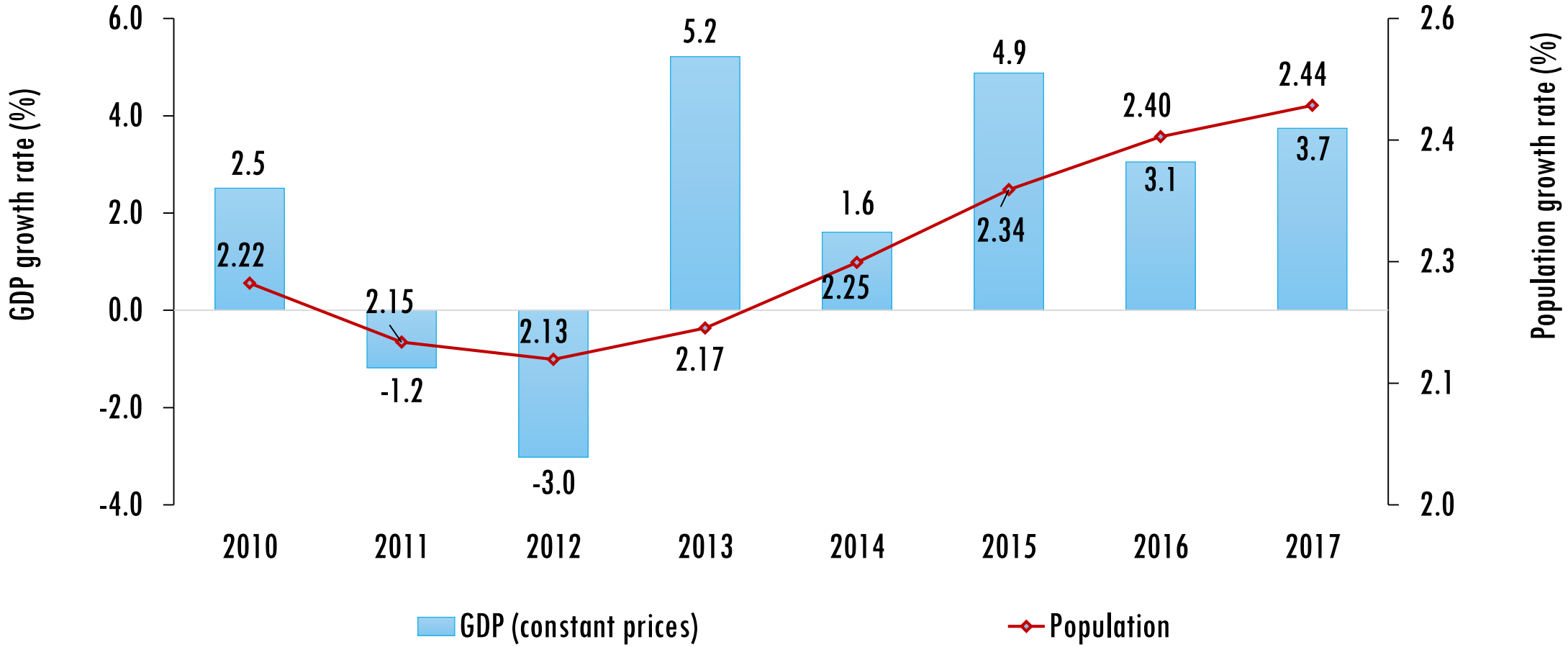
- 1.8 million km^2, a vast country with considerable diversity of ecology and people,
- Rainfall patterns: five vegetation zones from North to South:

1)	Desert	with 0-75	mm of precipitation,
2)	Semi-desert	with 75-300	mm,
3)	Low rainfall savannah	with 300-800	mm,
4)	High rainfall savannah	with 800-1500	mm, and
5)	Mountain vegetation	with 300-1000	mm.

MEPD, 2015

POLITICS AND STRUCTURAL CHANGES

➲ The July 2011 secession:



IMF (2016) and UN (2015)

LIVELIHOODS -1-

➲ Food demand (until 2030):

- Staple foods: from 6.5 million tonnes in 2010 to 10.1 million tonnes in 2030,
- Dairy products from 6.3 to 9.7 million tonnes and sugar from 0.9 to 3.4 million tonnes,
- Between 2017 and 2030:
  - Demands increase by 35%, 56% and 157%, respectively,
  - Demands for fats and meat products increase by 100% and 22%,

➲ Food production (until 2030):

- Between 2017 and 2030:
  - Staple foods, dairy products, and sugar increase by 6.8%, 56%, 21%, respectively,
  - Fats and meat products increase by 14% and 23%, respectively.

OECD-FAO (2017)

LIVELIHOODS -2-

➲ The friendship between Agriculture, Rural households and Poverty in the Sudan:

- 73% of the population live in rural areas,
- 58% of rural households lives below the poverty line (27% for urban households),
- The Poor are very likely reliant on agriculture: 65.4% of rural population are employed in agriculture (8.9% in urban areas).
- 61% of households in quintile 1 rely on agriculture compared to 20% in the wealthiest quintile

➲ Climate and Agriculture in the Sudan:

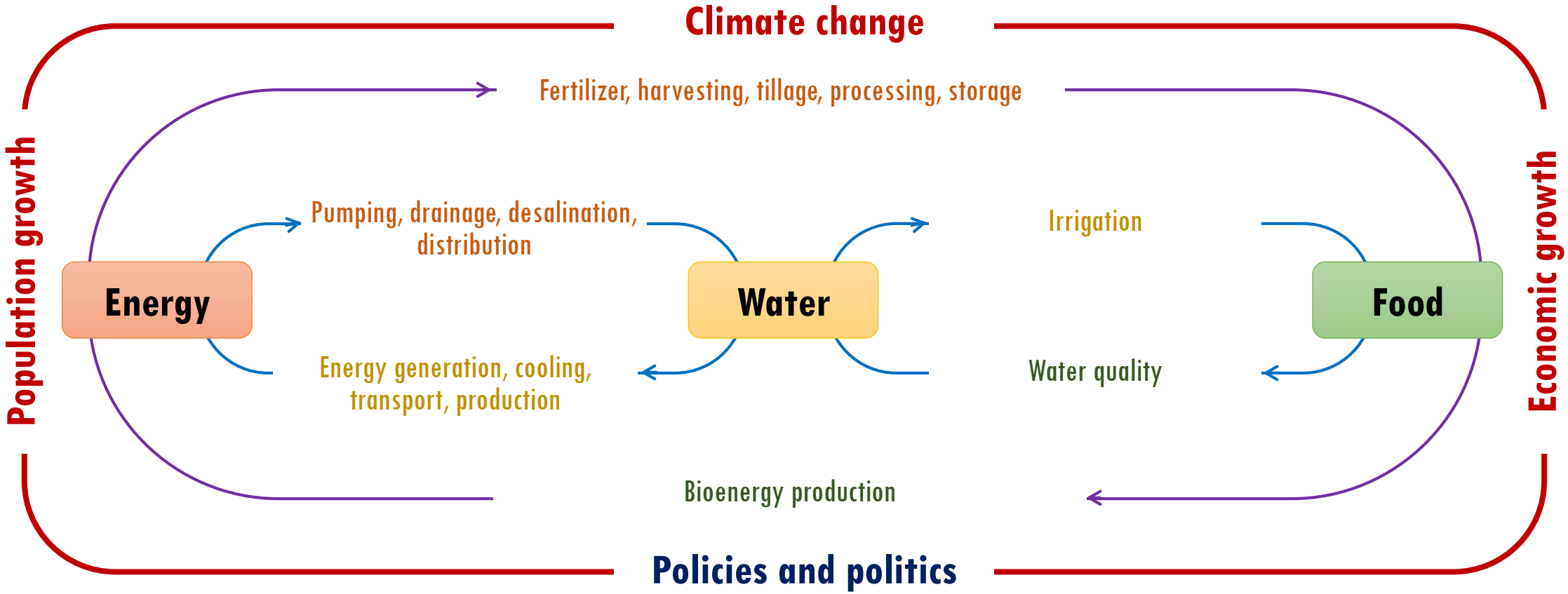
- Besides population and income growth, demand for food, water and energy, the Sudan is influenced by various environmental changes.
- Some happened in the past; several are happening and others projected to happen:
  - Frequently: increases in temperature, various floods, rainfall variability and concurrent droughts.
  - Less frequently: sea level rise, changes in seawater temperature and seawater salinity.
- Agriculture makes 1/3 of the GDP, 1/2 of foreign exchange and provides livelihoods to 65% of the people
  - 93% of annually cultivated land in the country is rainfed in 2016.

CBoS, 2016; MHRDL, 2013; FAO, 2017; USAID, 2016; FAO, 2015; Sayed and Abdala, 2013; Taha et al., 2013)

THE NEXUS SECTORS IN THE SUDAN

An overview

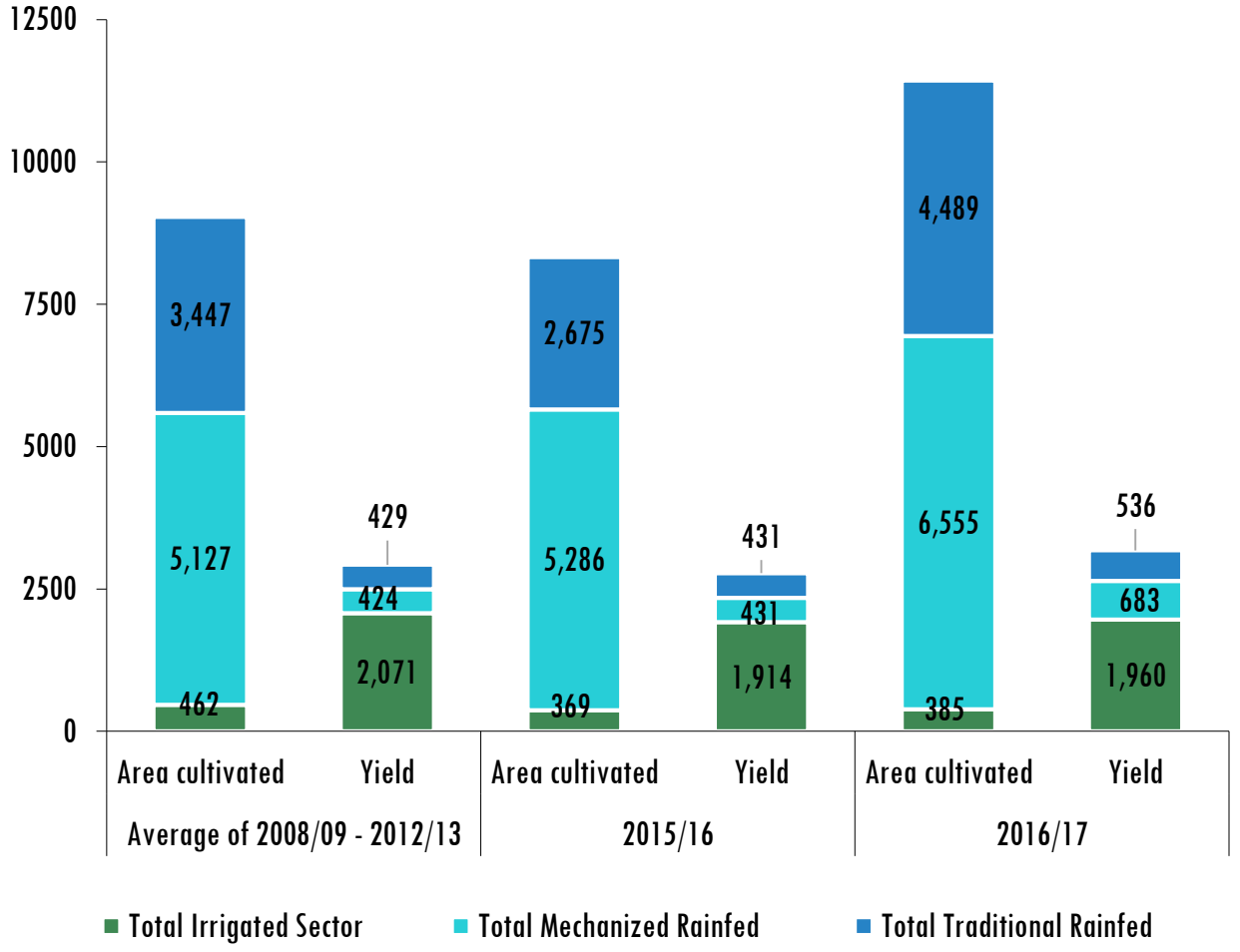
THE NEXUS SECTORS IN THE SUDAN



Inspired by Mohtar and Daher (2012)

AGRICULTURE ⚖ FOOD?

- Rainfed (93% of the land) and irrigated:
  - Cropping: 39% of the agricultural GDP (2015/16)
  - Livestock: 61% and
  - Forestry/fisheries: 1%.
- 56.3 million ha are arable land, only 30% is cultivated (16.9 million ha)
- Agriculture operates below its productivity potential (sorghum, cotton, groundnuts, sesame, millet and wheat)
- Fertilizer usage:
  - Ranked 129th from 155 countries.
  - Average is 7.3 kg/ha compared to 17 kg in Ethiopia (ranked 115th).



CBoS (2016); World Bank (2015); MAF (2017)

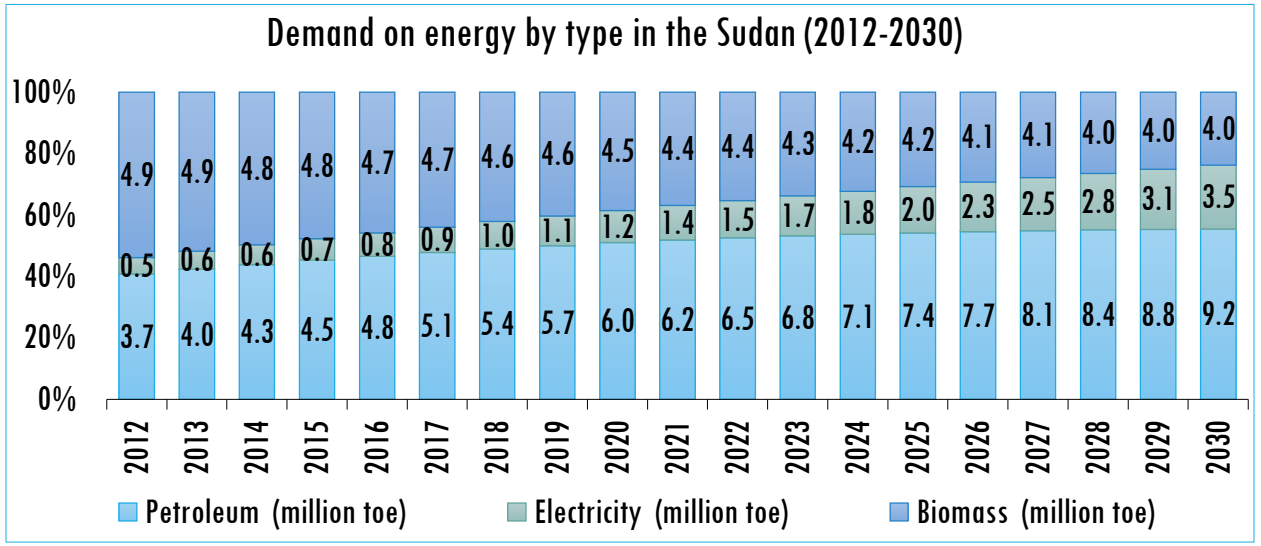
WATER AND NATURAL RESOURCES

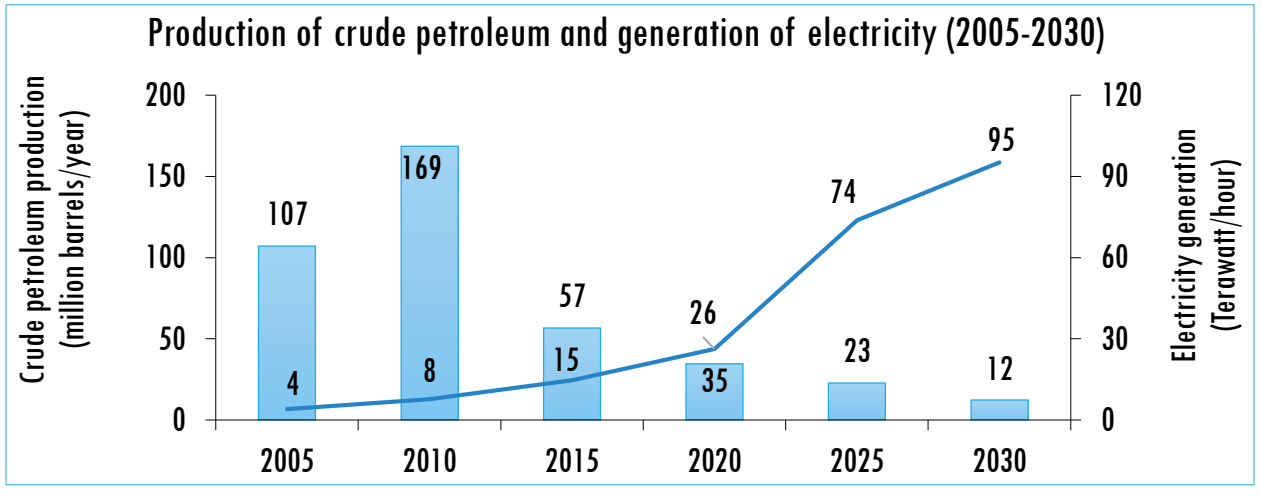
- The Nile is the amin lotic (running) water, 1700 km within borders including Blue & White Niles and the seasonal rivers such as Atbra, Dinder and Rahad.
- 43% of the Nile basin lies within Sudan and 72% of Sudan lies in the Nile basin
- Besides the river Nile, other lotic waters include seasonal Baraka, El Gash, Abu Habil and Wadi El Mugaddam,
- Freshwater use:
  - Agriculture: 96.2%, Domestic: 3.5% and Industry: 0.3% in 2014.
- Water budget:
  - Total IRWR is 4.0 billion cm/year, Total inflow is 99.3 billion cm/year (99.3% from the River Nile system and 0.7% from Eritrea).
  - Evaporation in the swamps is 19.3 billion cm/year, Natural surface water outflow to Egypt of 84.0 billion cm/year,
  - The Sudan Nile system water annual deficit is 4.0 billion cm/year (99.3-19.3-84.0 billion cm),
  - Agreement with Egypt: 65.5 billion cm/year should flow into Egypt from the Sudan. With unchanged inflow of water from the south into the Sudan: 18.5 billion cm/year from its Nile system water to Egypt.

MEPD (2015); FAO (2016)

ENERGY

- Primary sources of energy in the Sudan: hydropower, petroleum and bioenergy,
- Contributions: to total energy mix in 2013 were 5.6%, 40.0% and 54.4%, respectively,
- Plans to generate 4.4 terawatt by 2031:
  - Hydropower generation (23% of total expansions):
    - Northern state (29% of the new hydropower extensions), where Kajbar and Dal dams.
    - The remaining 71% from two dams in the River Nile state, Shereik and Dagash dams.
  - Thermal power generation (77%):
    - 8 stations in the Red Sea state (97% of planned additional thermal power generation),
    - One station in in Khartoum state and another
    - One station in Northern state.





MOTIVATIONS-OBJECTIVES

What do we know about climate change impact on the Sudan?

CLIMATE IMPACT ON THE SUDAN

Drought | **Rainfall variability** | **Floods** | **Temperature increase** | **Seawater temperature** | **Sea level rise**

Agriculture

- Loss of productive land, pasture and water due to expanded desertification
- Shortened growing season and reduced yields and/or crop failure
- Conflict between pastoralists and farmers over resources
- Rural to urban migration due to strain on rural livelihoods
- Damage of crops, agricultural land and infrastructure

Water resources

- Increased evaporation from water storage facilities, reducing water supply
- Decreased river flows from the Nile, leading to reduced availability of water for irrigation, drinking and sanitation
- Conflict over rights and access to water at the local, national and regional levels

Costal zones

- Intensification of storm surges and cyclones, damaging existing infrastructure
- Increase in seawater temperature damages coral reef systems through bleaching
- Increase in seawater temperature damages mangrove systems
- Increase in sea-surface temperature damages sea grass and salt marsh ecosystems

Energy

- Increased evaporation in water storage areas and reduced river flows, resulting in reduced water availability for hydropower generation
- Increased energy consumption

Legend

- Stressor
- Sector
- Impact
- Affected communities and areas

• Communities: poor farmers, poor people, senior citizens, children and women • Areas: northern, middle and middle western parts	• Communities: poor farmers, pastoralists, communities relying on rainfed agriculture • Areas: all the country especially areas with temperature rise of 2.5°C.	• Communities: pastoralists, communities in flood areas, poor farmers • Areas: south, mountainous areas in northern east and southern east	• Communities: communities in coastal areas of the Red Sea state • Areas: Red Sea state with the direct impact and all the country indirectly

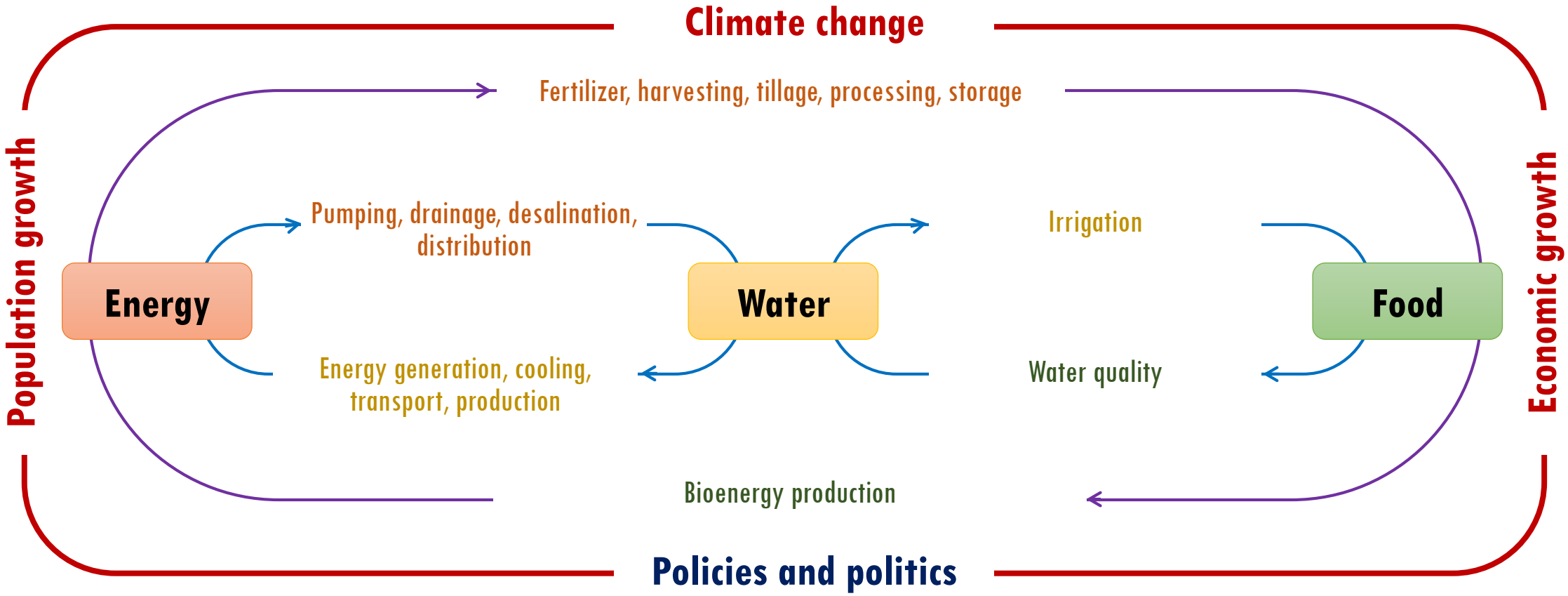
Own elaboration

METHODS

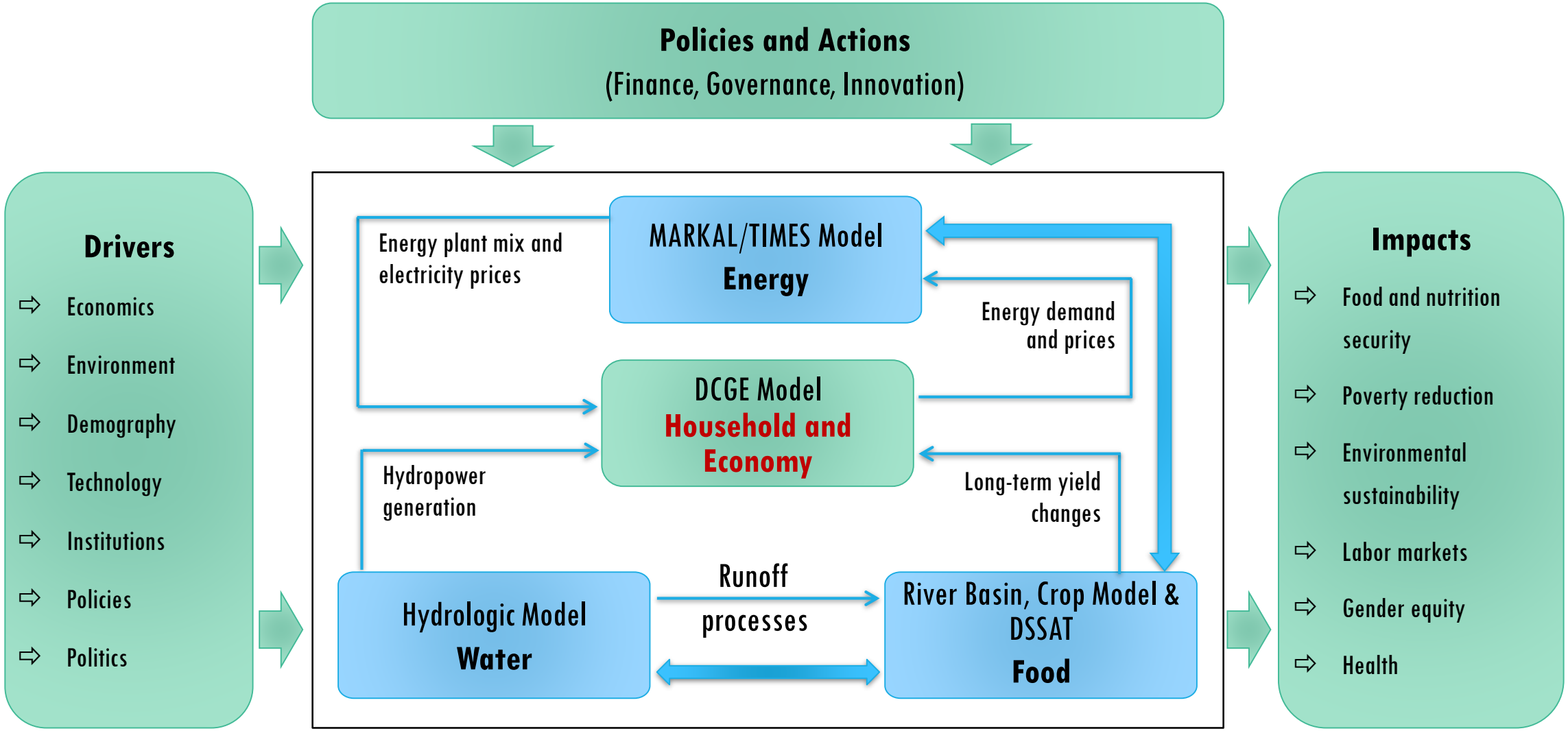
An overview

THE NEXUS MODELING SUITE

- The interplay between water, food and energy and its main drivers



THE NEXUS MODELING SUITE



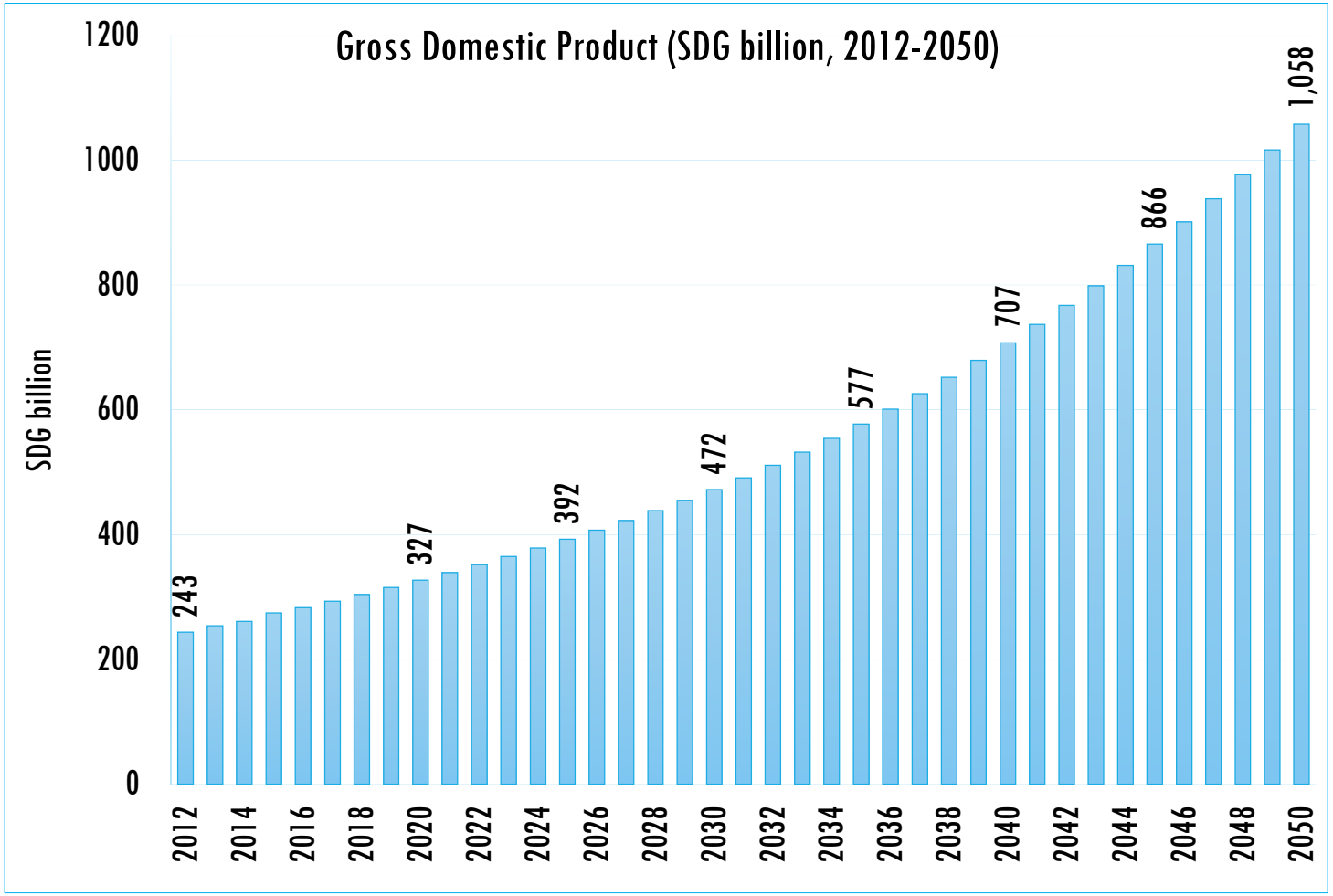
Enhanced from Al-Riffai et al. (2017)

SIMULATION SCENARIOS

[1] Global climate = global food prices
[2] Local climate = local yield changes
[3] Climate variability
[4] A nexus intervention

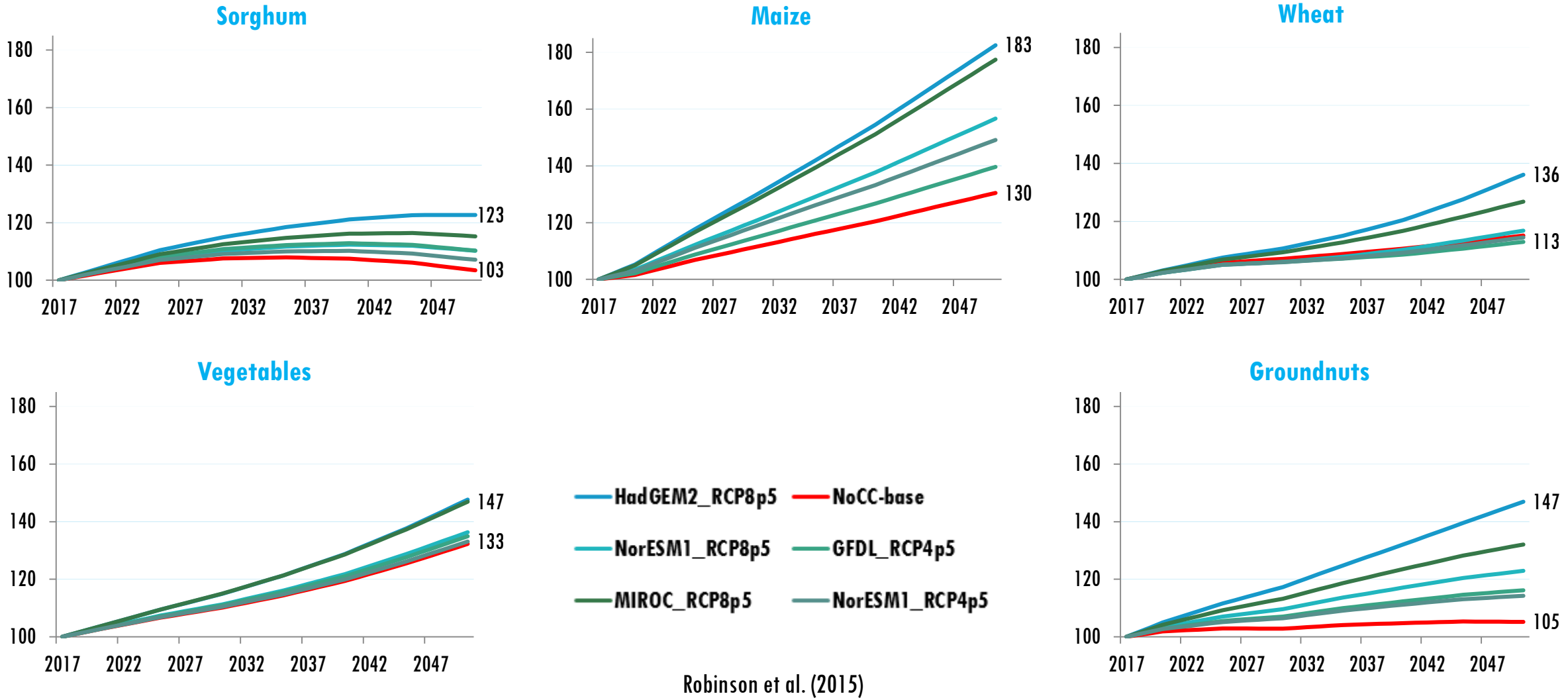
BASELINE DEVELOPMENT

- Population growth from the UN with 2.17 in 2013 to 2.07 in 2030,
- Labor supply took the growth rates of the population
- GDP growth rates until 2022 from the IMF-WEO (2017) and preserved afterward,
- Government consumption spending from IMF-WEO (2017),
- GDP growth rates are met using TFP, while meeting the sectoral (agriculture, industry and services) shares until 2016 and sustaining them afterwards.



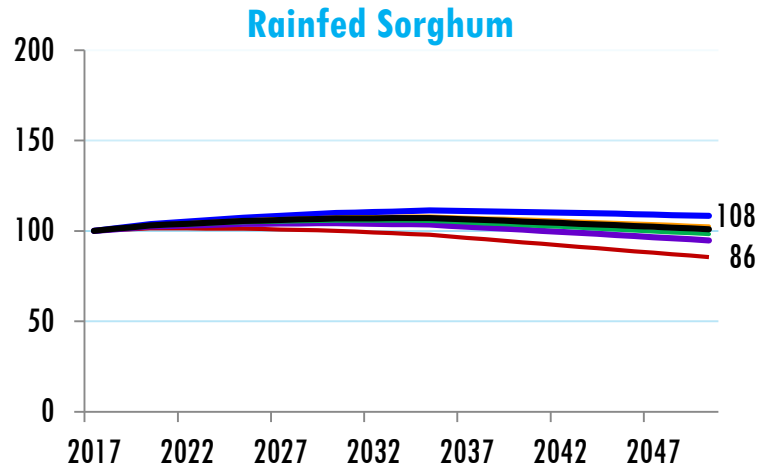
CGE model

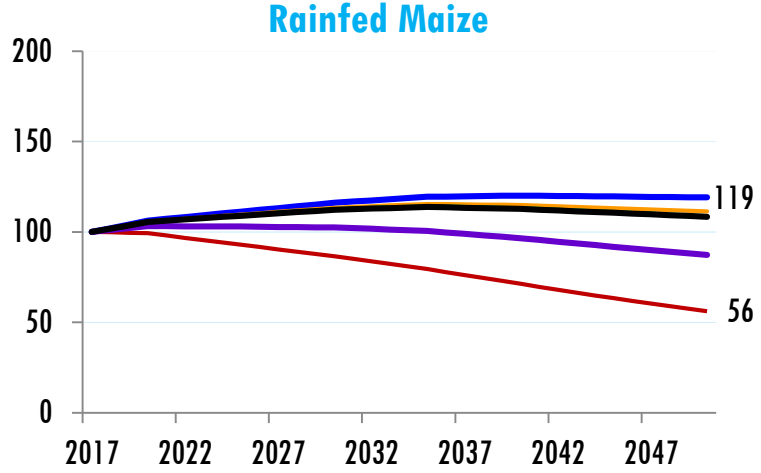
[1] EFFECTS ON GLOBAL FOOD PRICES (2017=100)

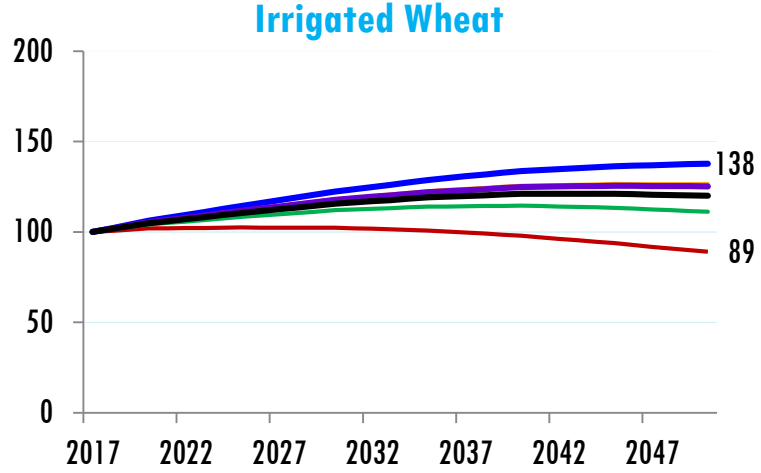


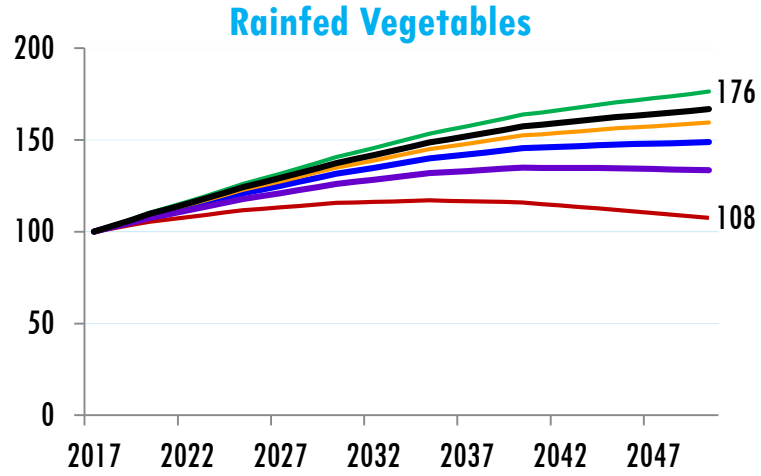
Robinson et al. (2015)

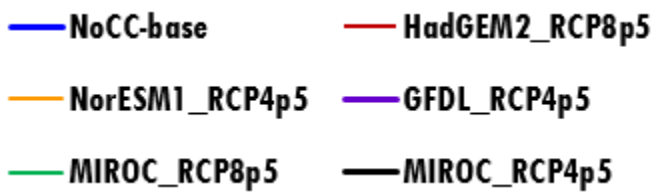
[2] LOCAL YIELD CHANGES (2017=100)



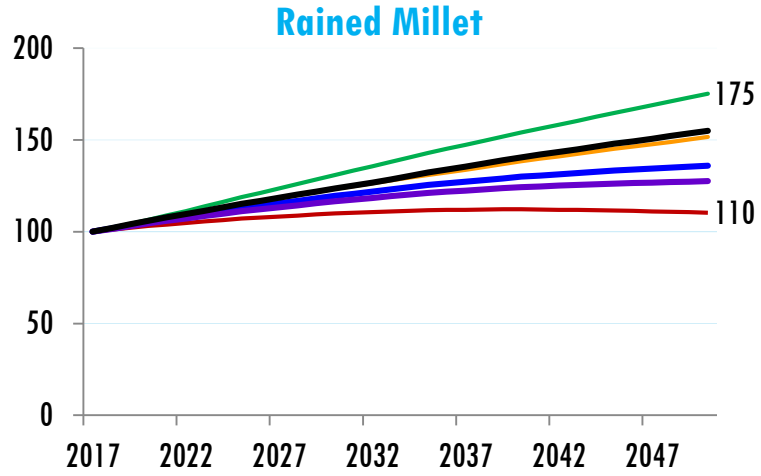








Robinson et al. (2015)



[3] STOCHASTIC VARIATIONS IN CROPS YIELD

- Economic simulation models are often deterministic in nature, thus results are dependent on point estimates of key exogenous variables,
- Uncertain factors: extreme weather, stock, energy prices, growing food demand affected the international agricultural markets (Tangermann, 2011),
- Hence, incorporating uncertainties in economic simulation models of agricultural markets is necessary,
- We simulated 10,000 random values for each stochastic variable (1984 -2014),
- We assured that simulated matrix and the matrix of historical deviates have the same means and equivalent correlation matrices at 5% level,
- We generated three scenarios corresponding to 95% quantile, mean, and 5% quantile values, respectively.

[4] A NEXUS POLICY INTERVENTION

Policy focus	Policy Intervention	Water Security	Energy Security	Food Security
Food	Encountering yield changes by adjusting crops productivity in the irrigated and rainfed sectors. The objective is the restoring agricultural GDP to its NoCC level	Direct (-) Increased demand for irrigation water	Direct (-) Increased demand for energy in agriculture	Direct (+), indirect (+/-) Increased production Increased imports
Energy		Direct (+)	Direct (+)	Direct (+/-), indirect (+/-)
Water		Direct (+)	Direct (-)	Direct (+), indirect (+)

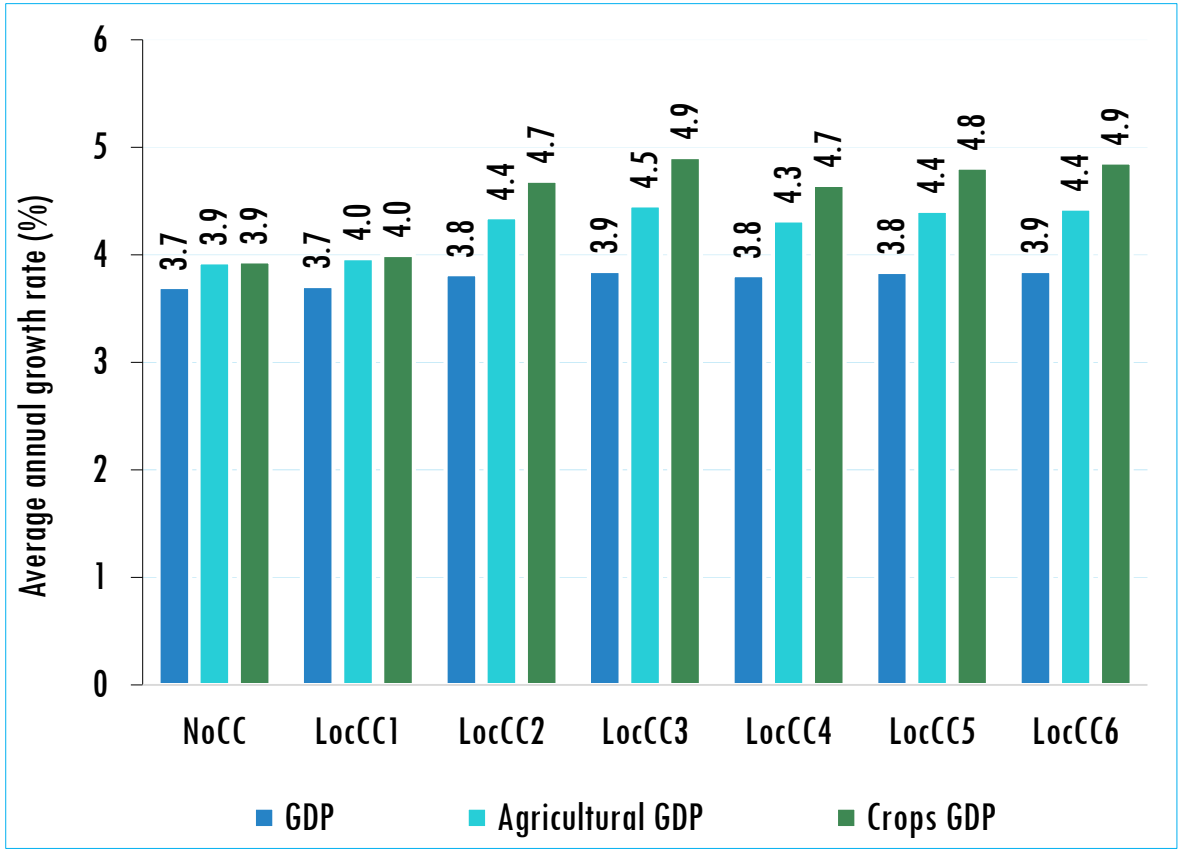
Inspired by Nielson et al. (2015).

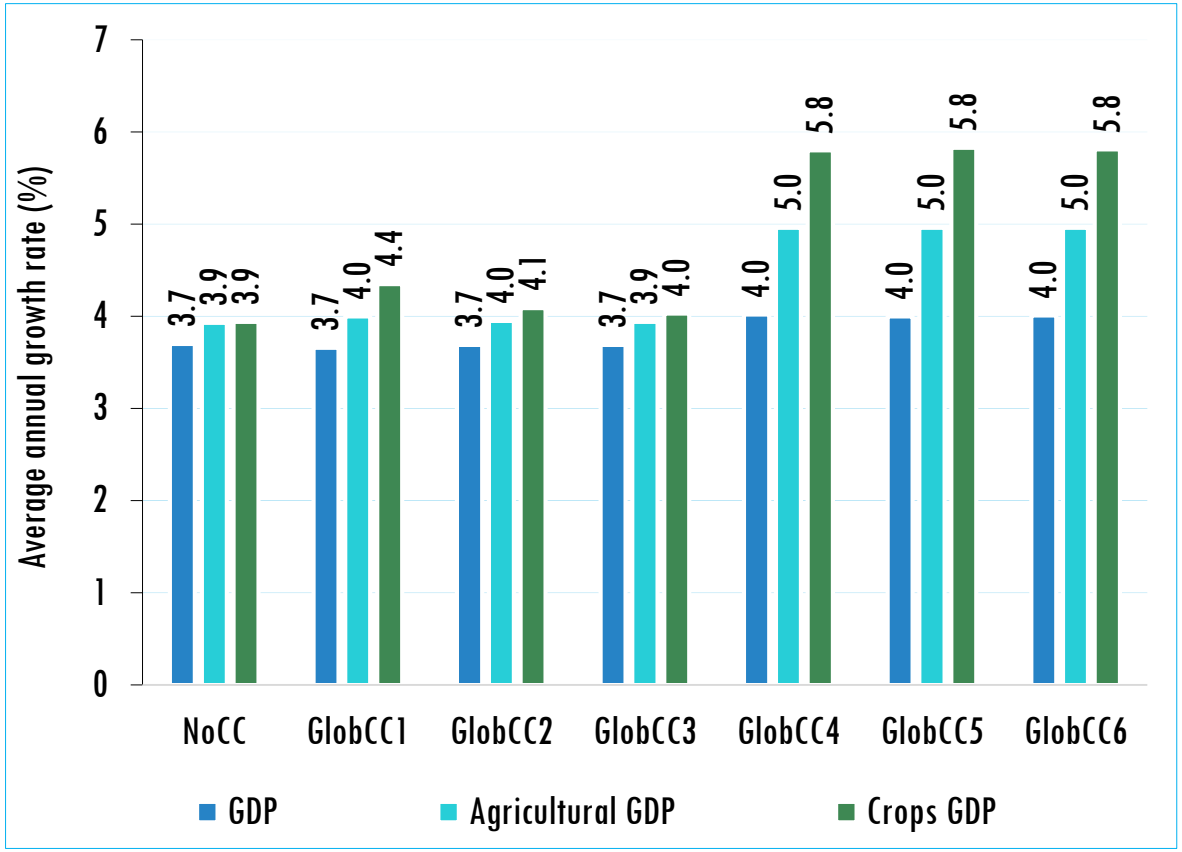
PRELIMINARY RESULTS

[1]

Changes driven by local yields and global food prices

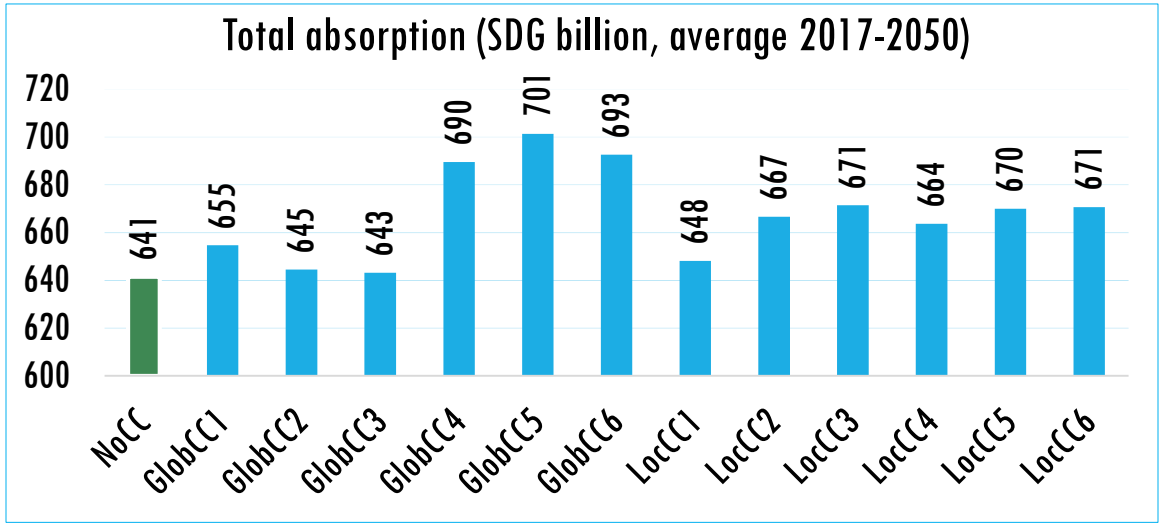
GDP AT FACTOR COSTS (AVERAGE ANNUAL GROWTH %)

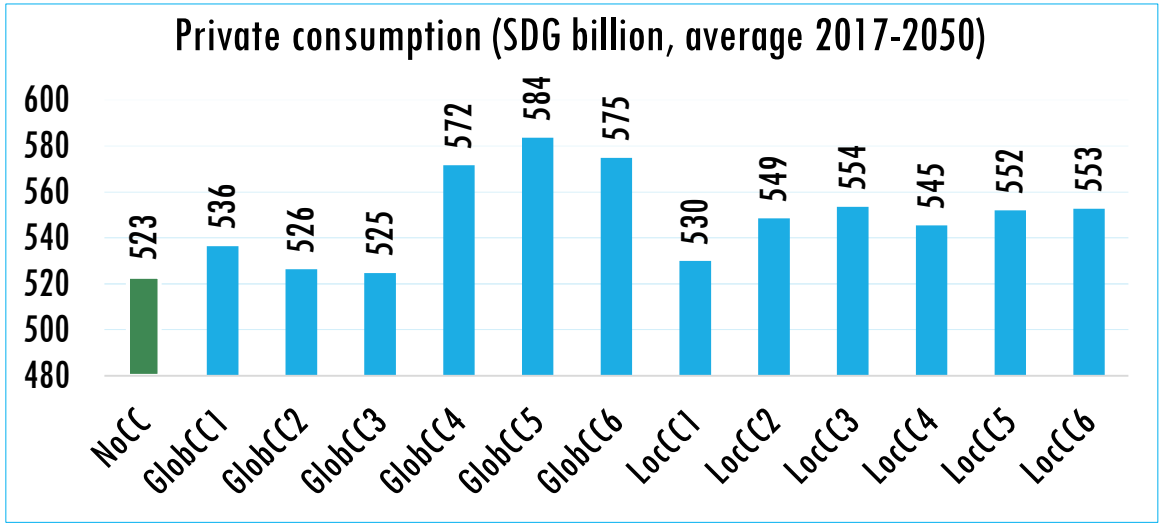


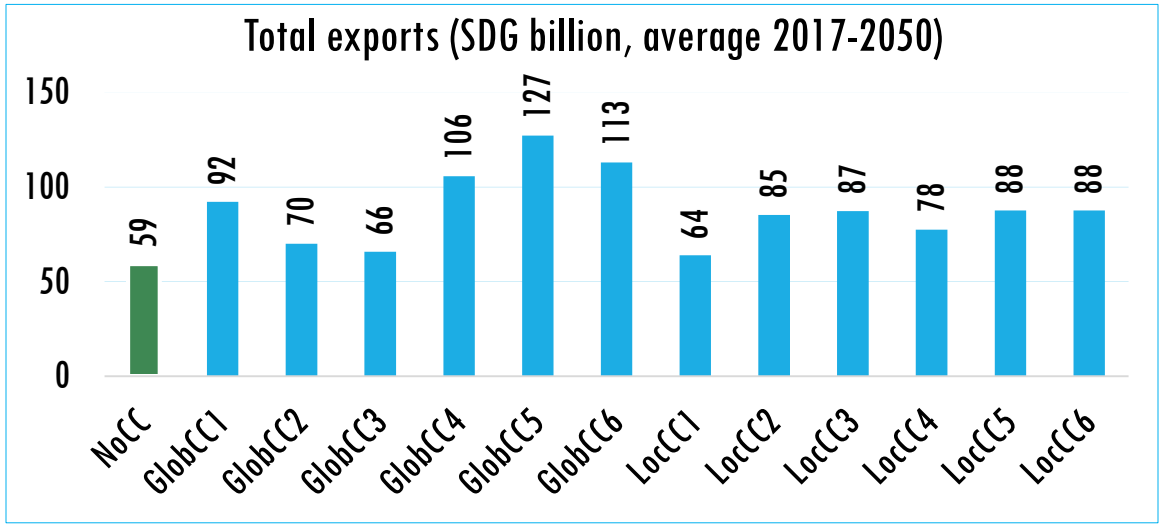


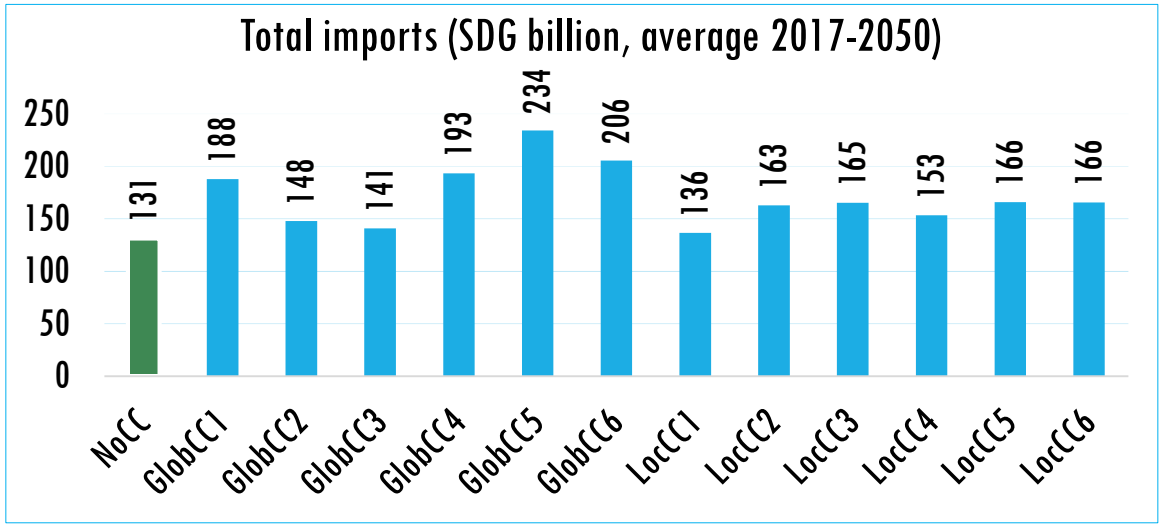
CGE model results

MACROECONOMIC INDICATORS (SELECTION)









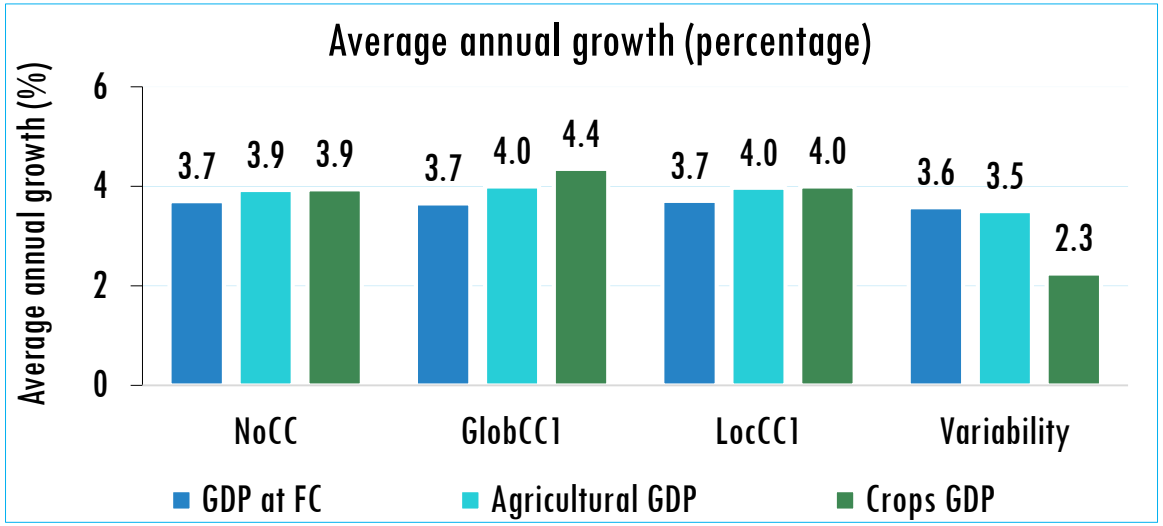
CGE model results

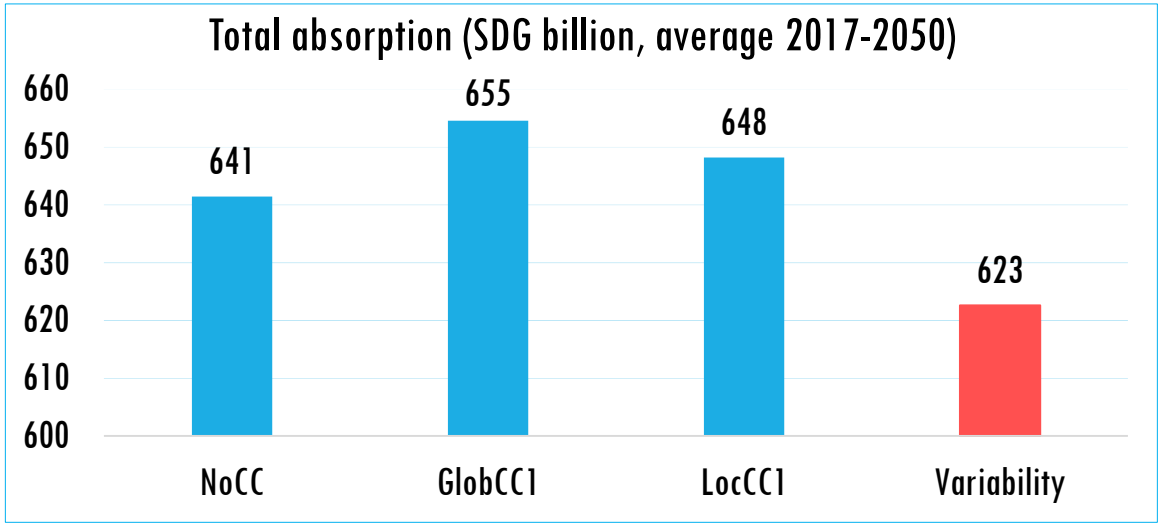
PRELIMINARY RESULTS

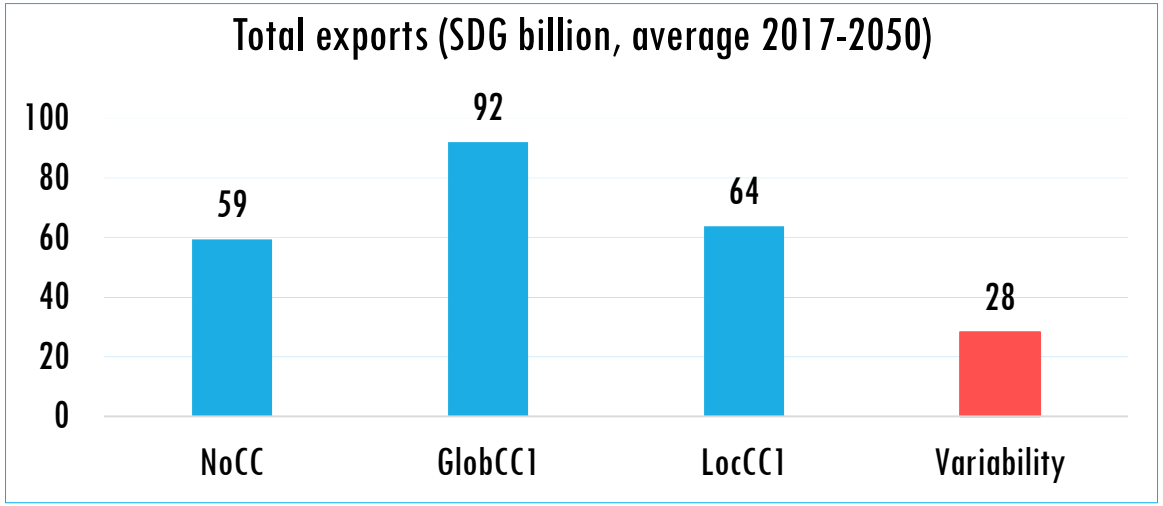
[2]

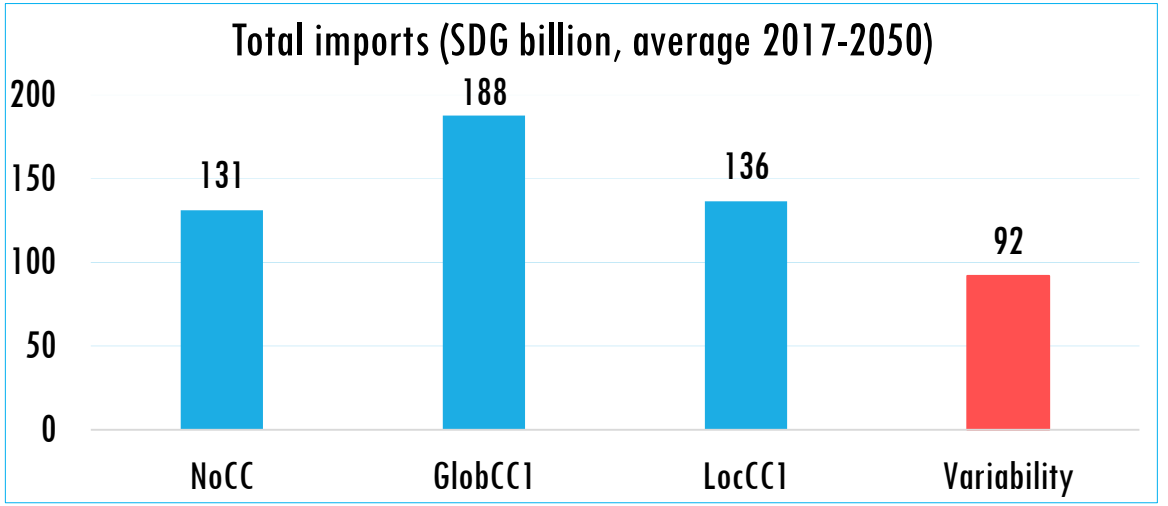
Stochastic variations in crops yield

MACROECONOMIC INDICATORS



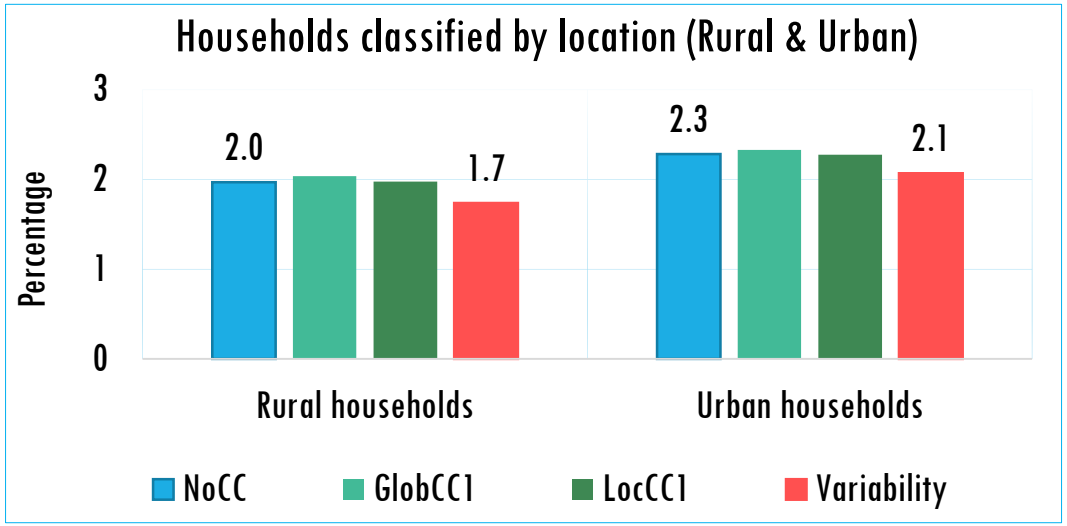


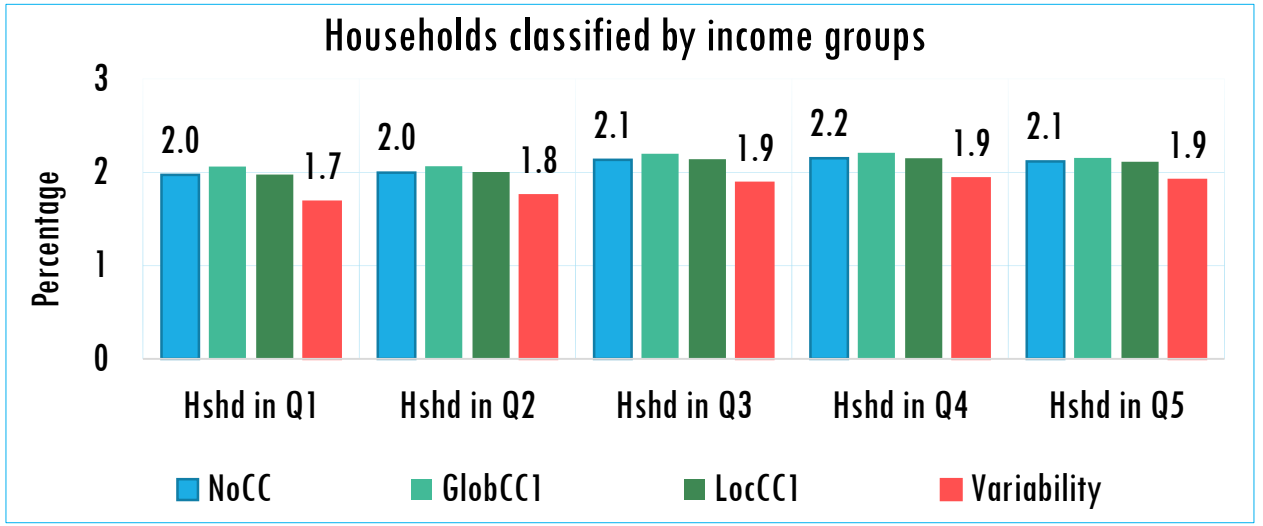


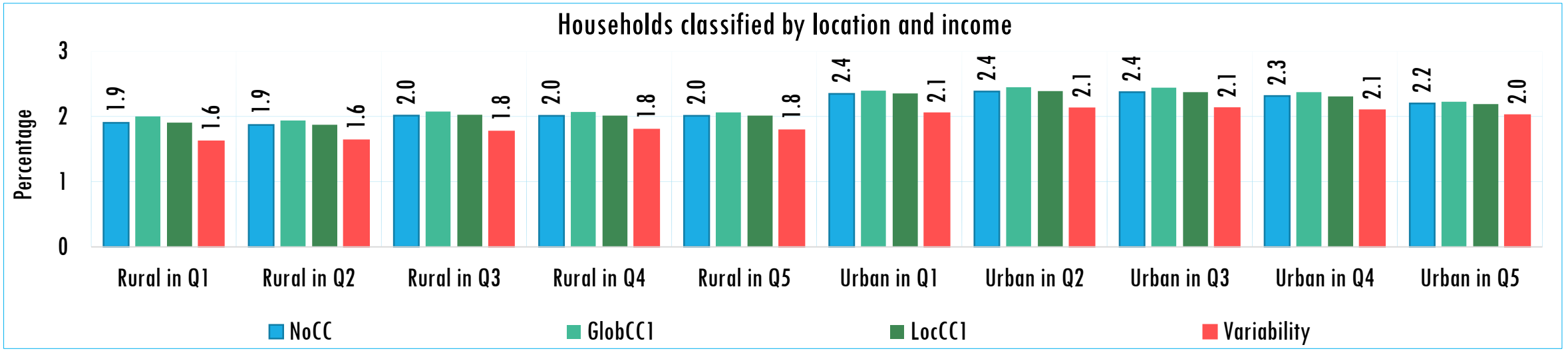


CGE model results

AVERAGE ANNUAL CHANGE IN EQUIVALENT VARIATION (% 2013-2050)







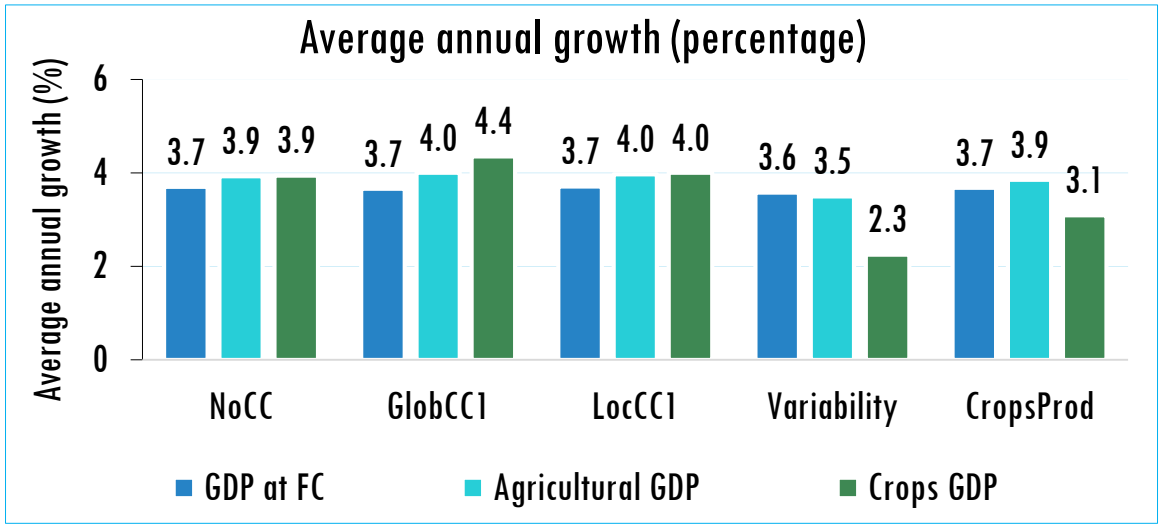
CGE model results

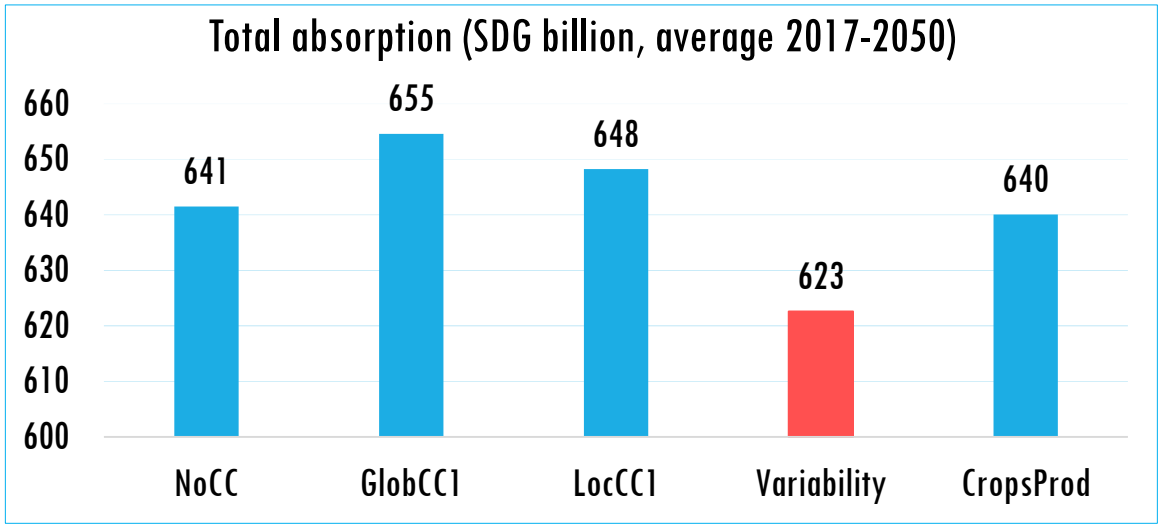
PRELIMINARY RESULTS

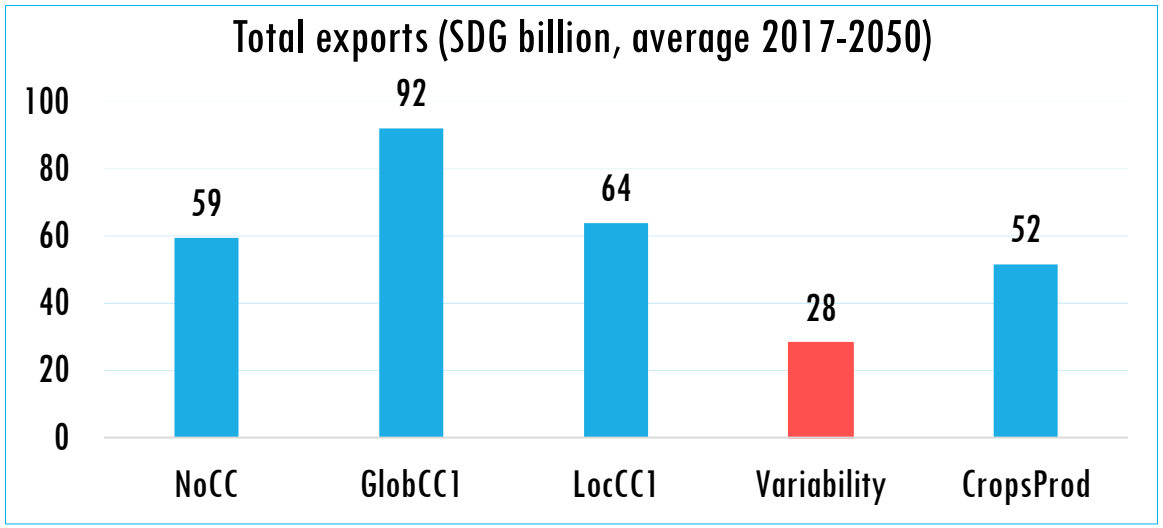
[3]

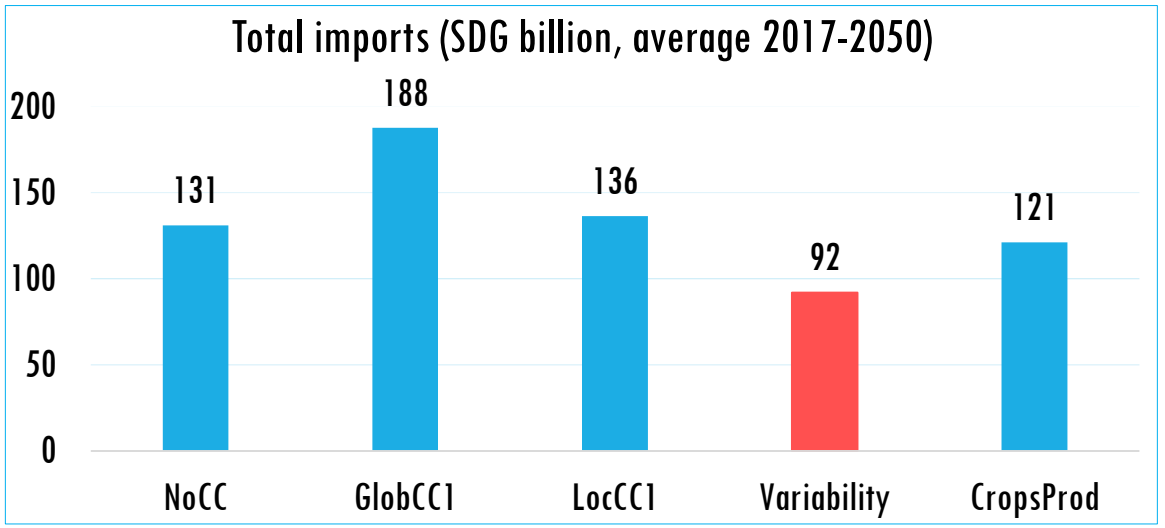
A nexus intervention

MACROECONOMIC INDICATORS



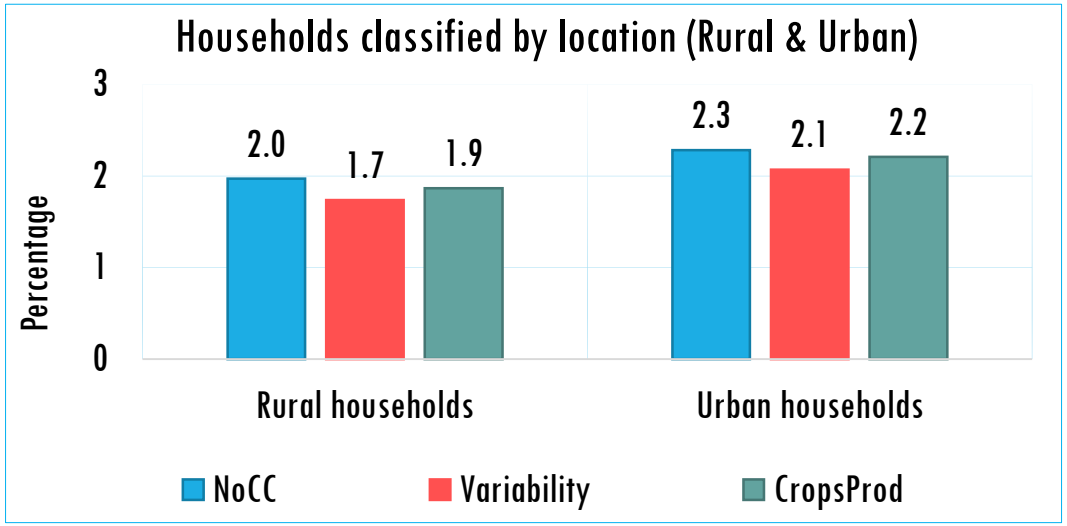


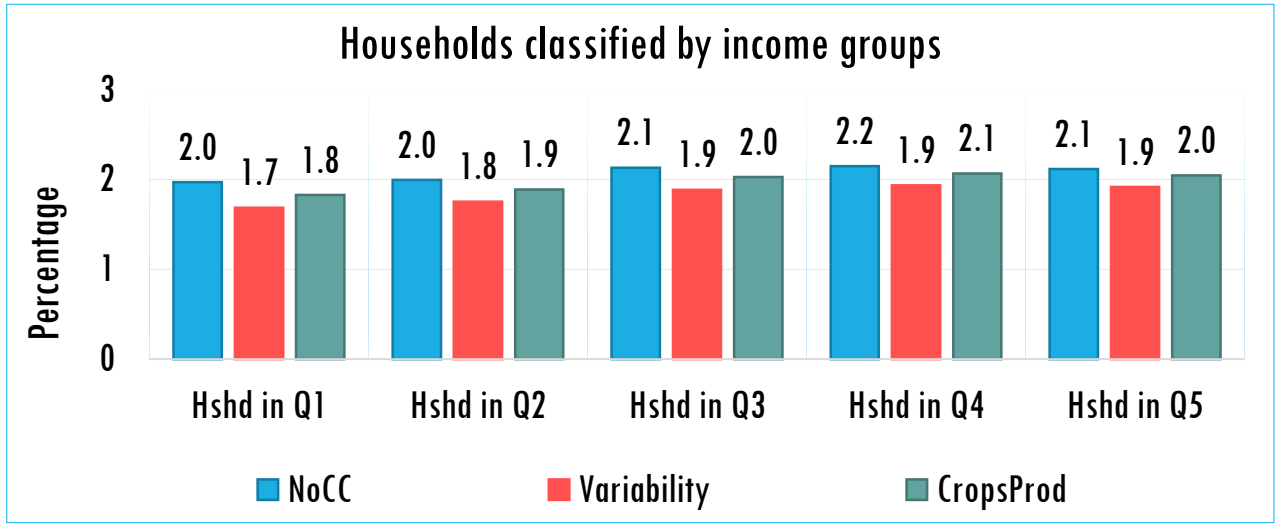


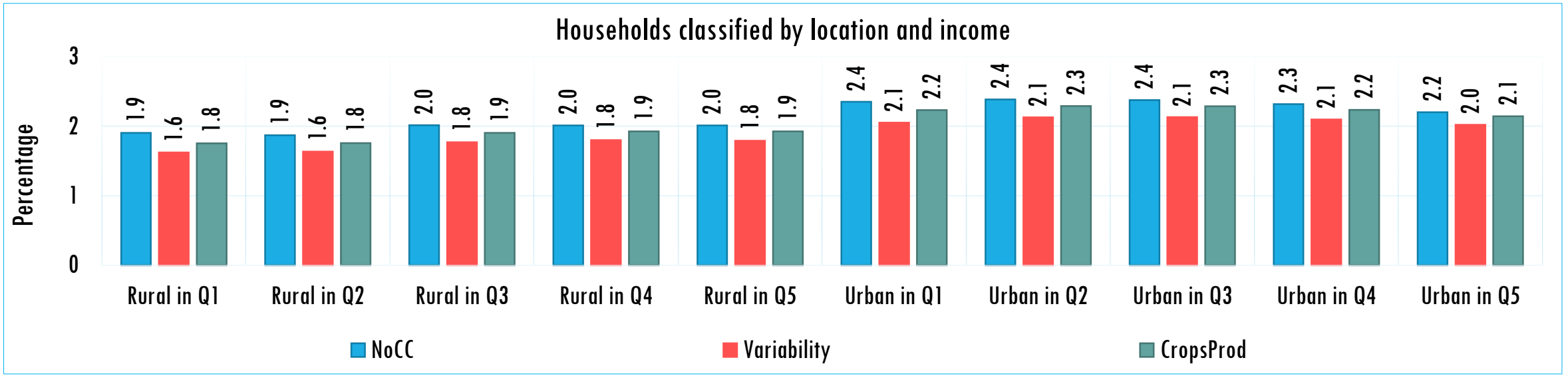


CGE model results

AVERAGE ANNUAL CHANGE IN EQUIVALENT VARIATION (% 2013-2030)







CGE model results

CONCLUSIONS

Summary and implications

CONCLUSIONS

- Projected local yield and global food price changes trigger good performance at the macro level,
- Empirical evidence suggest rainfall variations and fluctuating crop yields,
- Adding some uncertainty to the model resulted in considerable negative effects,
- Productivity enhancement by 2% in irrigated and 3% in rainfed sector could encounter the yield shocks and restore agricultural GDP and GDP at FC to their NoCC level,
- This lead to a higher GDP at MP, total exports, total imports and total absorption compared to those of NoCC,
- For households however, average annual changes in equivalent variation are slightly lower under the Nexus Scenario than the NoCC,
- Other nexus interventions are to be implemented.

SOURCES

Full list

SOURCES

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