Intro to Socio-Economic Benefits
of
Climate Information Services

Format of Presentation

CLIMATE INFORMATION SERVICES

- Global economic cost of natural disaters
- Hydromet Hazards
- Forecast Verification
- CIS

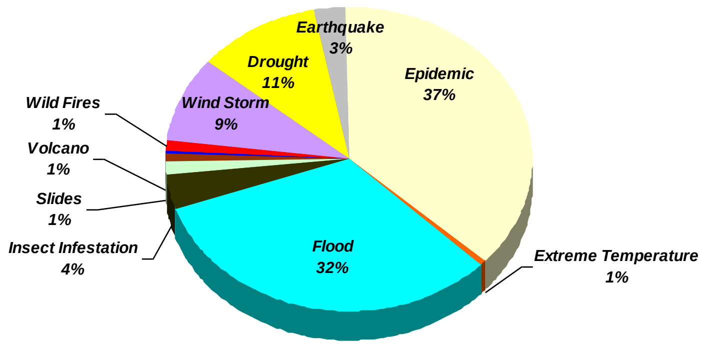
CIS AND GLOBAL ECONOMIC COST OF DISASTERS

The reported global cost of natural disasters has risen significantly, with a 15-fold increase between the 1950s and 1990s. During the 1990s, major naturalcatastrophes are reported to have resulted in economic losses averaging an estimated US$66bn per annum (in 2002 prices). Record losses of some US$178bn were recorded in 1995, the year of the Kobe earthquake – equivalent to 0.7 per cent of global GDP (Munich Re, 2002).

It is also estimated that in developing nations losses are typically 10-14 % of GDP, Abramovitz, (2001),.

Global Distribution of Disasters Caused by Natural Hazards and their Impacts in Africa(1980-2007)

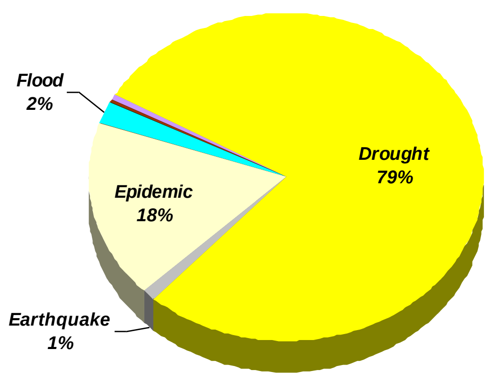
Number of disaster events - 1980-2007 (RA I)



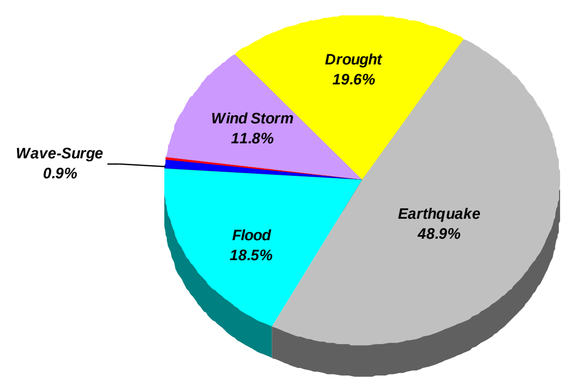
97% of events
99% of casualties
61% of economic losses

are related to hydro-meteorological hazards and conditions.

Casualties - 1980-2007 (RA I)



Economic losses - 1980-2007 (RA I)



HYDROMET HAZARDS

Hydrometeorological hazards, typically droughts/floods when they intersect with vulnerability/exposure of communities wreak havoc on socio-economic development. Droughts of early 1990's and recently 2015/16 over Southern Africa led to disruption in hydropower generation, massive food and non-food importation into the region at enormous costs. GDP were reversed due to economic damages.

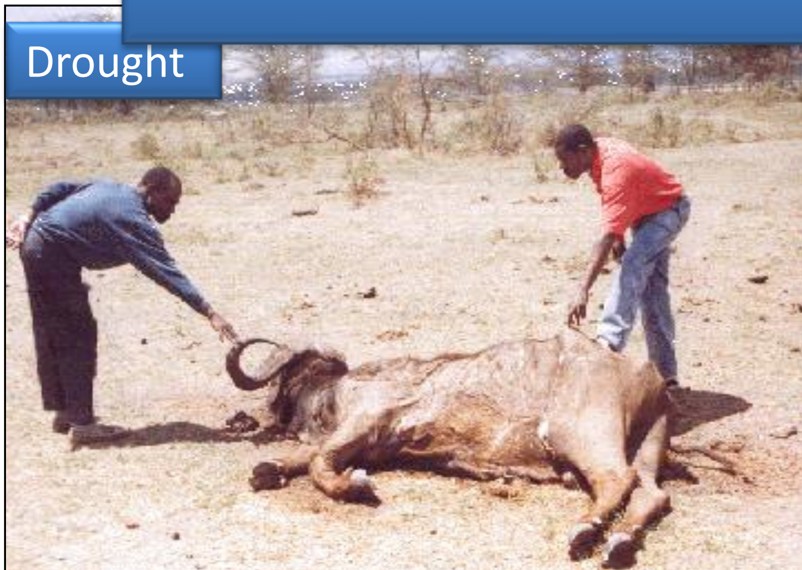
The visit of tropical cyclone Eline to Southern Africa in 2000 resulted in loss of lives, damaged to infrastructure such as roads and bridges, some of which are still in disrepair nearly two decades later.

- Elsewhere in Africa, the stories are similar, the droughts that visited the parts of the Greater Horn of Africa in the mid-1980's and again in 2011 having led to losses of life. Lives are lost,

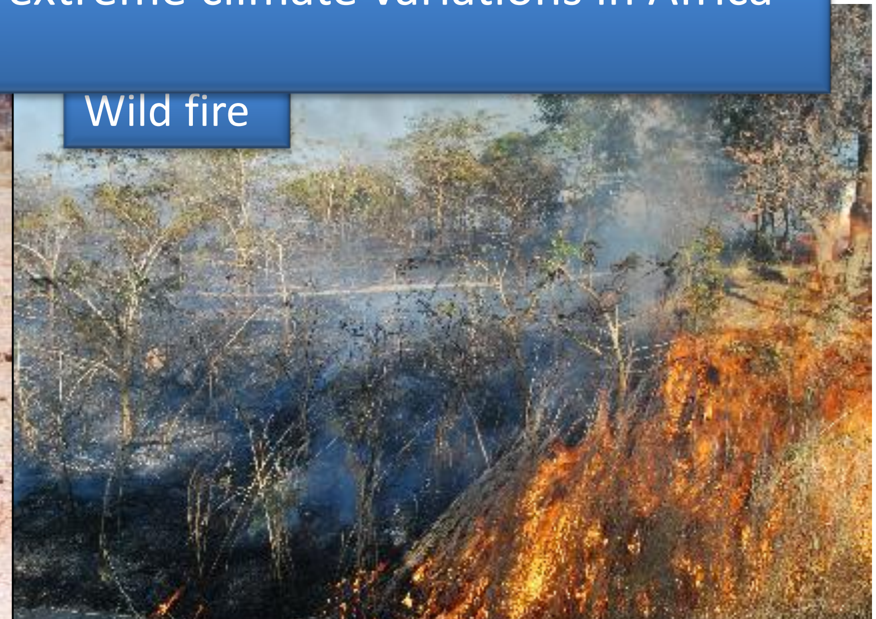
Some of which could have been avoided if early warning had been accompanied by early action.

Typical devastating impacts of extreme climate variations in Africa

Drought



Wild fire



Thunderstorm

Flooding

Disasters ranked according to (a) deaths and (b) economic losses (1970-2012).

(a)	Disaster Type	Year	Country	Number of Deaths
1	Drought	1983	Ethiopia	300000
2	Drought	1984	Sudan	150000
3	Drought	1975	Ethiopia	100000
4	Drought	1983	Mozambique	100000
5	Drought	1975	Somalia	19000
6	Flood	1997	Somalia	2311
7	Flood	2001	Algeria	921
8	Flood	2000	Mozambique	800
9	Flood	1995	Morocco	730
10	Flood	1994	Egypt	600

(b)	Disaster Type	Year	Country	Economic loss in USD Billions
1	Drought	1991	South Africa	1.69
2	Flood	1987	South Africa	1.55
3	Flood	2010	Madeira	1.42
4	Storm (Emille)	1977	Madagascar	1.33
5	Drought	2000	Morocco	1.20
6	Drought	1977	Senegal	1.14
7	Storm (Gervaise)	1975	Mauritius	0.85
8	Flood	2011	Algeria	0.79
9	Storm	1990	South Africa	0.69
10	Storm (Benedicte)	1981	Madagascar	0.63

Source-wmo 2014

HYDROMET BENEFITS

Climate system can bring favourable conditions to communities, well distributed seasonal rains both temporally and spatially.

- This can lead to good agricultural production;
- Boosting the GDPs of the region, through availing agricultural commodities needed by locally industry for finished goods, or for international trade.
- Such would encourage other sectors of the economy to perform better.

However, it is not often that such favourable climate conditions are readily taken advantage of by communities.

This is in part due to inadequate investments in the NMHSs in order to:

- generate and disseminate CIS of highest quality;
- enable appropriate action to be taken by communities: appropriate seed varieties for maximum productivity, well-planned hydropower generation.

What needs to happen

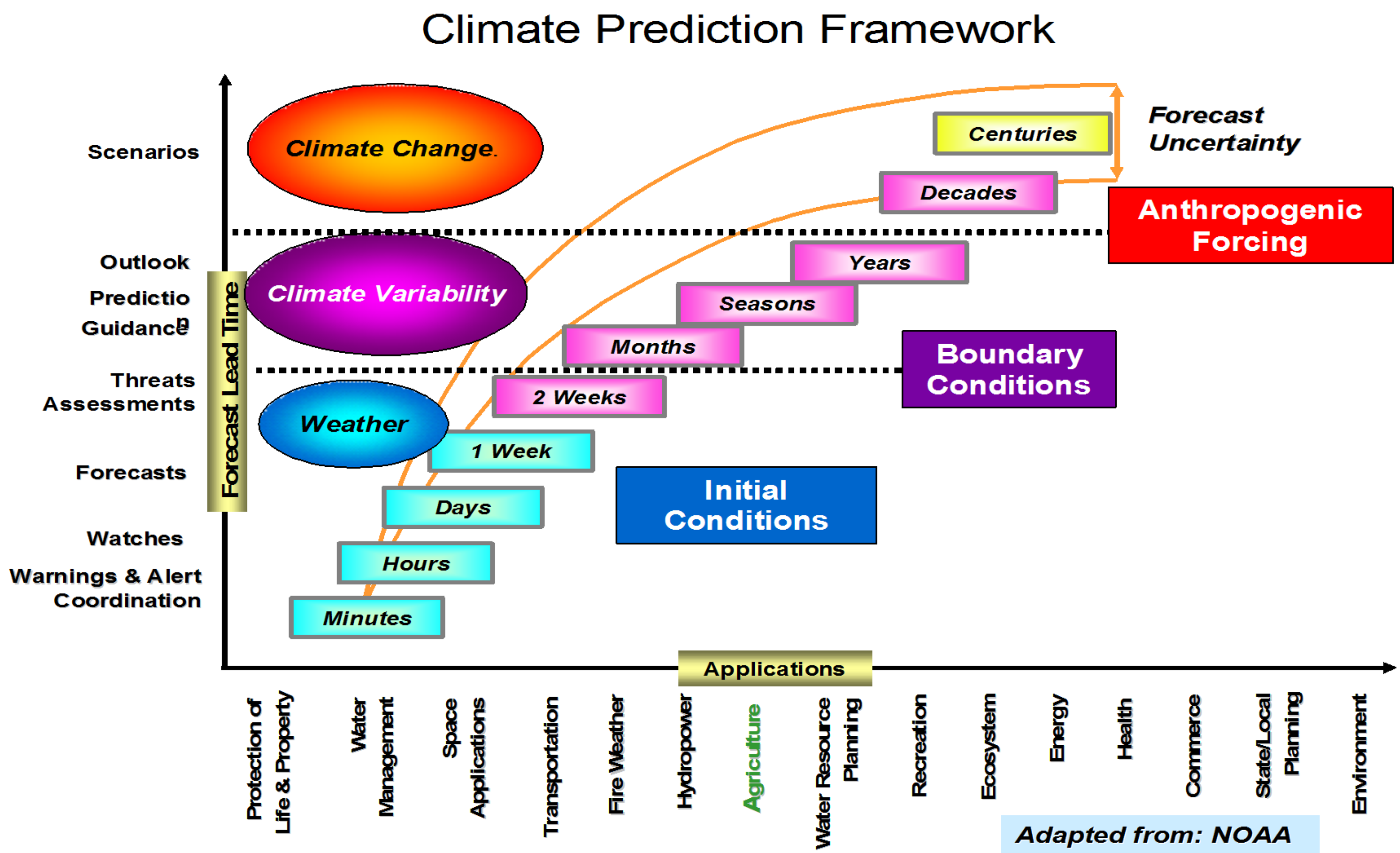
- The negative impacts of hydrometeorological hazards on agriculture and food security, water resources oftentimes lead to disasters. Over 90% of natural disasters in Africa are a consecutive consequence of these hazards.
- Climate information Service (CIS) is an important component of the evidence base required to guide decisions regarding appropriate levels of investment to minimize negative potential impacts on the economy, ensuring uninterrupted delivery of critical services and infrastructure.
- Investing in the development of early warning systems (CIS) and contingency planning, impacted sectors (such as agriculture) is necessary to help protect socio-economic welfare.

CIC

Contributes to mitigation of adverse impacts of extreme climate variations on socioeconomic development.

- This is achieved through the monitoring of near real-time climatic trends and generating medium-range (10-14 days) and long-range climate outlook products on monthly and seasonal (3-6 months) timescales.
- These products are disseminated in timely manner to the communities of the sub-region principally through the NMHSs, regional organizations, and also directly through email services to various users who include media agencies.

Seamless hydrometeorological and climate services



GFCS
GLOBAL FRAMEWORK FOR
CLIMATE SERVICES

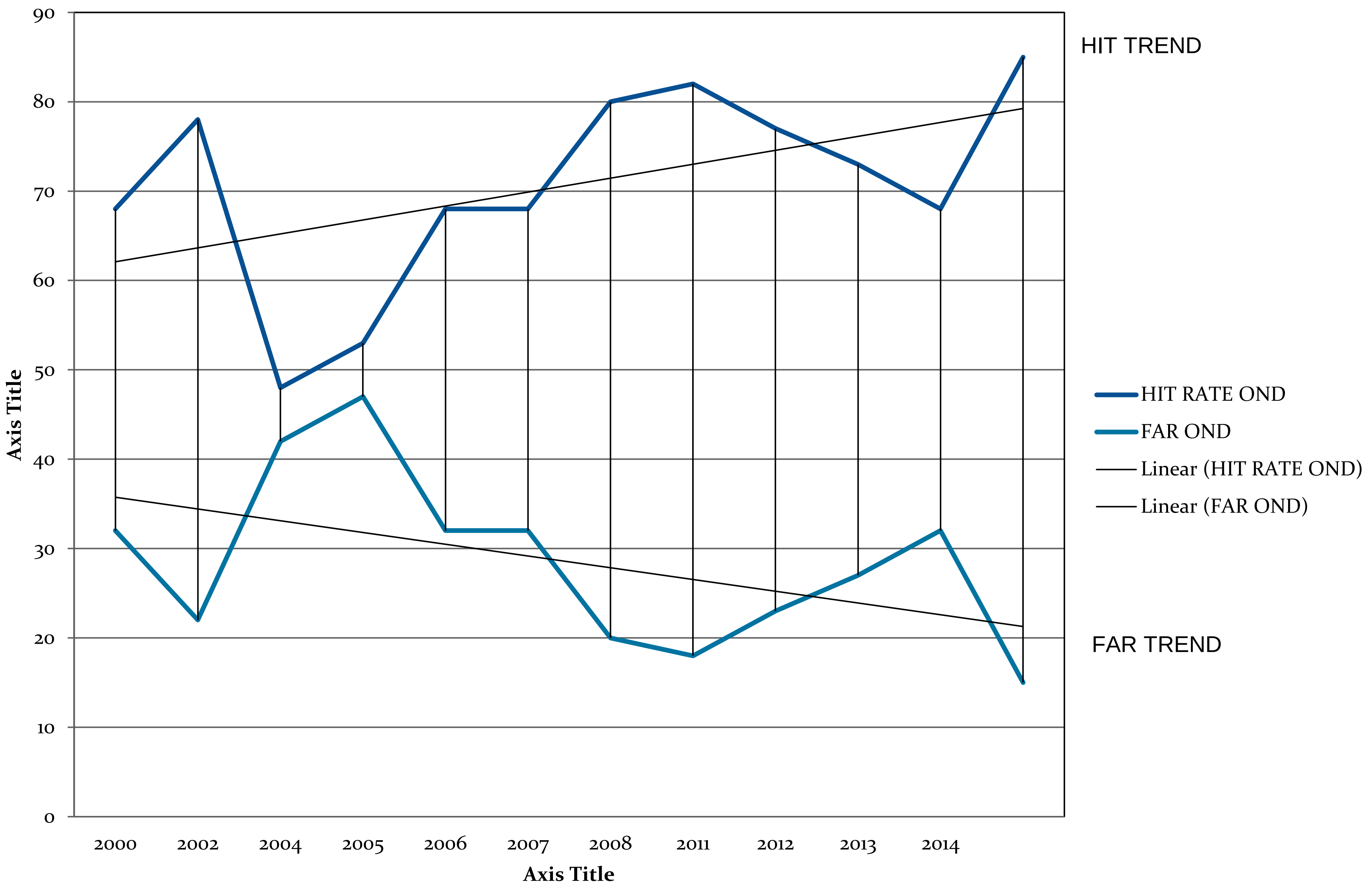
Evaluation and verification of the forecasts

- Many societal and economic systems are vulnerable to the impacts of climate variability and change.
- Decision-makers require high-quality, reliable, timely information on current, predicted and projected conditions for safety and security, and for adaptation strategies and measures.
- The requires that we evaluate and verify the forecast to assess their applicability.

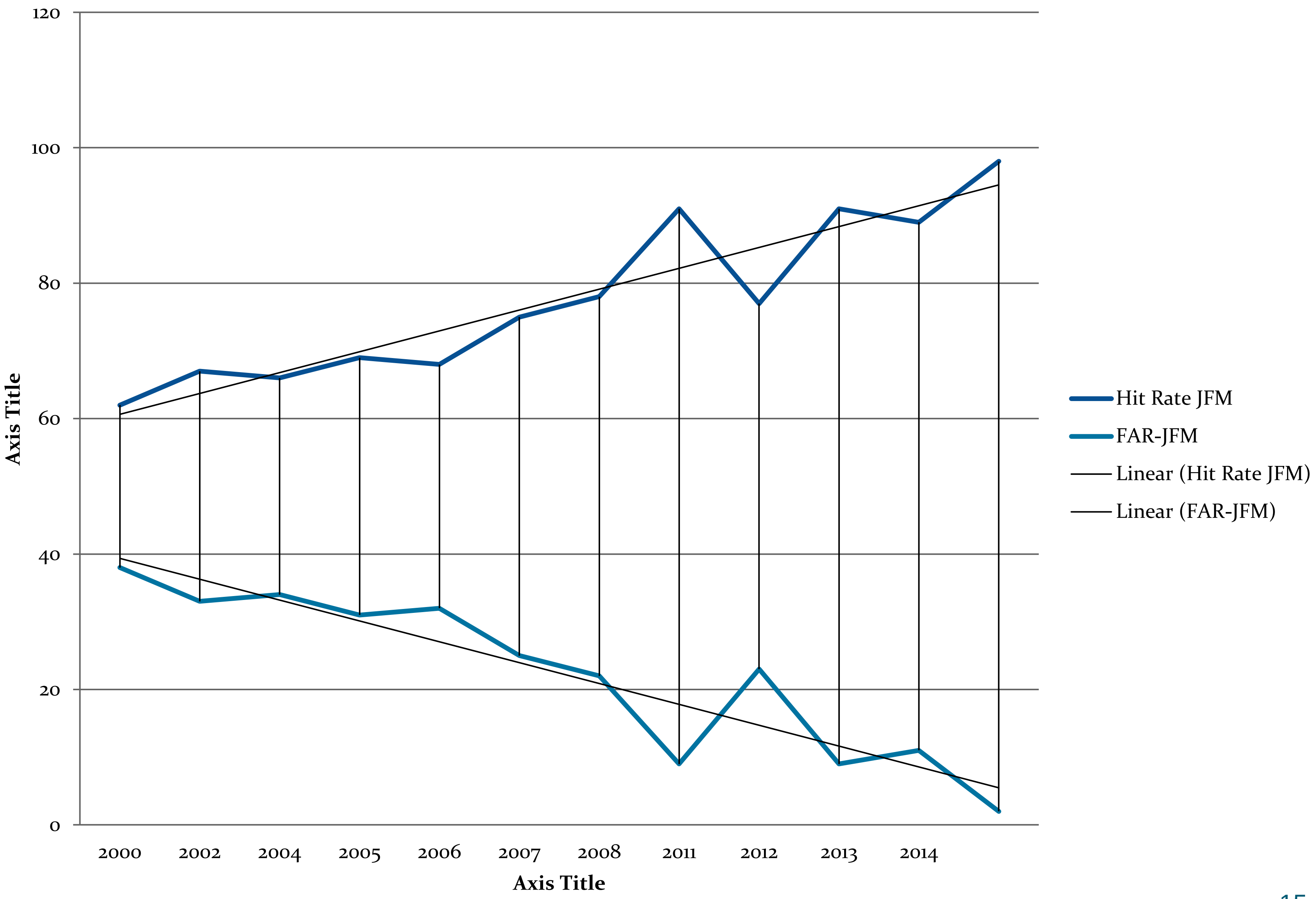
Results

Forecast verification results help answer users' questions about quality, not as a set of academic statistics.

Trend of Hit Rate vs FAR



Trend of Hit Rate vs False Alarm



SARCOF seasonal forecasts have on average period where study focuses (2001 – 2012); (2001-2012), and beyond

- A positive trend of 13% of HR has been observed (62 to 75%) on OND period and 20% on JFM season (68-88%);
- A reduction of FAR of 10% has been noticed (35 – 25%) on OND period and 15% on JFM period (33-18%);
- Certain areas appear to perform better than others, potentially due to erratic tropical cyclone activity

Emerging Opportunities for National Meteorological and Hydrological Services ….

- Traditionally, disaster risk management has been focused on post disaster response in most countries!

- New paradigm in disaster risk management - Investments in preparedness and prevention through risk assessment, risk reduction and risk transfer ….
  - Adoption of Hyogo Framework for Action in 2005-2015 by 168 countries (Kobe, Japan)

Implementation of the new paradigm in DRM would require meteorological, hydrological and climate information and services!

Assessing the Socio-Economic Benefits (SEB) of Climate Information Services (CIS)

March 2018

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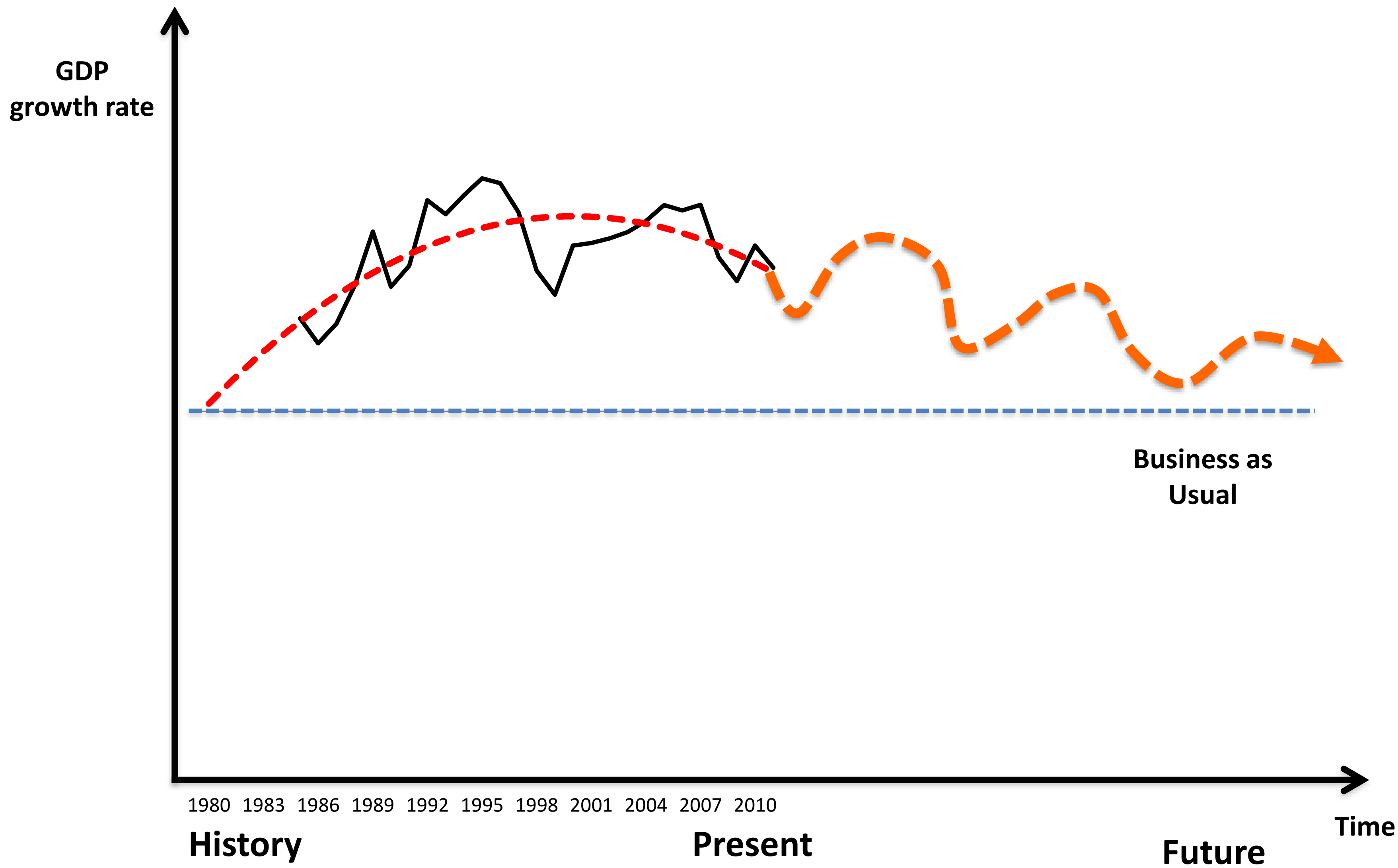
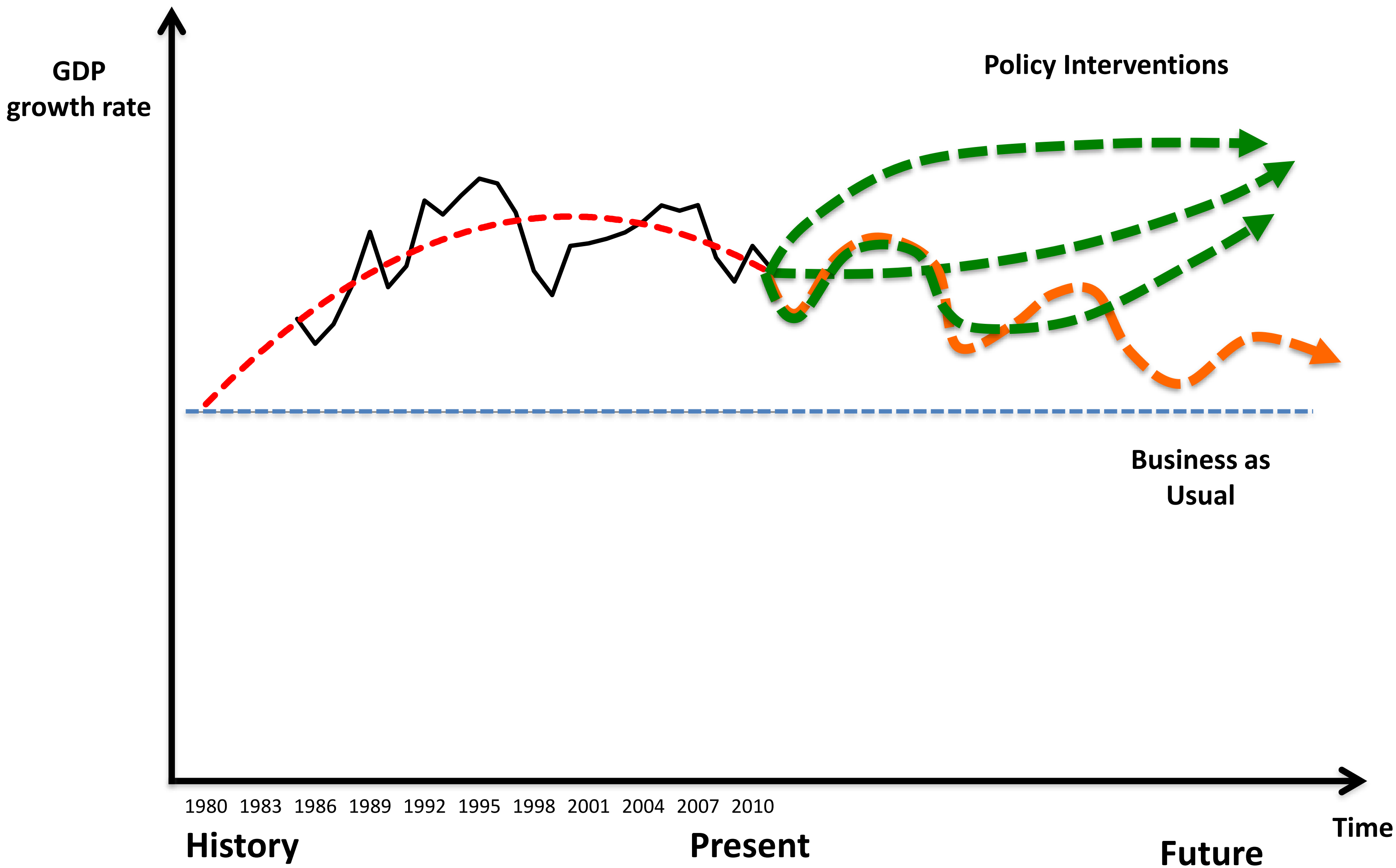
Ph.D. candidate University of Bergen

KnowlEdge Srl

Rationale for SEB Analysis



Rationale for SEB Analysis



Socio-Economic Benefits

The Socio-Economic Benefits of Climate Information Systems are many and varied.

- Some are direct (e.g. weather information, rainy days), some indirect (e.g. higher yield) some are induced (e.g. higher tax revenues).
- Some affect households (e.g. avoided damage to private property), others impact on businesses (e.g. avoided supply chain disruption) and the government (e.g. reduced infrastructure expenditure).

Socio-Economic Benefits (2)

The Socio-Economic Benefits of Climate Information Systems are many and varied.

- Some are expressed in <u>economic</u> terms, some others have <u>social</u> or <u>environmental</u> dimensions.
- Some appear <u>immediately</u> and on a <u>continuous</u> basis, while some others will emerge <u>over time</u> (e.g. through improved systemic resilience).

Socio-Economic Benefits (3)

- The challenge is to estimate required **investments**, resulting **avoided costs** as well as **added benefits**.
- An opportunity would be missed if decisions only aim at mitigating costs and passively adapt to climate change.
  - If a more active approach is taken, new opportunities may emerge, and avoided costs could be reinvested in more resilient economic activities.

Assessment of SEBs from CIS

Investments −

(**Avoided Costs** + **Added Benefits**)

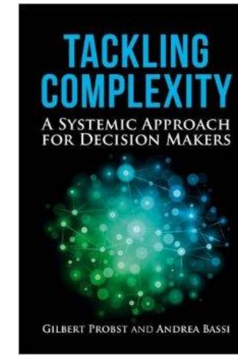
Avoided Costs

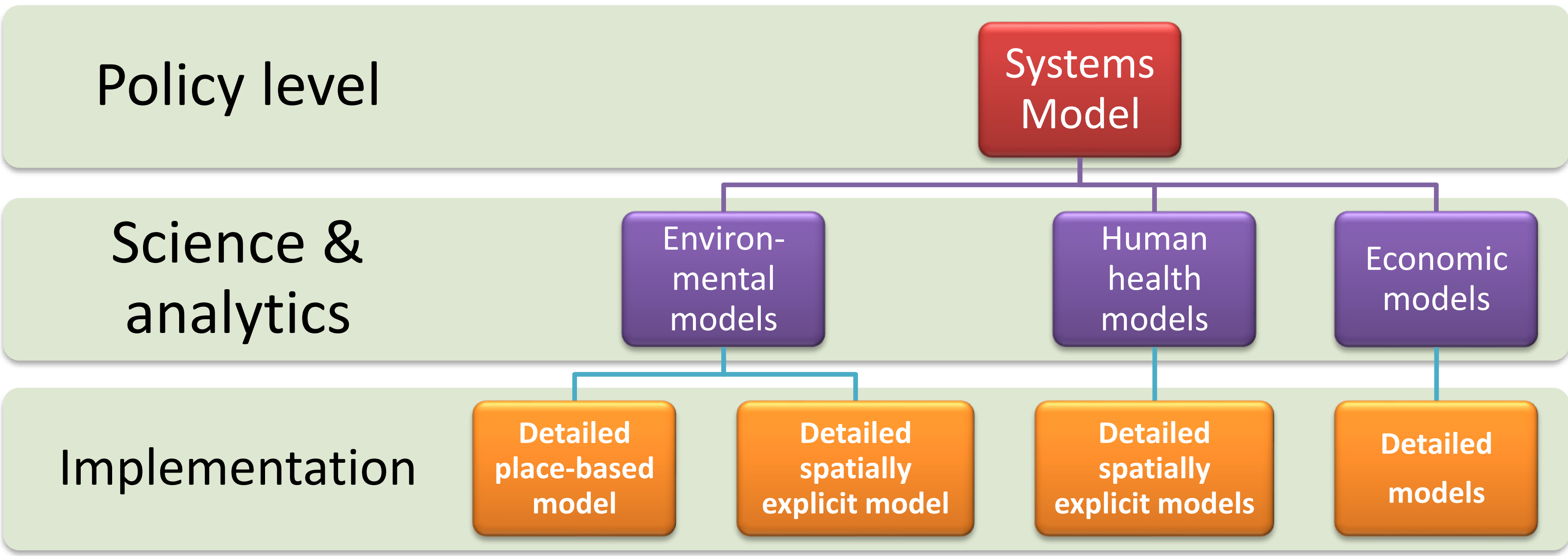
- ✓ *Environmental*
  - *Remediation costs*
- ✓ *Social*
  - *Life and infrastructure losses*
- ✓ *Economic*
  - *Reduced water consumption (and cost)*

Added Benefits

- ✓ *Environmental*
  - *Ecosystem Services*
- ✓ *Social*
  - *Employment*
- ✓ *Economic*
  - *Income and GDP growth*

System models and their use in decision making





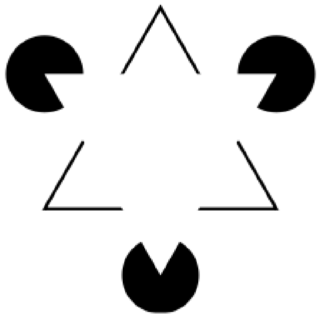
There is no single model that can address all the needs of decision makers and stakeholders at multiple scales

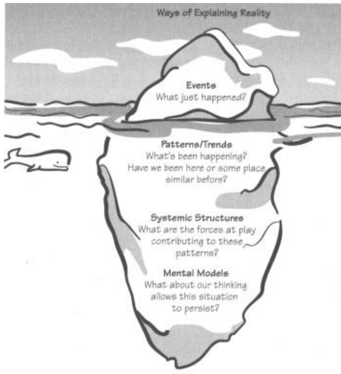
Theoretical framework of the models

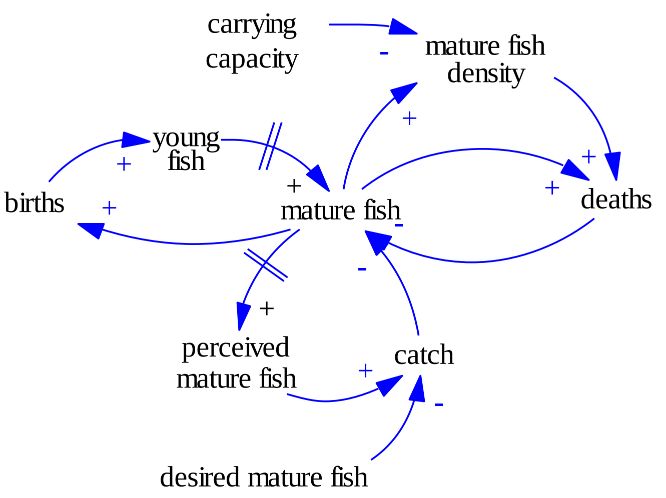
- Combination of methods (e.g. optimization, econometrics and simulation).
- Unifying framework: *System Dynamics*
- Stakeholder engagement approach: *Systems Thinking* (with causal loop diagrams)
- Mathematical foundation: non-compensatory aggregation of indicators, differential equations
- Underlying drivers of change: stocks and flows, capturing feedback loops, delays and nonlinearity

Systems Thinking and System Dynamics

- **Systems thinking** attempts to understand a whole system rather than its parts, utilized to identify the most effective leverage points to stimulate change within the system
- Created by Jay Forrester in the late 1950s at the MIT, methodological foundation of "The Limits to Growth", **System Dynamics** is an integrated and quantitative (modeling) approach utilized to understand situations for (complex) real world issues to guide decision making over time for achieving sustainable long term solutions *(SD class, SPL – 2012)*.

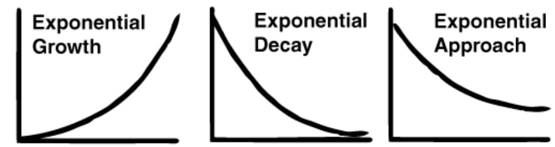


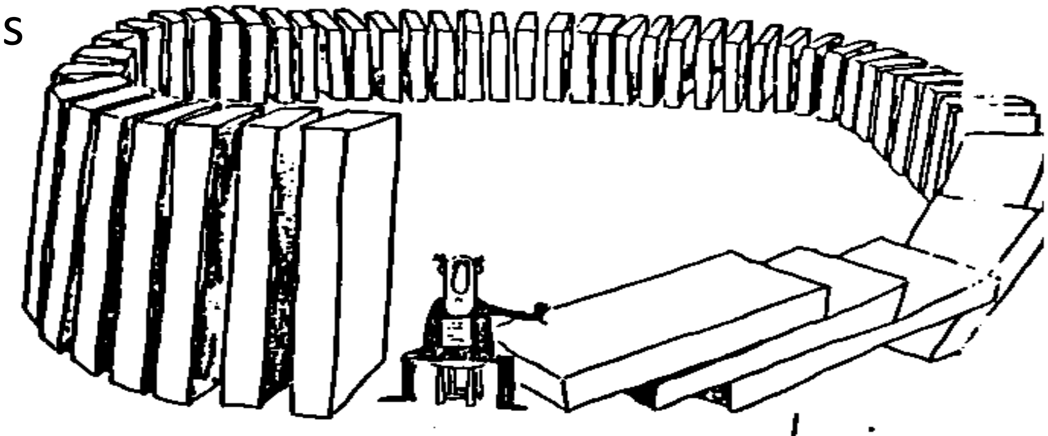




System Dynamics allows…

- Understanding how structure leads to behavior (through causal relations, stocks and flows)
- Simulation across time scales (with semi-continuous runs, using differential equations)
- Disaggregated spatial assessments (with the possibility to use subscripts and use GIS as input)
- Modeling across disciplines (integrating optimization and econometrics in a single model framework)





Drawing by Levin; © 1976 The New Yorker Magazine, Inc.

Added value compared to other tools?

- High degree of customization.
- Broad stakeholder participation in the development of the tool, with emphasis not only on indicators but on causal relations also (with connections within and across sectors, for social, economic and environmental indicators).
- Integrated and dynamic modelling framework (starting simulations in the past to improve validation), targeting green growth policy formulation and assessment.
- Transparency of the approach (both for indicators and model) and accessibility.

Causal Loop Diagrams (CLD)

- Represent the feedback structure of systems!

- Capture:
  - The hypotheses about the causes of dynamics
  - Mental models of individuals or teams
  - The important feedbacks driving the system
- Critical aspects:
  - Think in terms of cause-and-effect relationships
  - Focus on the feedback linkages among components of a system
  - Determine the appropriate boundaries for defining what is to be included in the CLD

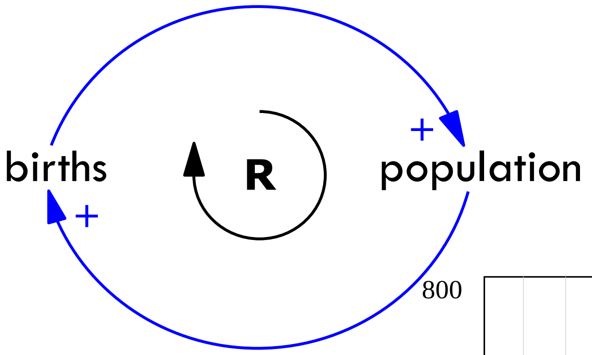
Reinforcing Loops (1/2)

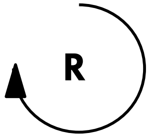
- Reinforcing loops tend to increase and amplify everything happening in the system (i.e. action - reaction).

Example:
Fold a paper (0,1 mm) 42 times:

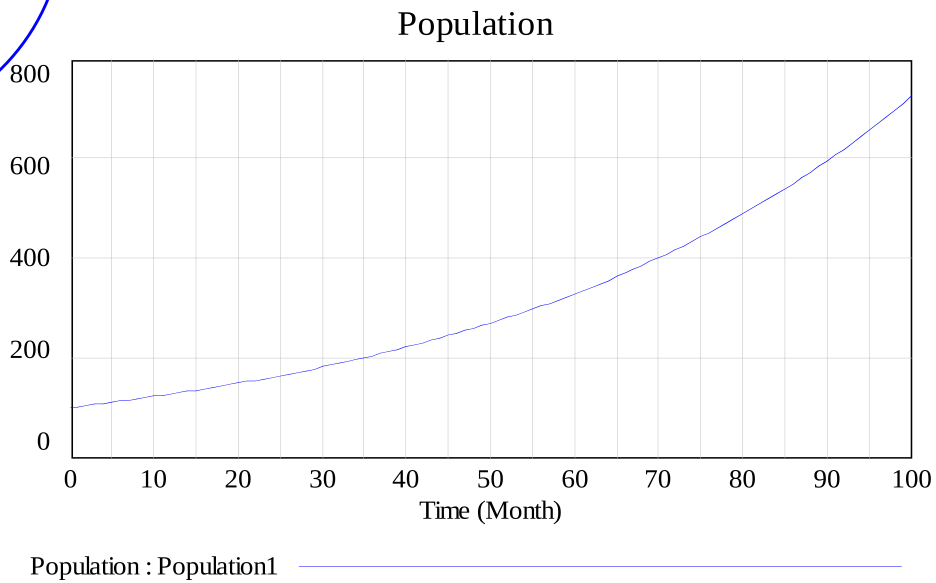
- What would be the final thickness of such paper?
- The result is a thickness larger than the distance between the Earth and the moon = 0,1*2^42 (43,980,465,111 cm = 439,804 Km)

Reinforcing Loops (2/2)





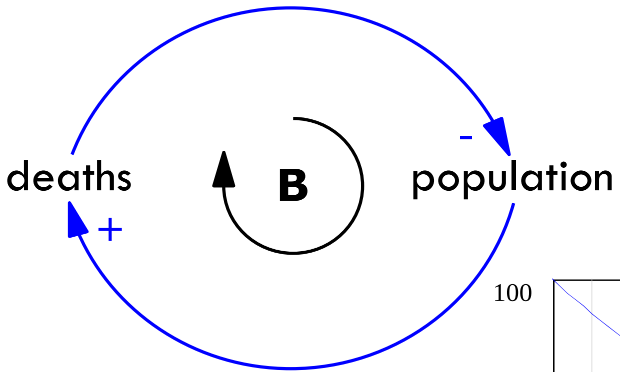
Self reinforcing

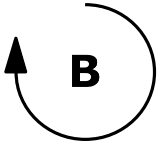


Balancing Loops (1/2)

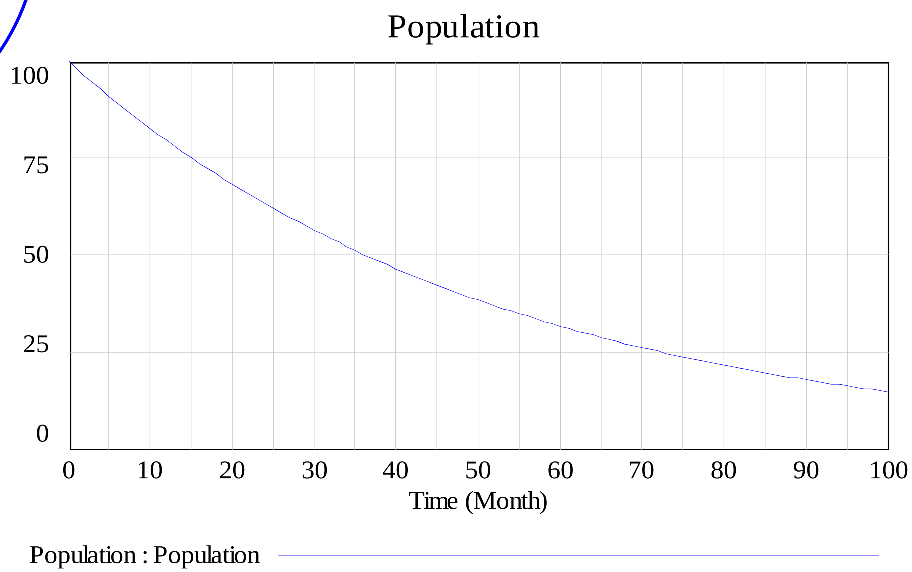
- Negative loops are counteractive and oppose change.
- Balancing loops represent a self limiting process, which aims at finding balance and equilibrium.

Balancing Loops (2/2)

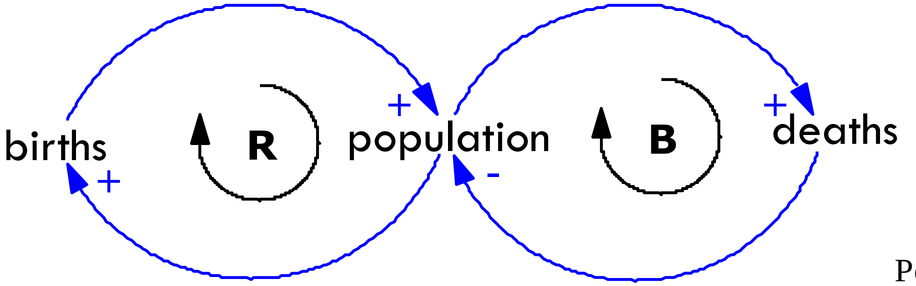


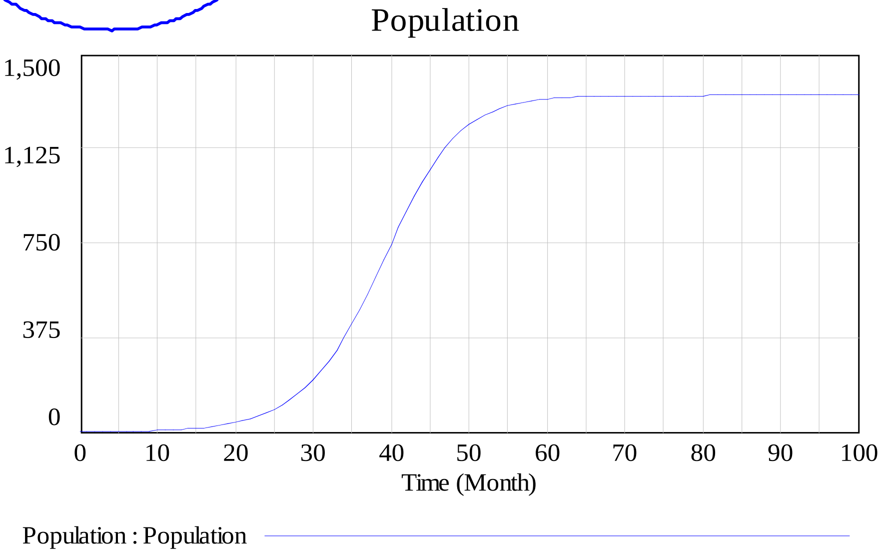


Self balancing

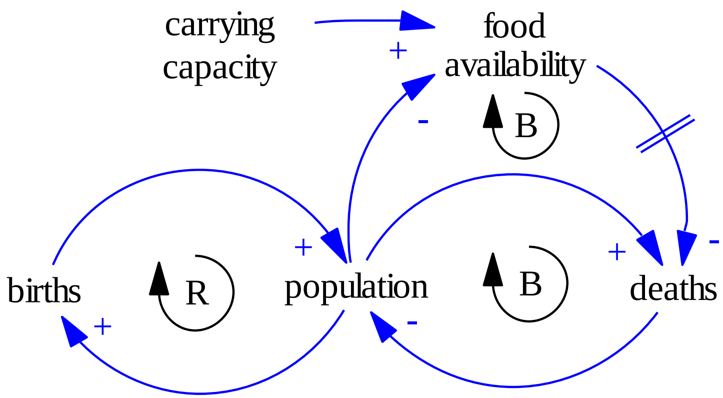


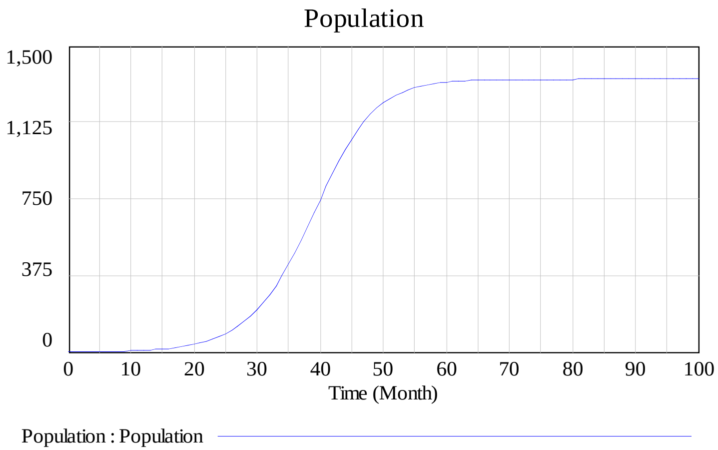
Combining feedback loops

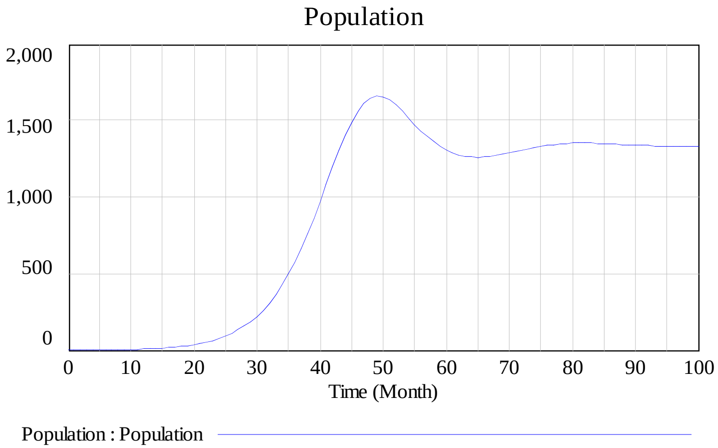




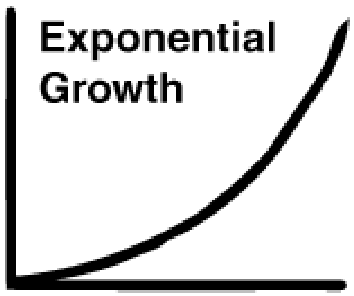
Feedback Loops and Delays

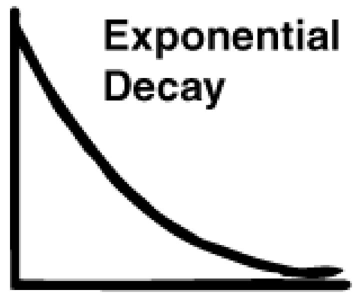


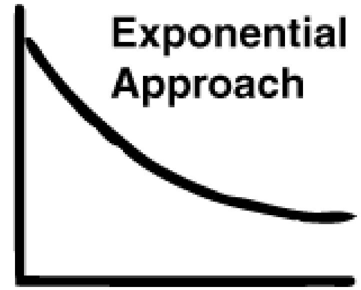




Potential Modes of Behaviour

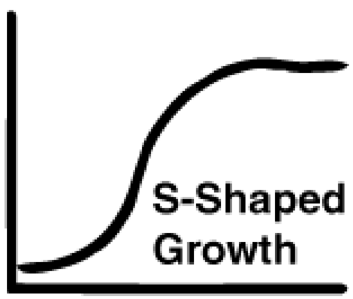


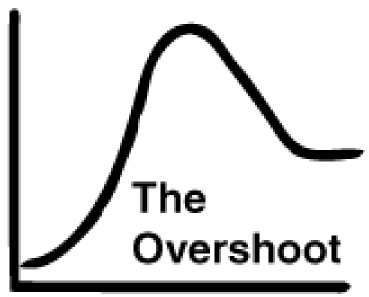


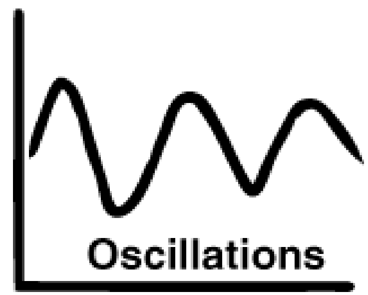


Population?

Shellfish beds?







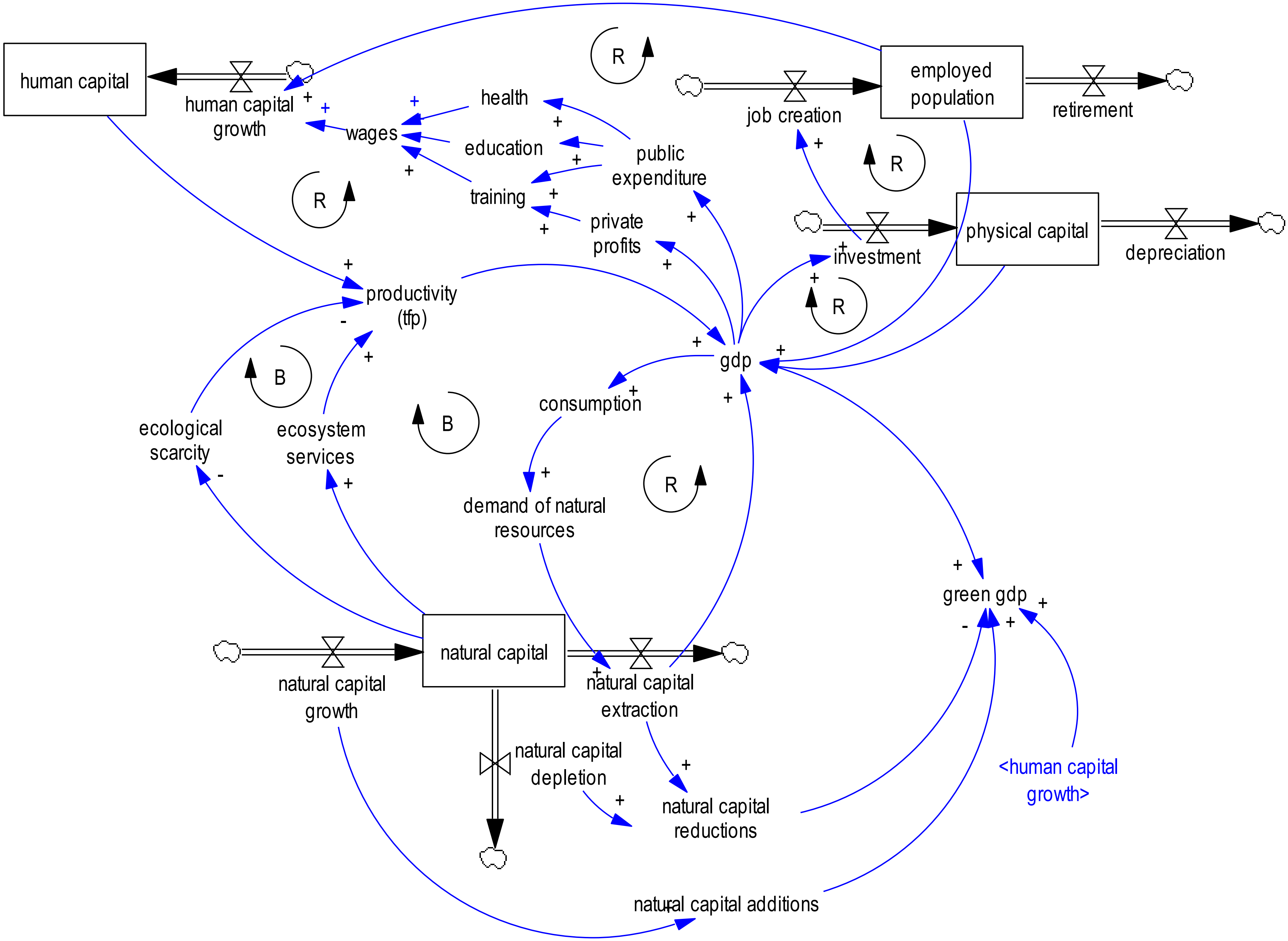
Employment creation?

Housing prices?

Congestion?

Land-use, Water and Economies Dependent on infrastructure

Land-use, Water and Economies Dependent on infrastructure



human capital
human capital growth
wages
health
education
training
public expenditure
private profits
employed population
job creation
retirement
physical capital
investment
depreciation
productivity (tfp)
gdp
consumption
demand of natural resources
ecological scarcity
ecosystem services
green gdp
natural capital
natural capital growth
natural capital extraction
natural capital depletion
natural capital reductions
natural capital additions
<human capital growth>
R
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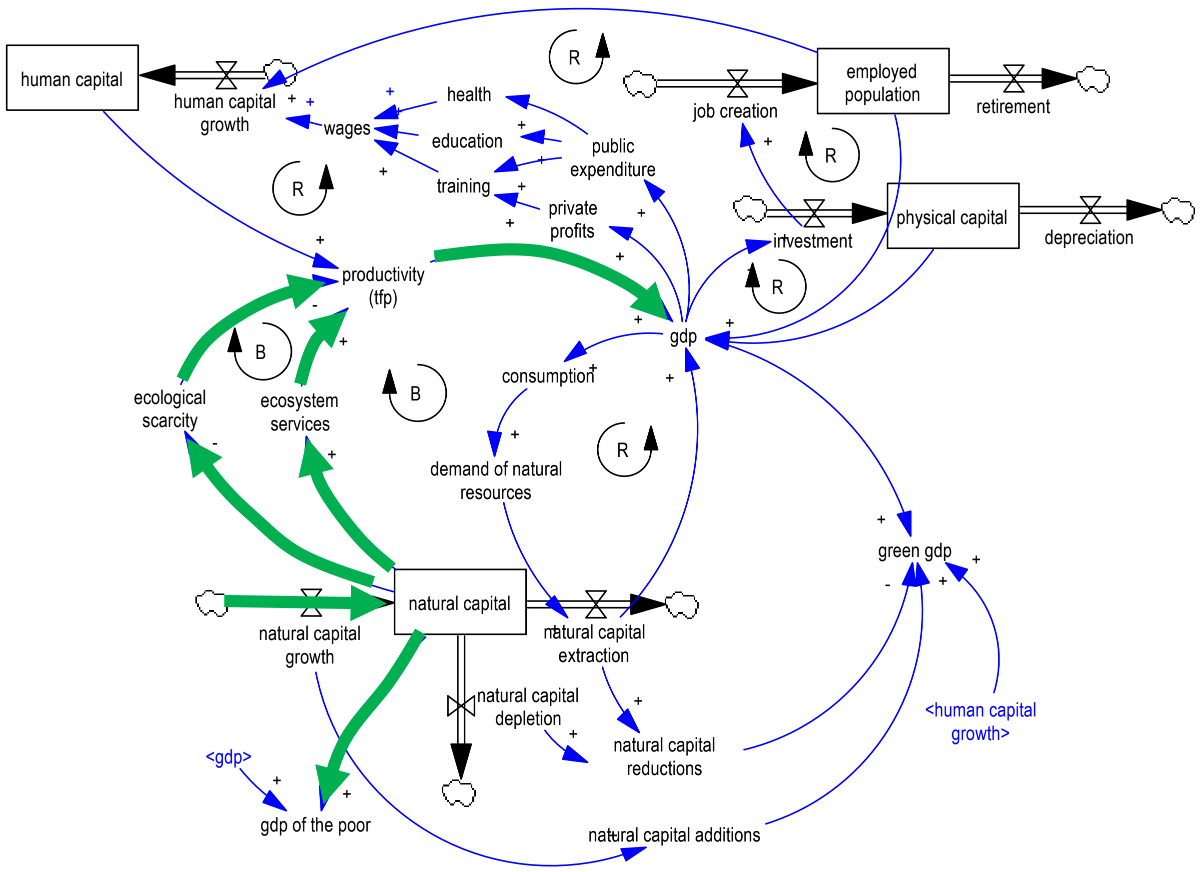
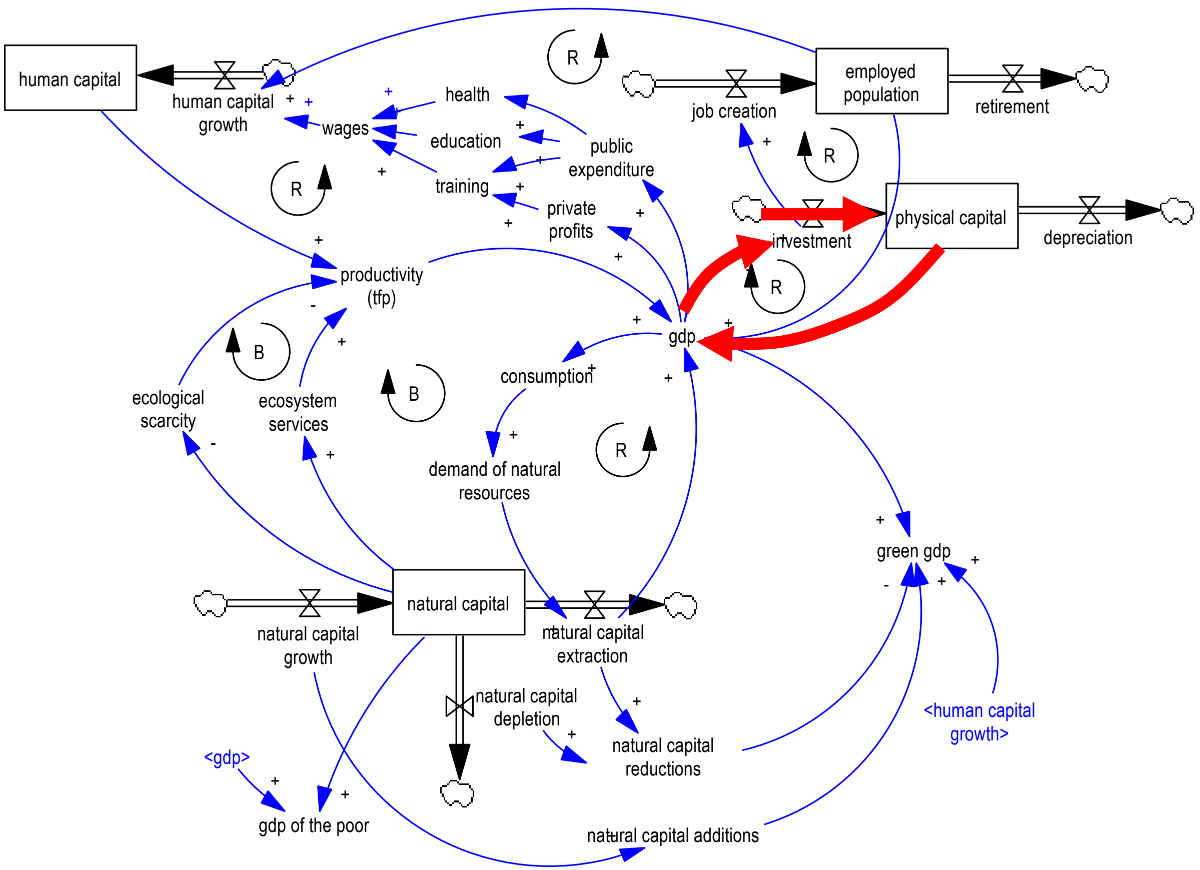
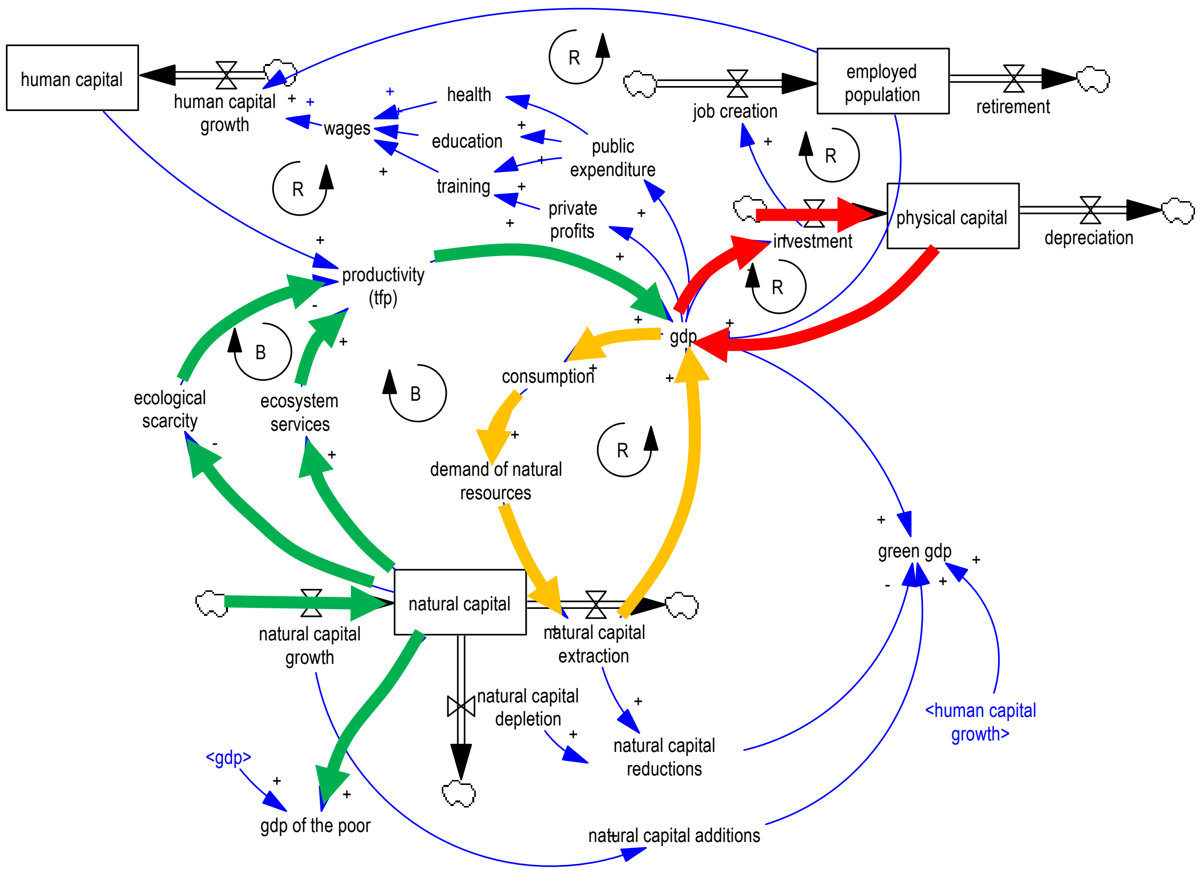
Systems analysis: value addition?



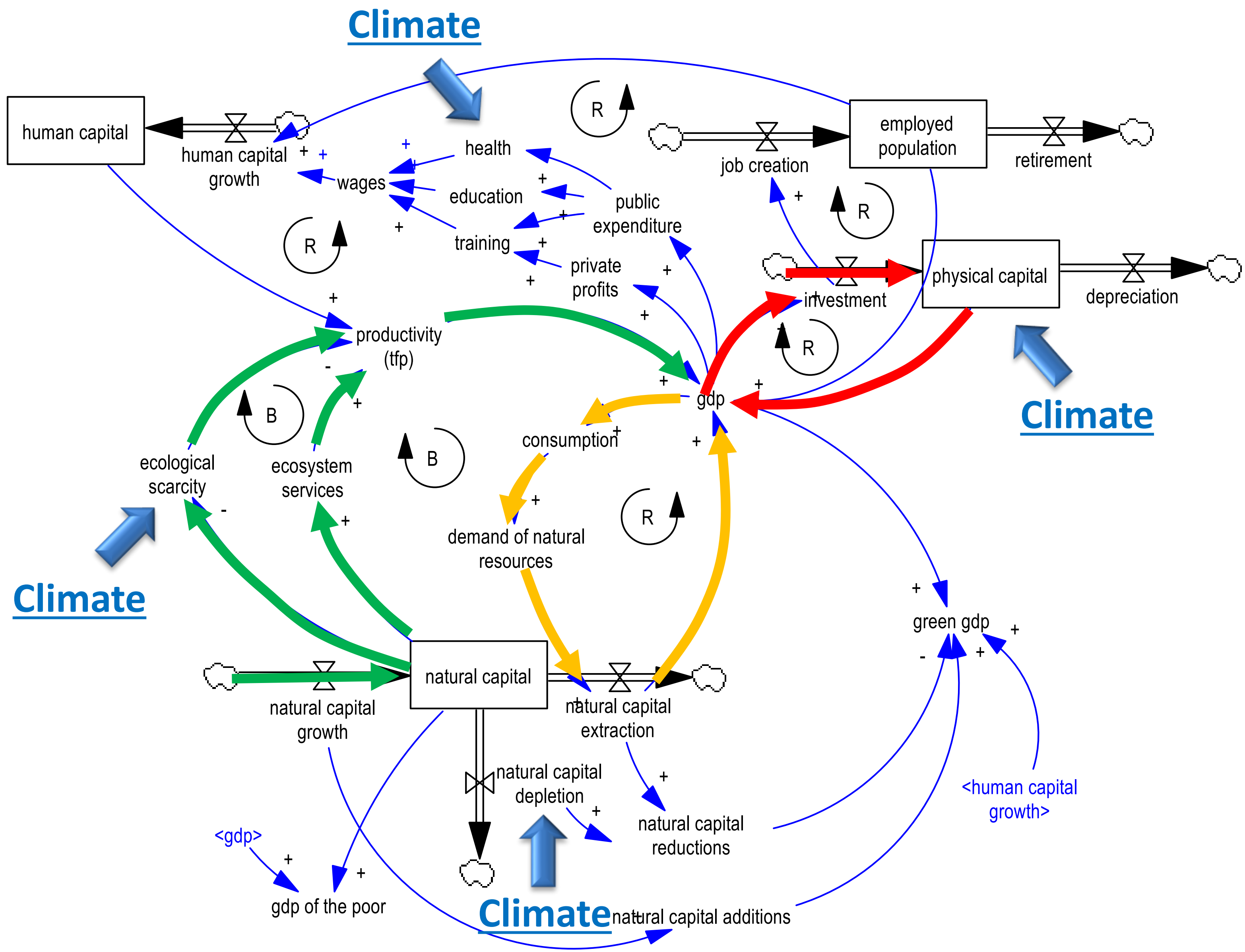
Systems analysis: value addition?



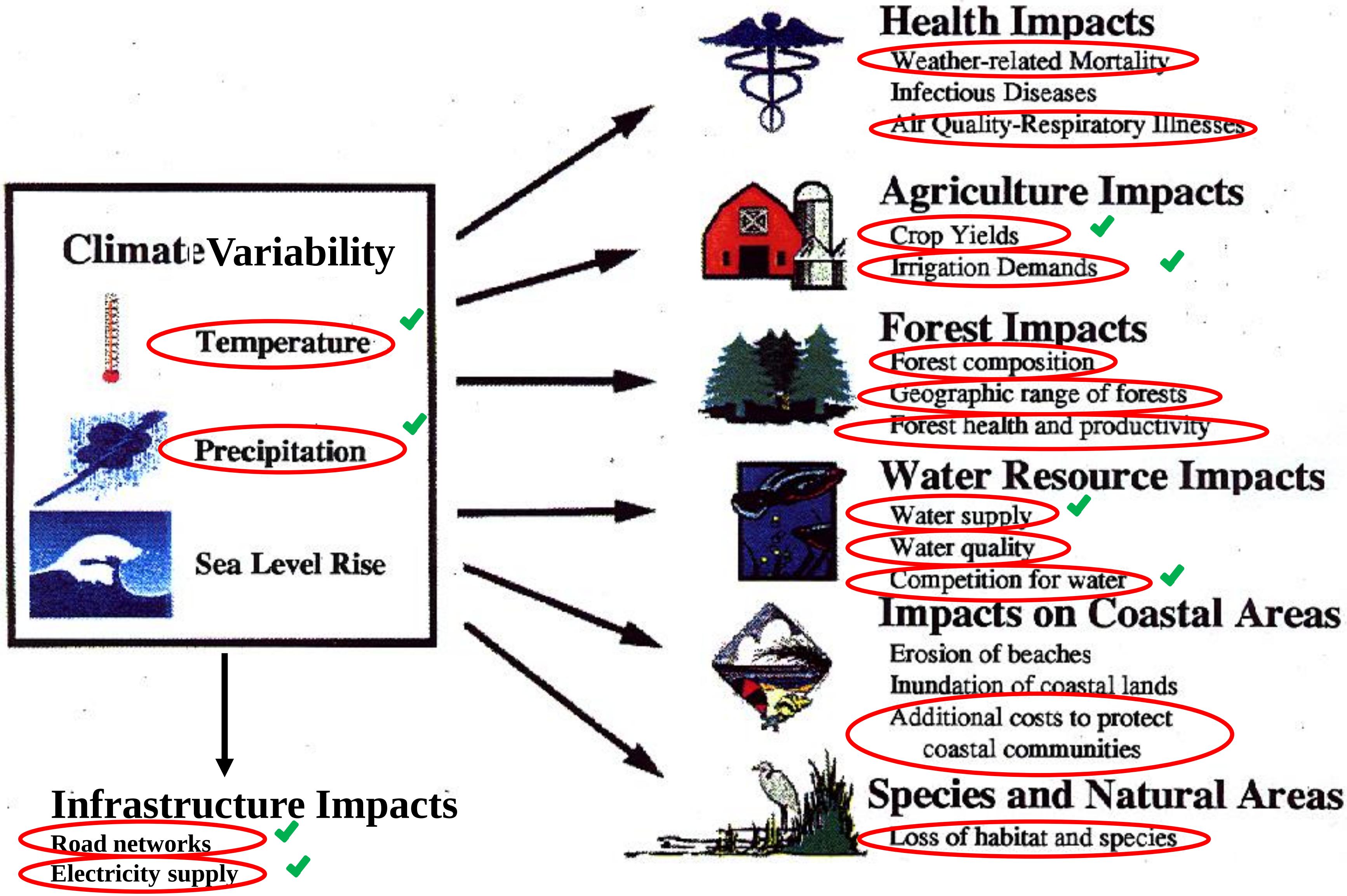
Systems analysis: value addition?



Systems analysis: climate impacts?



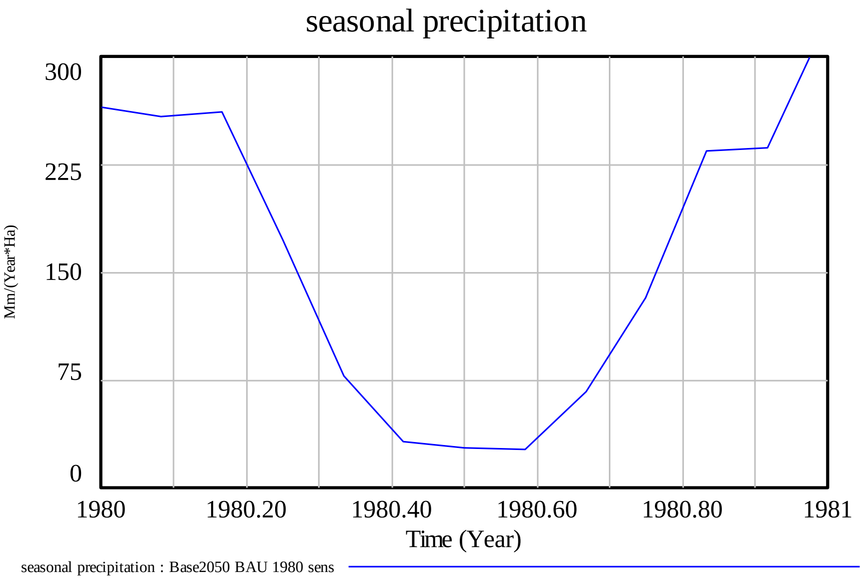
Climate impacts

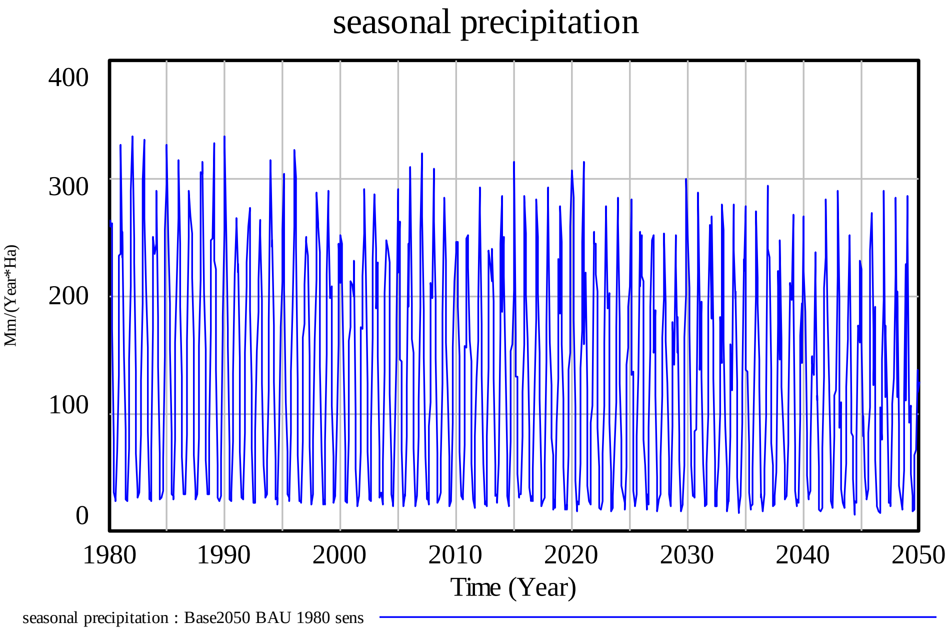


Calibration of precipitation

- Precipitation

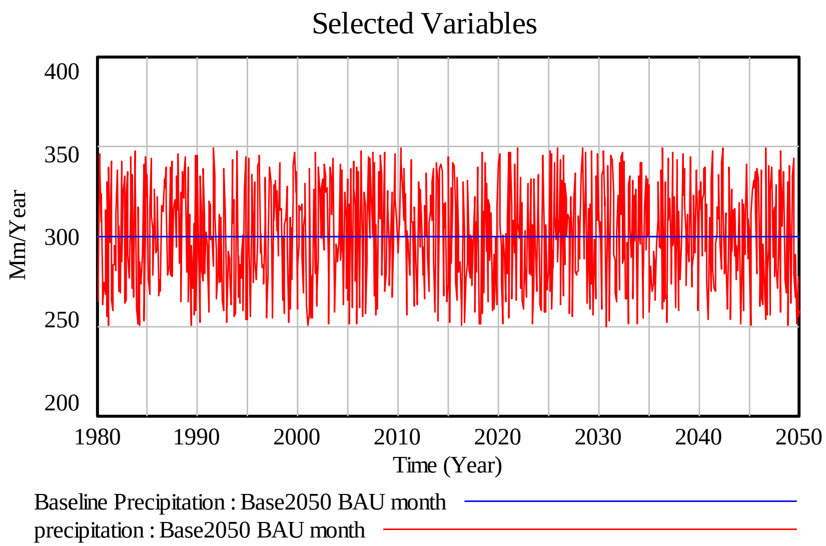
  The annual rainfall is distributed over the year to capture seasonal patterns and their cascading effects.



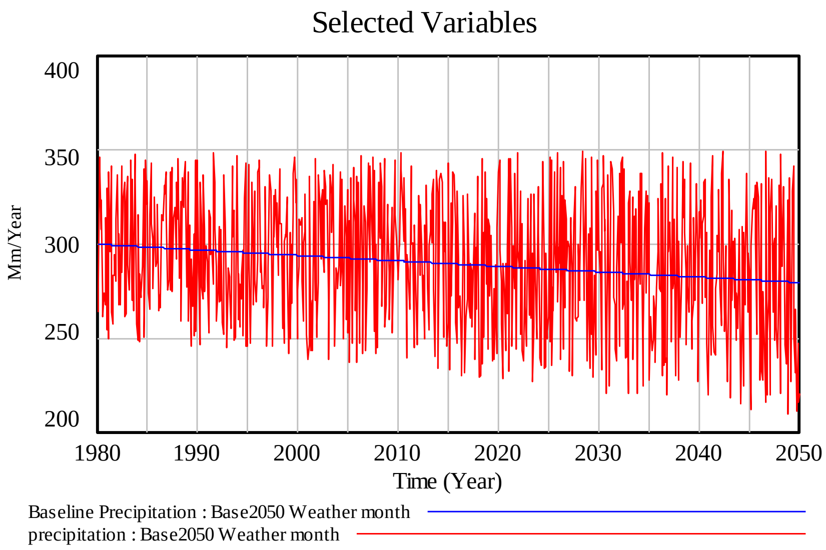


Climate variability and trends

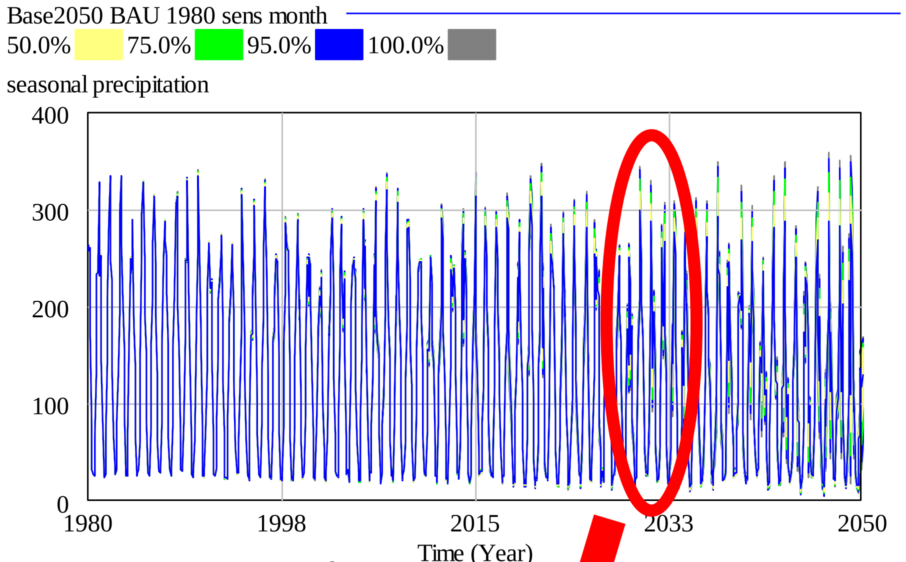
Baseline simulation with constant seasonal precipitation and without variation in precipitation.



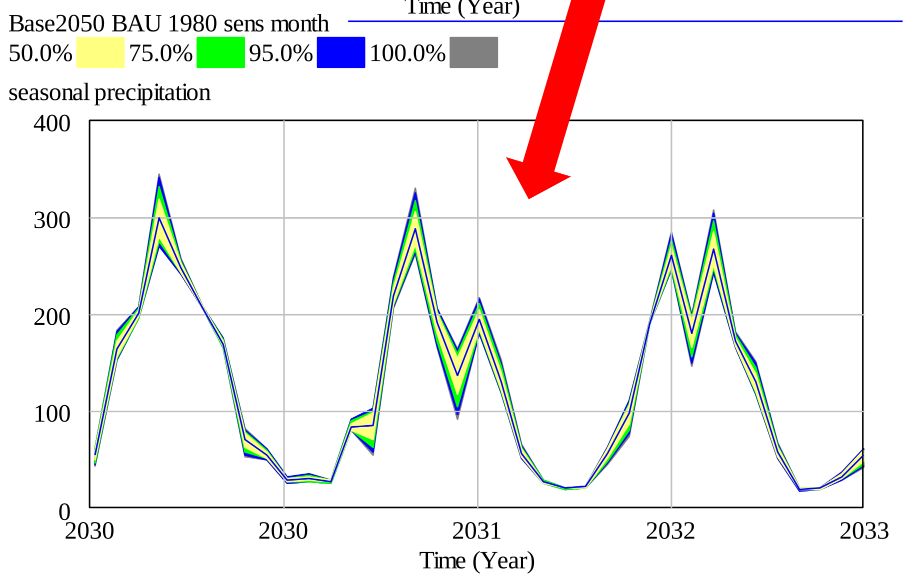
Weather scenario assuming a decreasing trend in annual precipitation and an increasing variability in precipitation.

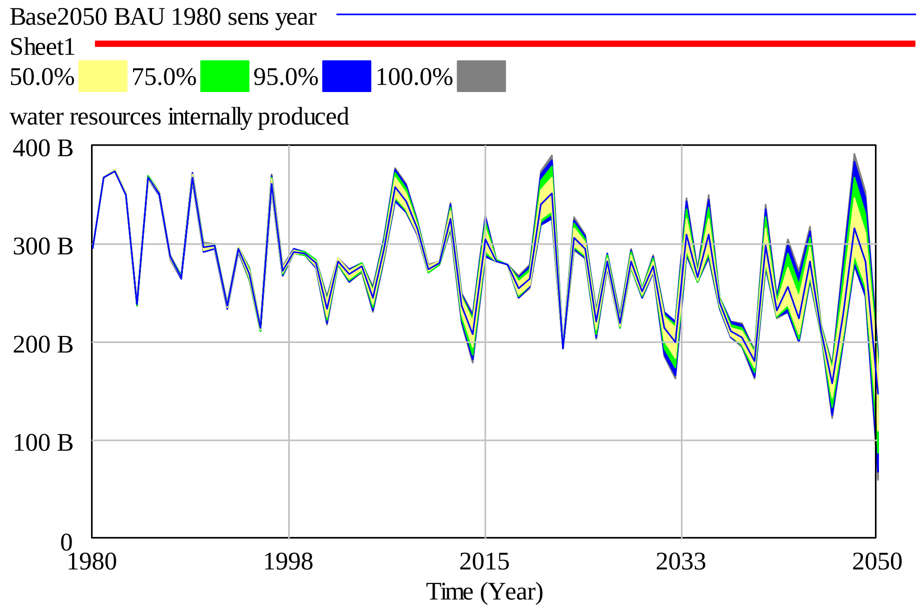


Variability in precipitation to capture uncertainty

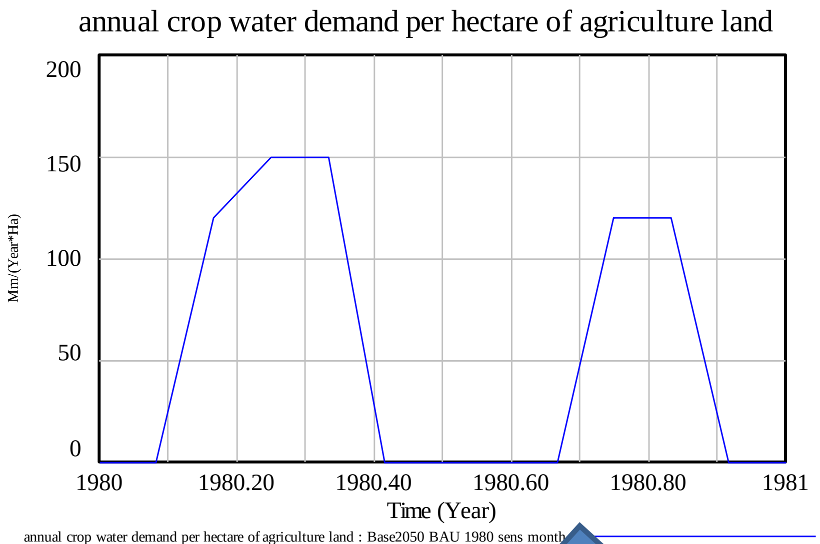


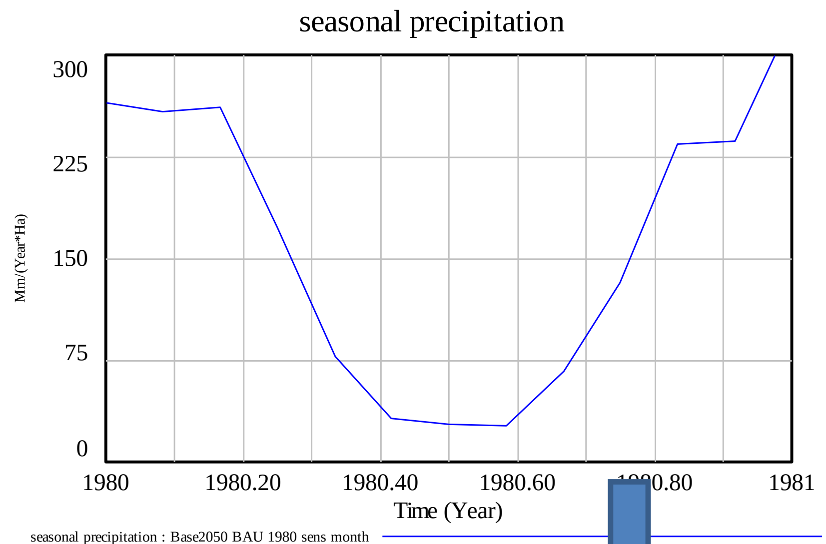
Small variabilities in seasonal precipitation can, over the total area, cause large variations in the total amount of water resources produced internally (total precipitation less evapotranspiration.



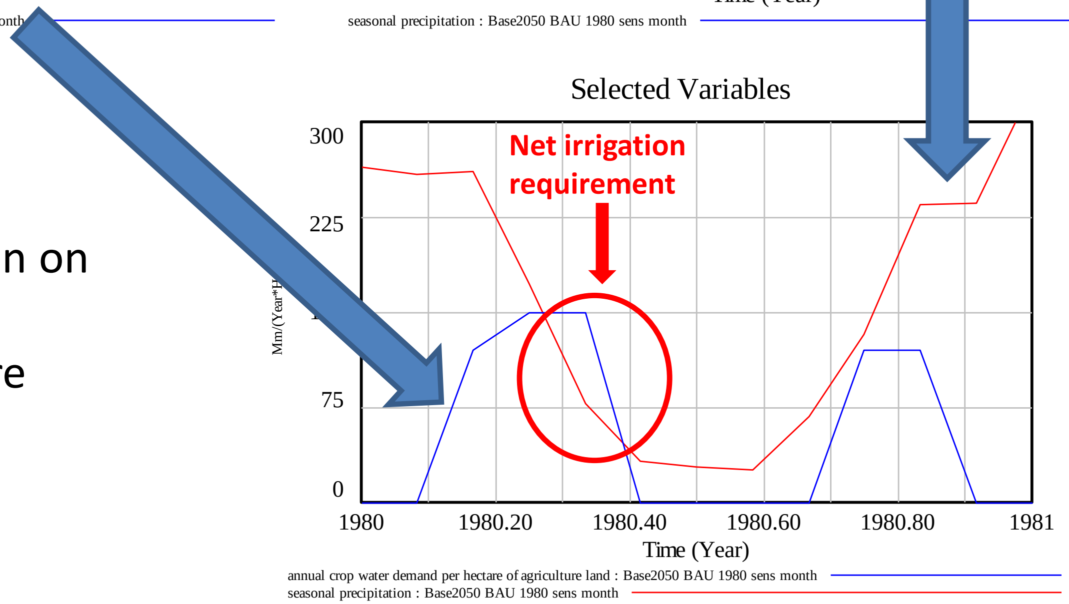


Accounting for seasonal water needs

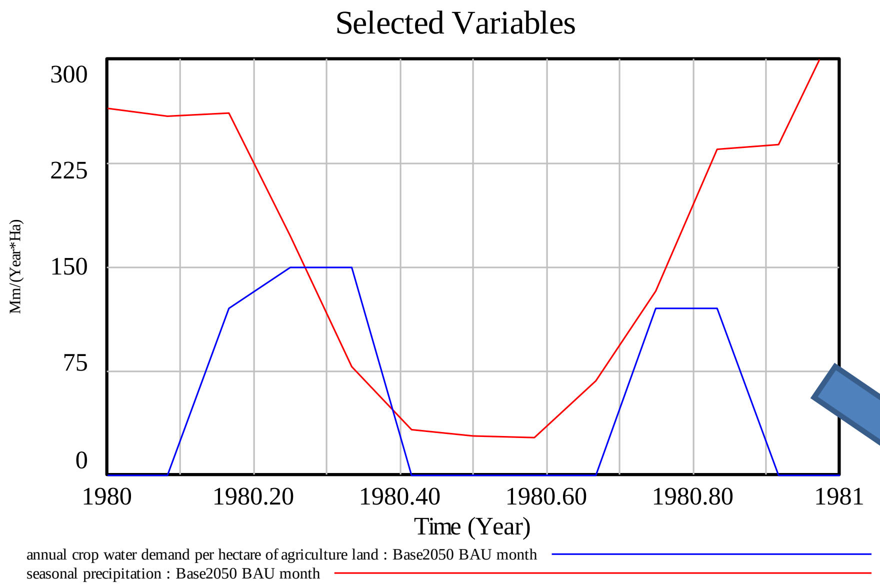




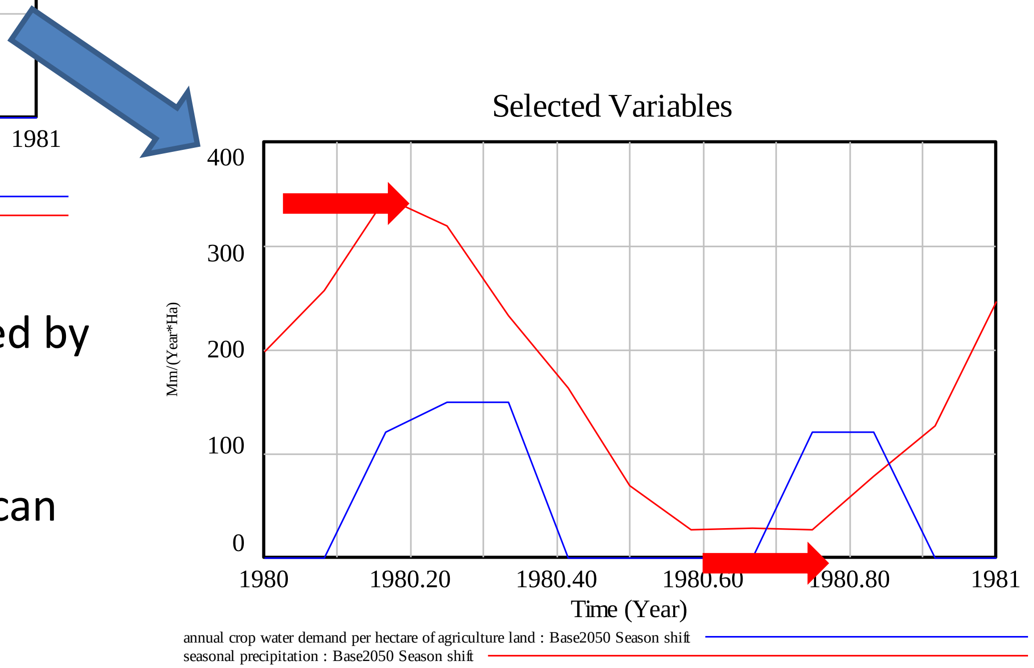
Crop water requirements are compared to seasonal precipitation on a monthly base to derive the net irrigation requirements per hectare



Seasonal shift



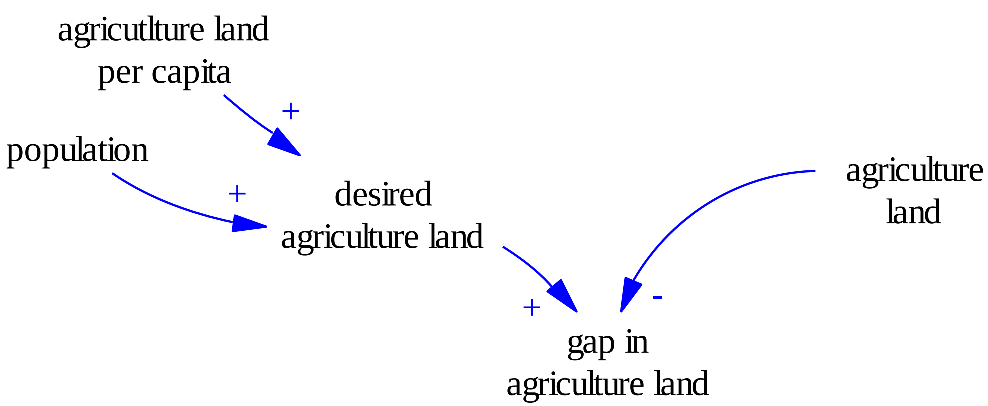
The formulation of the model allows for capturing a seasonal shift in precipitation.



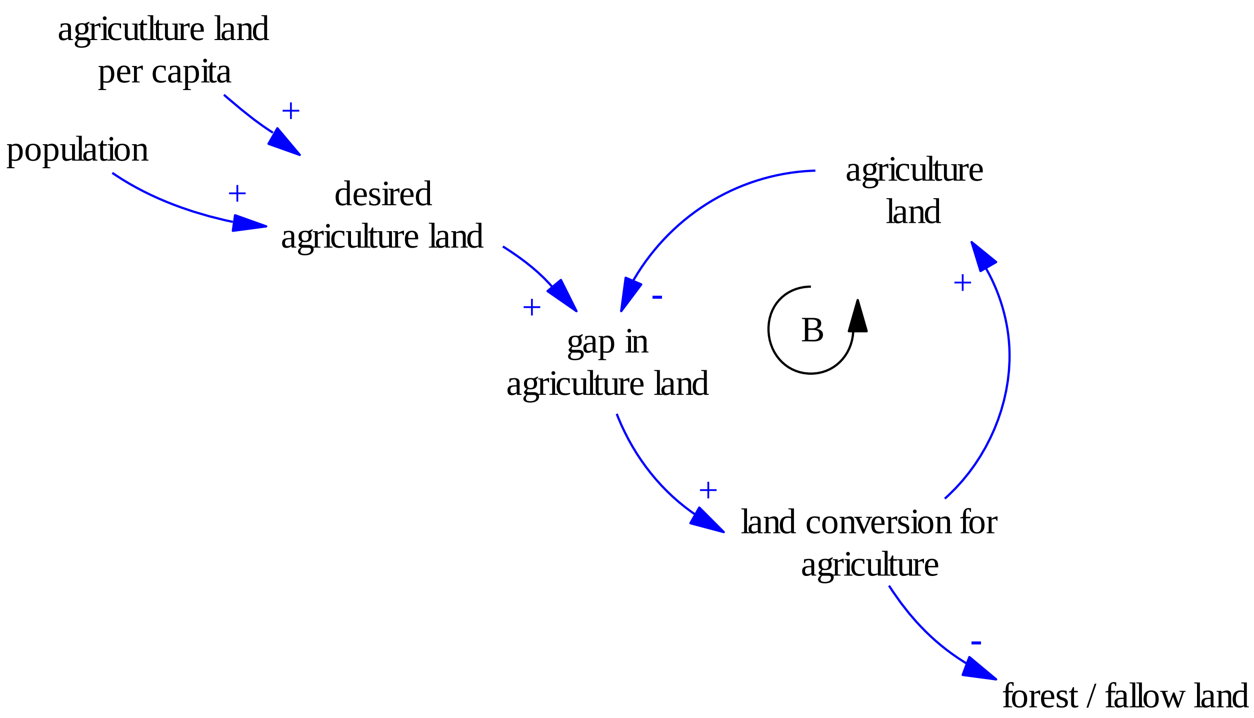
In this example, the rainy season is shifted by 2 months, from the start of the season.

A gradual shift in seasonal precipitation can be included to see the impacts on the performance of the system over time.

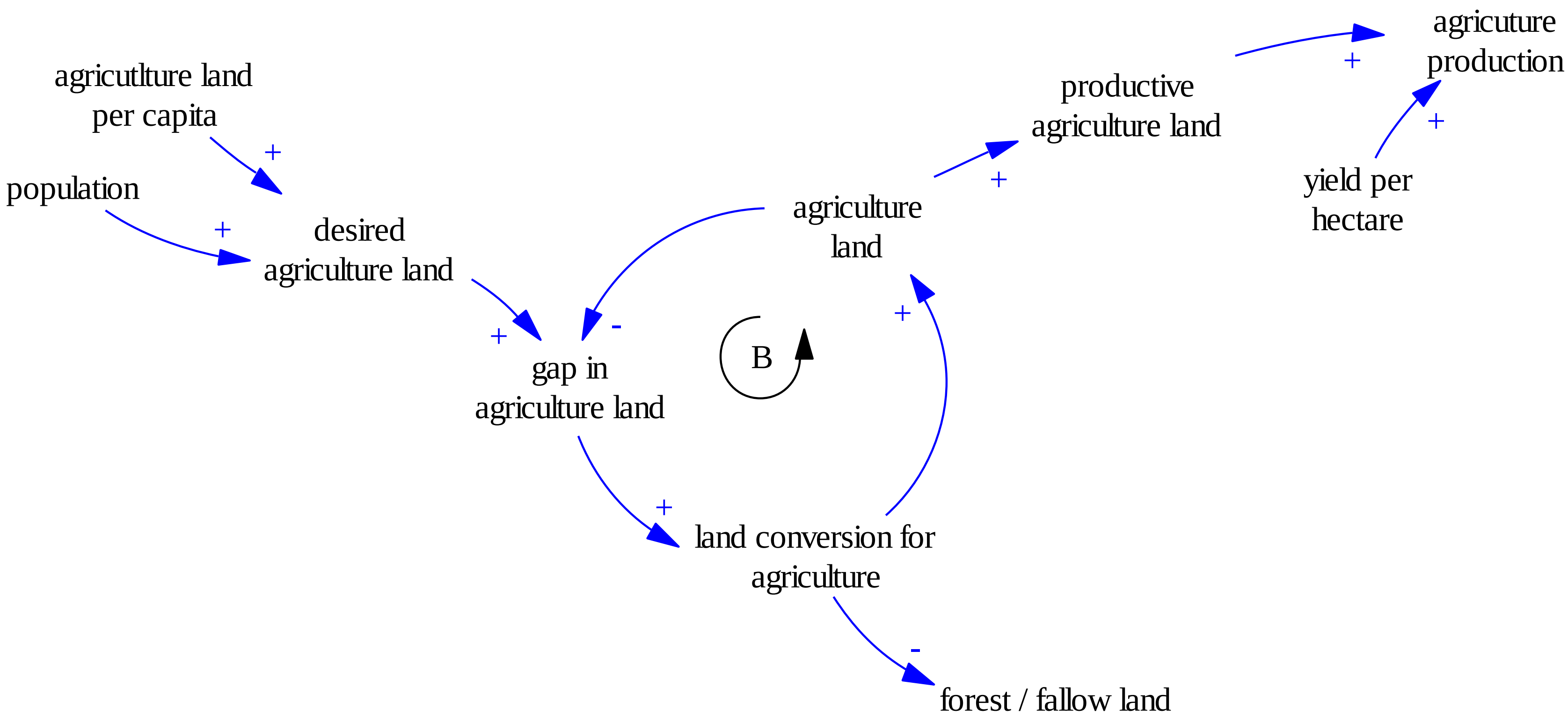
CLD Agriculture



CLD Agriculture



CLD Agriculture



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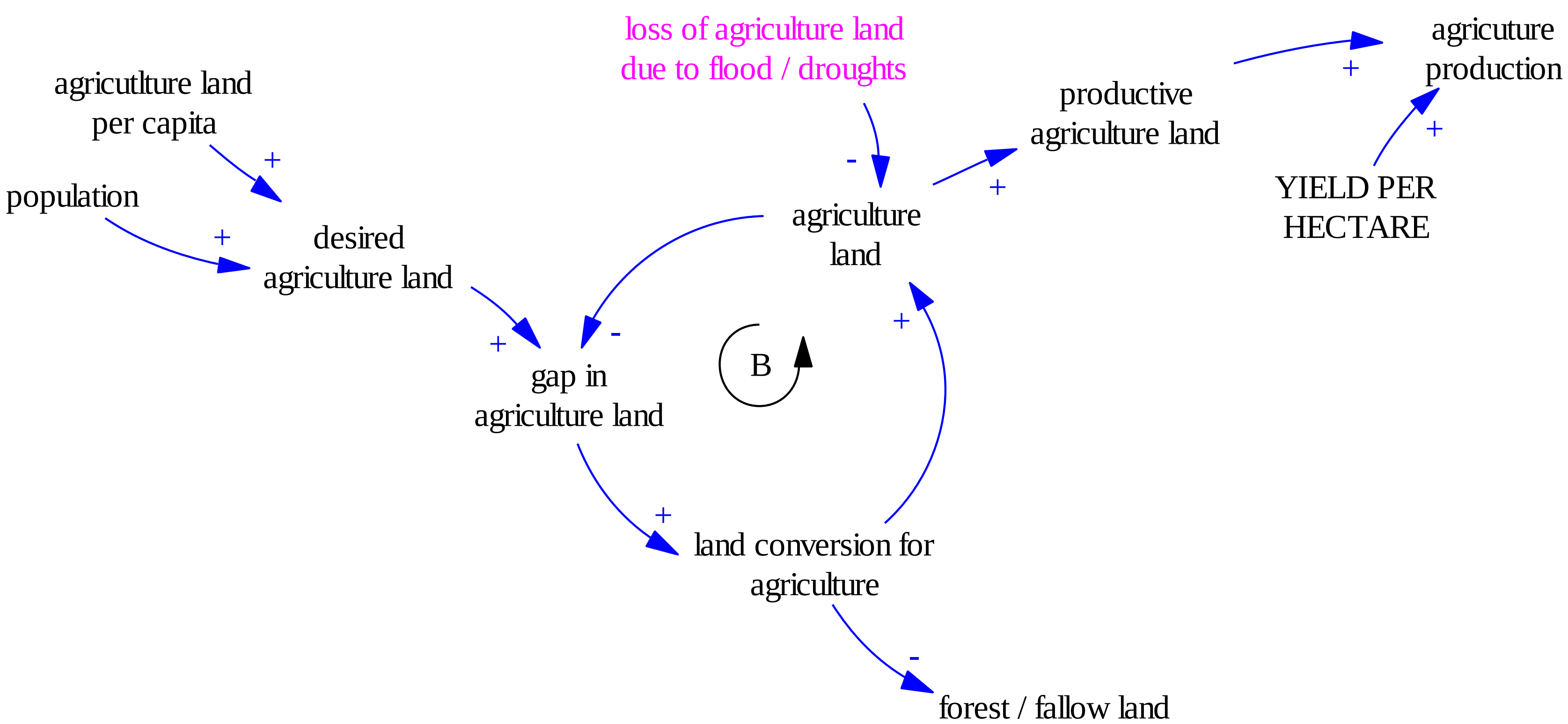
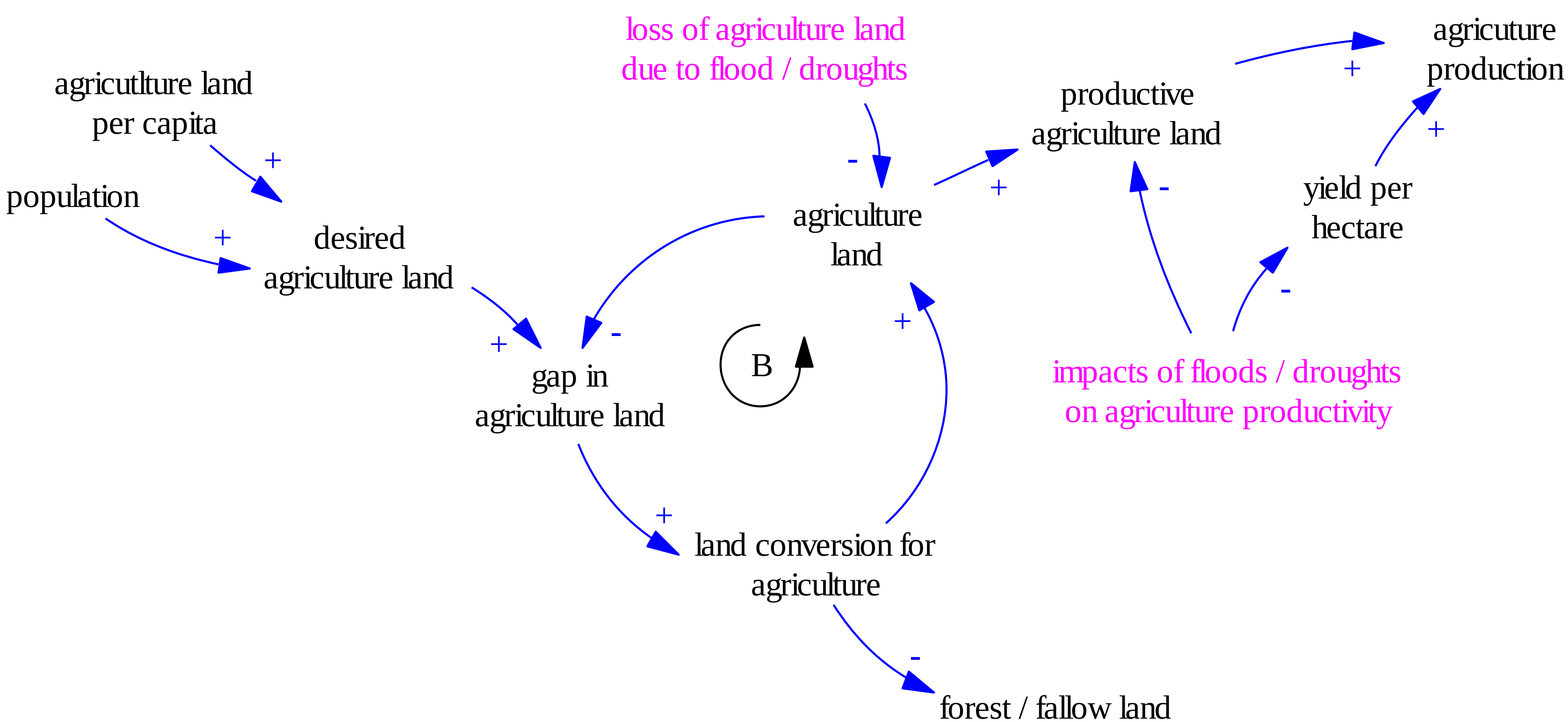
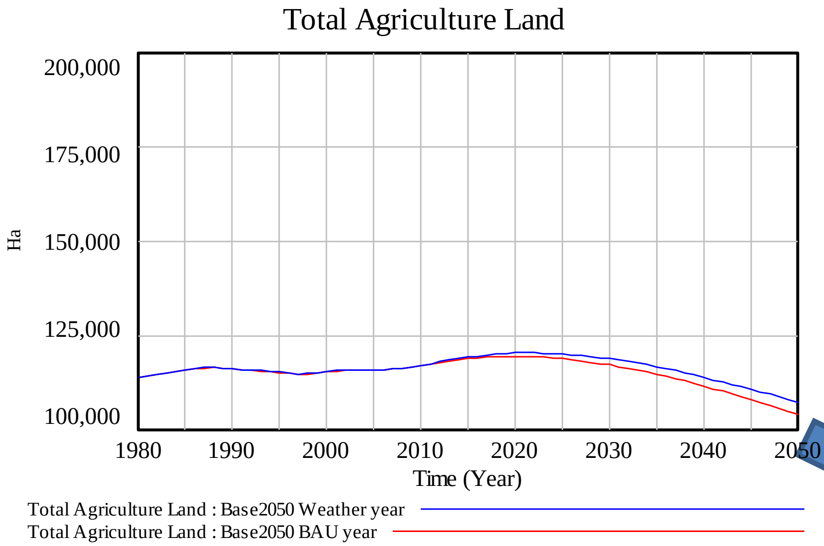
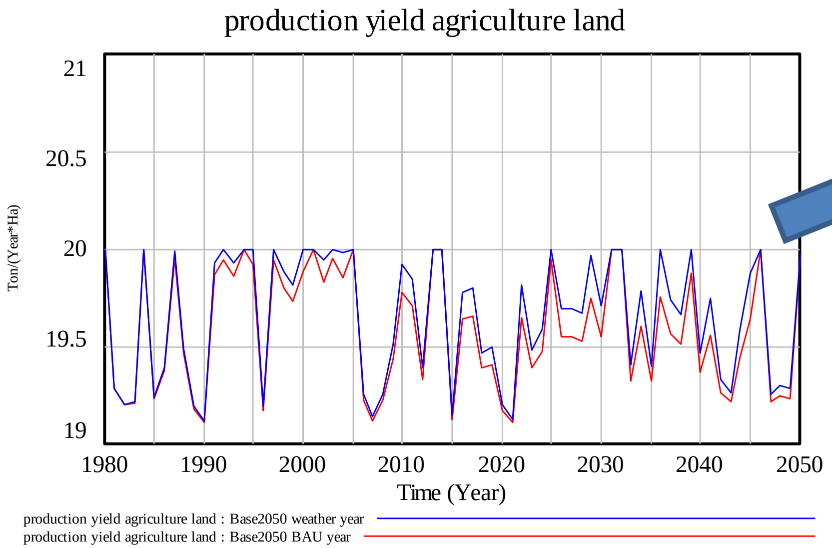


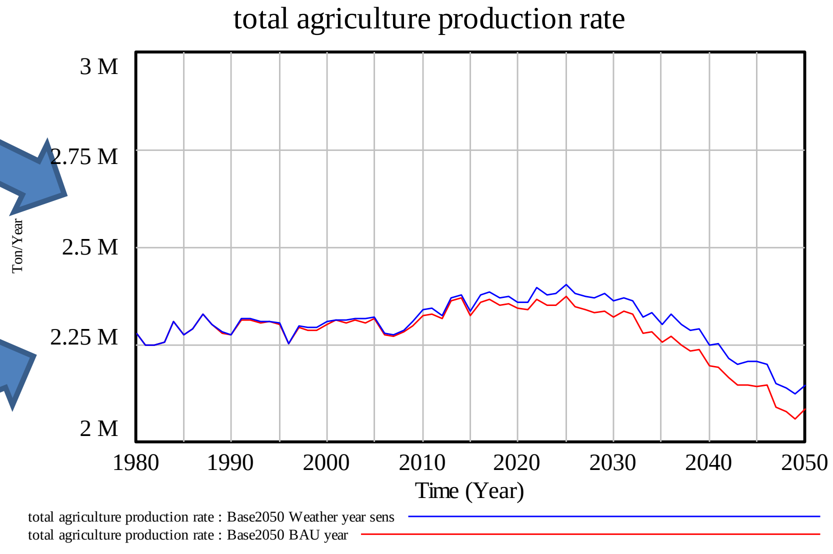
CLD Agriculture



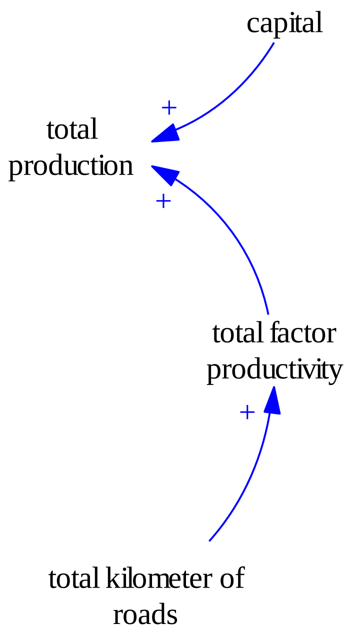
First order impacts - Agriculture



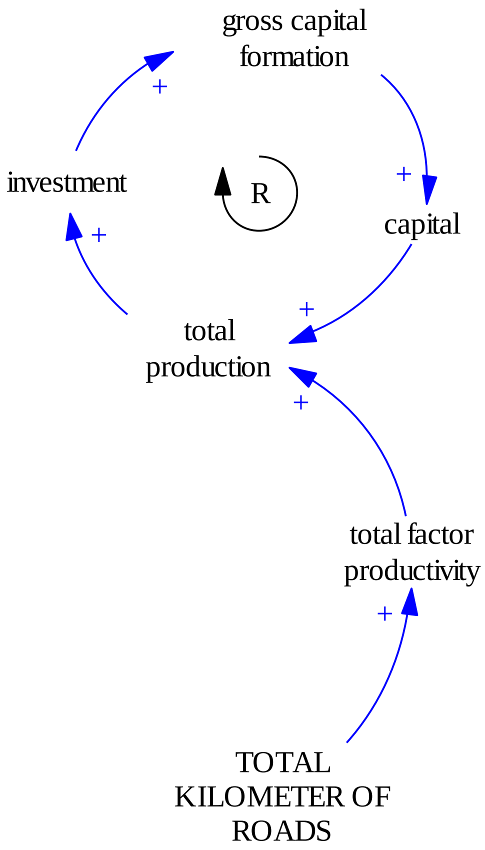




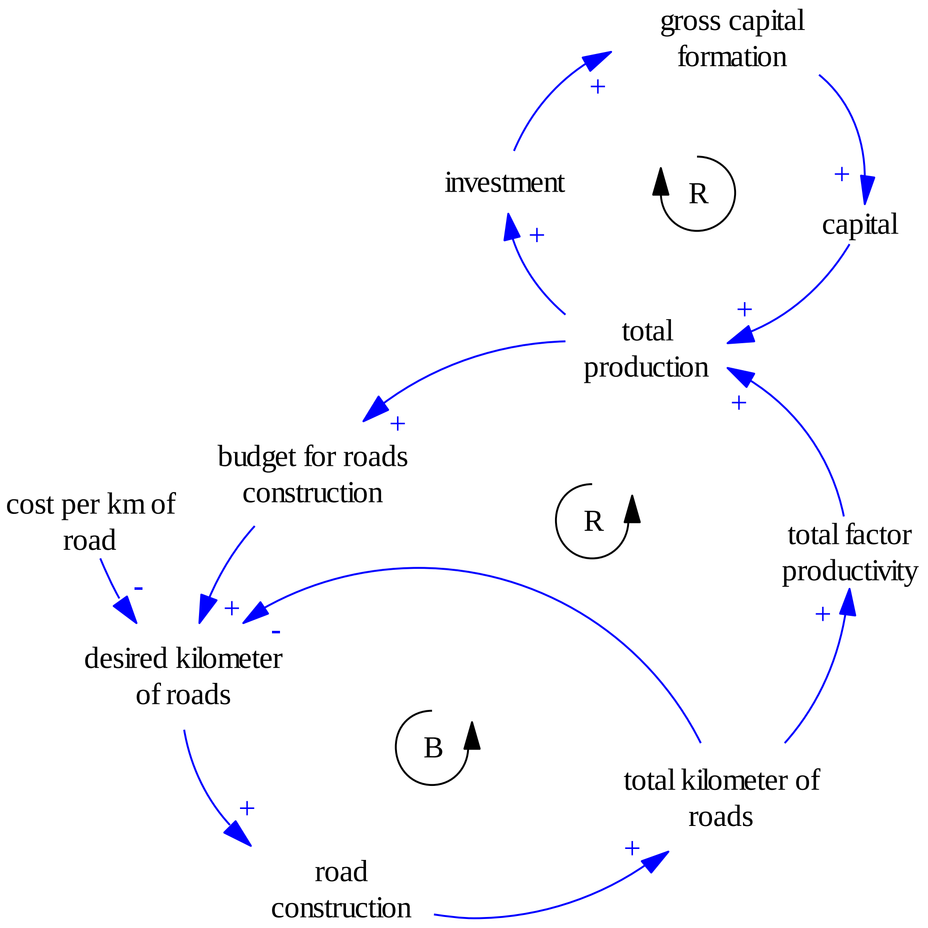
CLD Infrastructure



CLD Infrastructure



CLD Infrastructure



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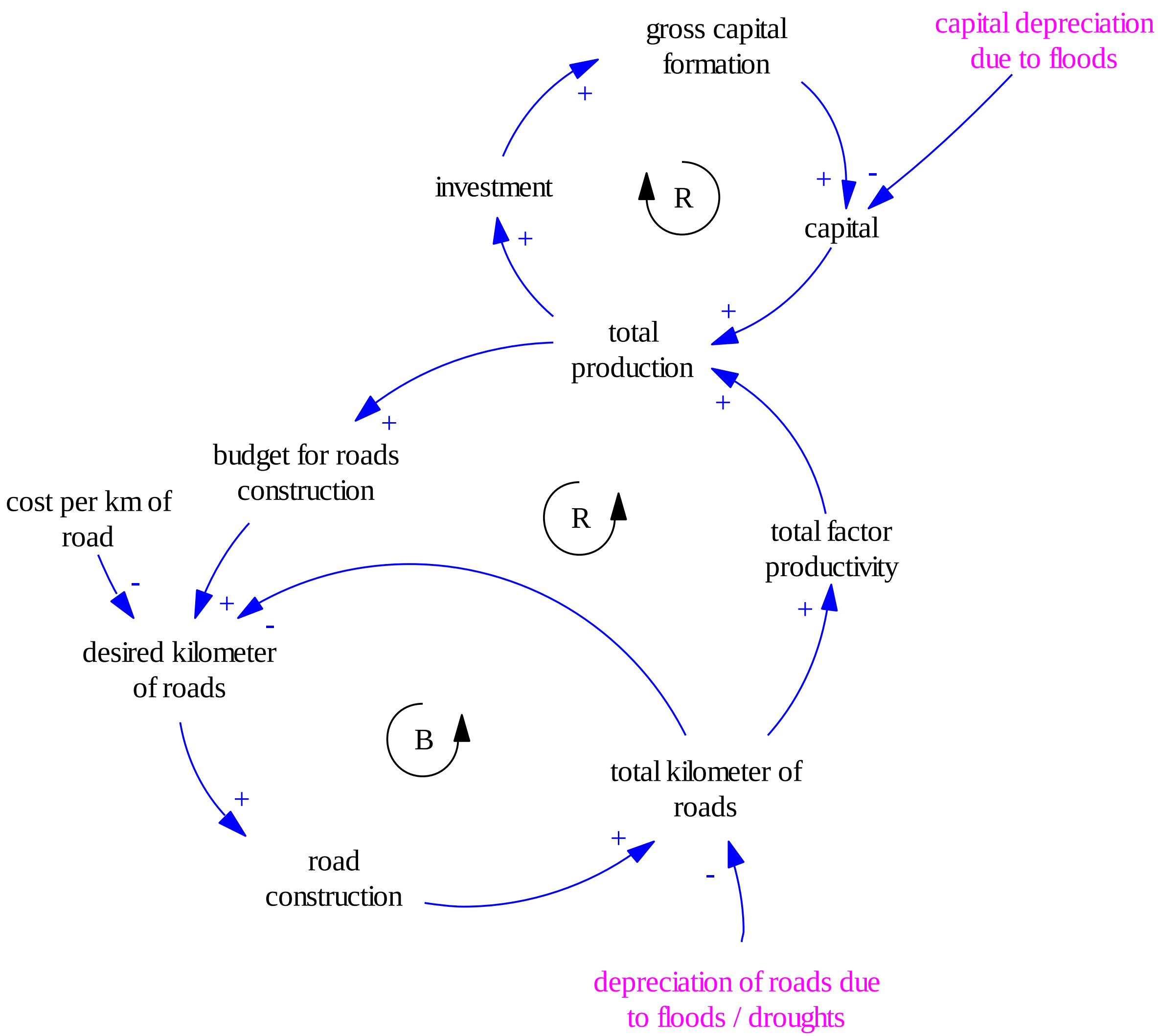
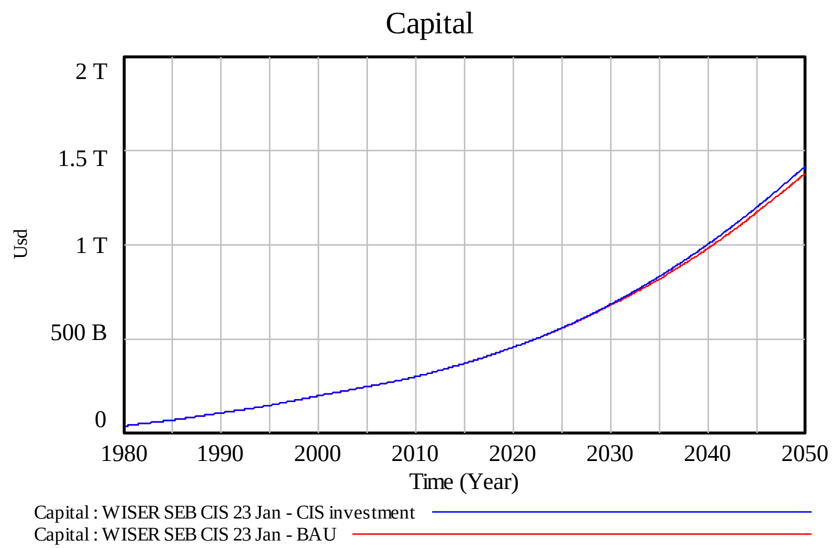
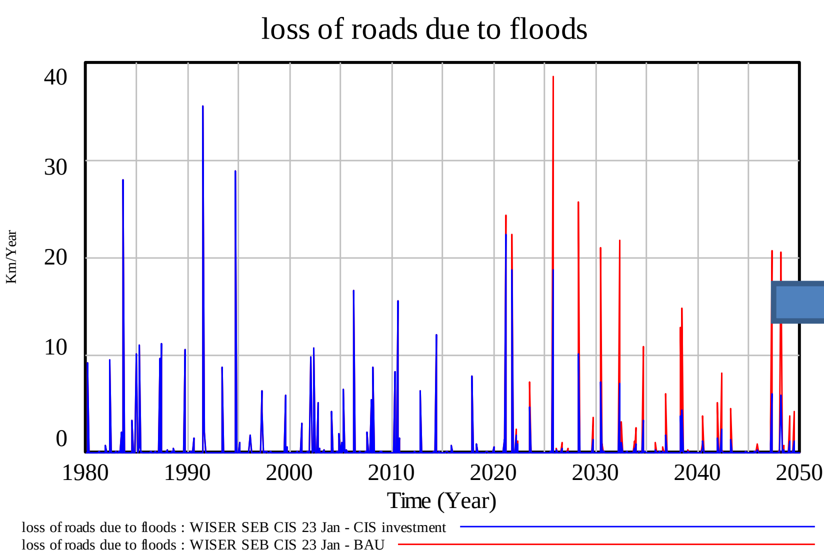


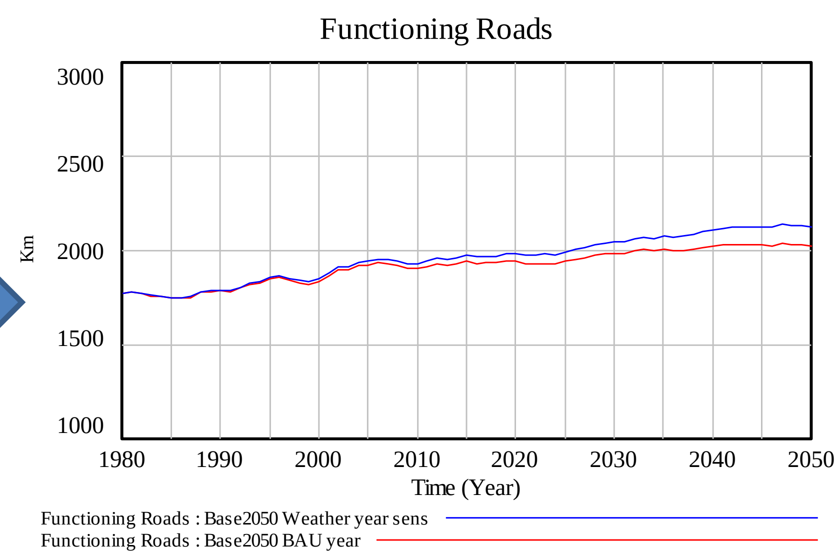
First order impacts - Infrastructure

The decreasing trend in precipitation leads to a reduced number of floods, and consequently a reduced loss of roads and capital.

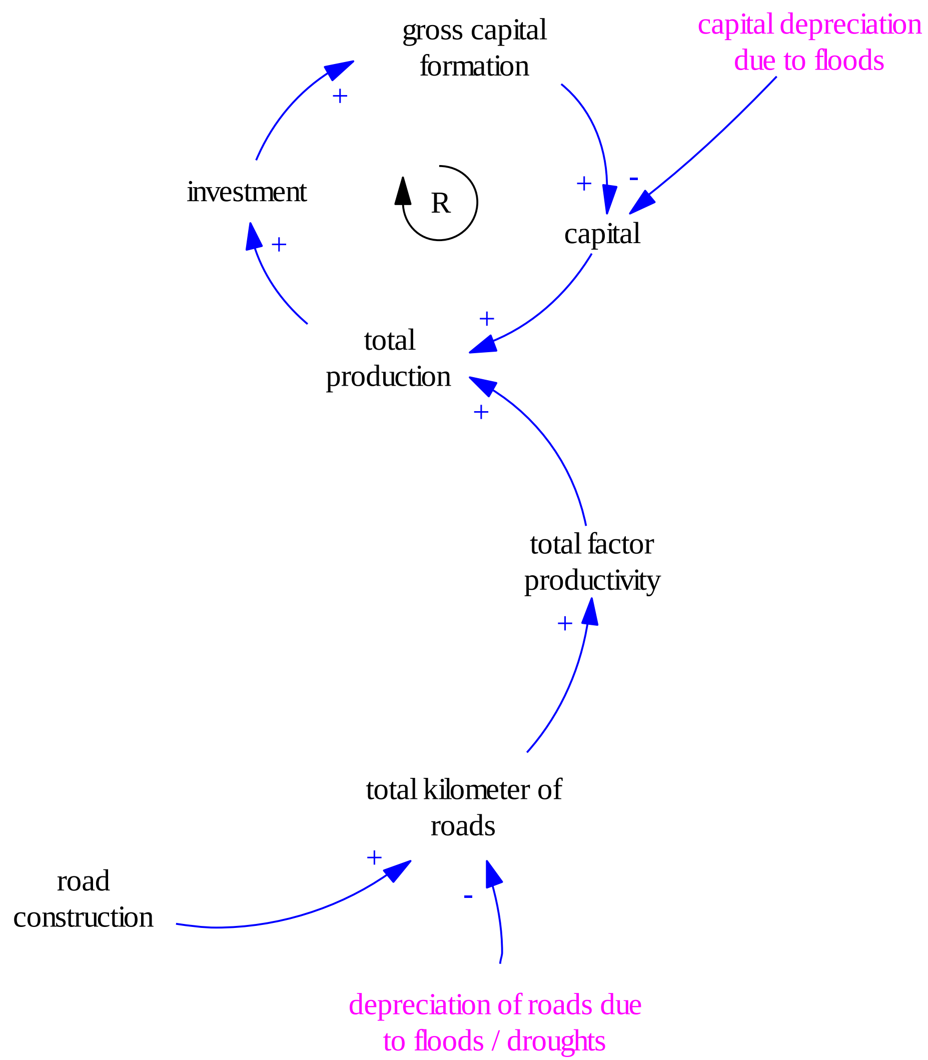
Could reduced precipitation and higher variability lead to more volatile events which cause more severe damage?



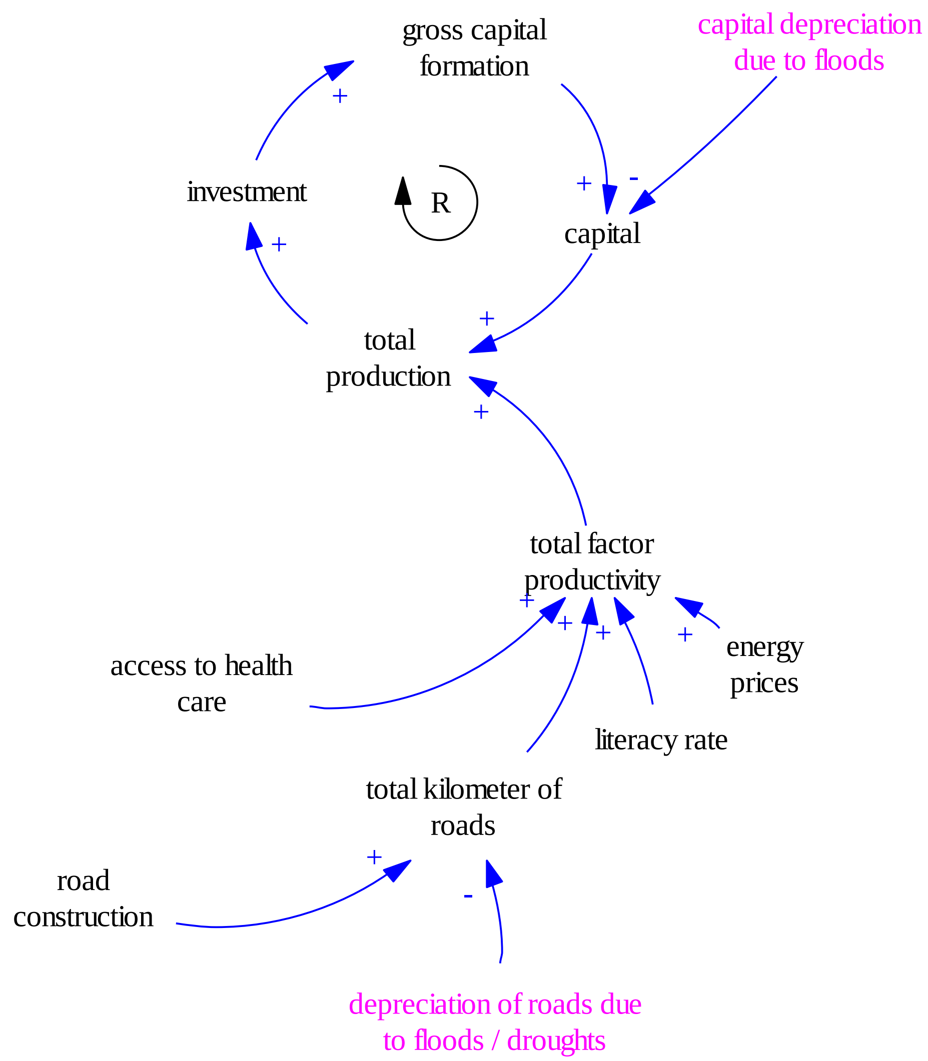




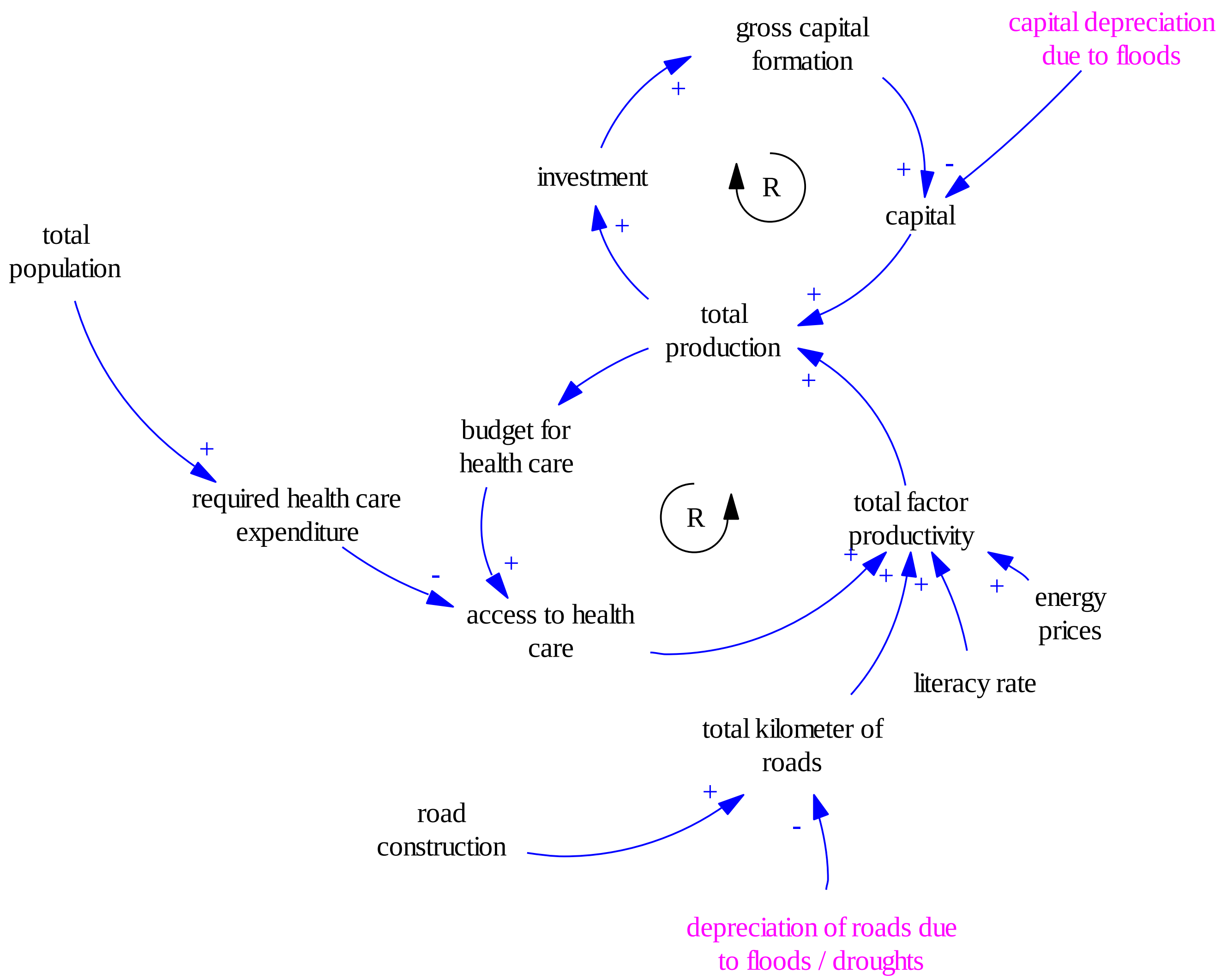
CLD Macroeconomy



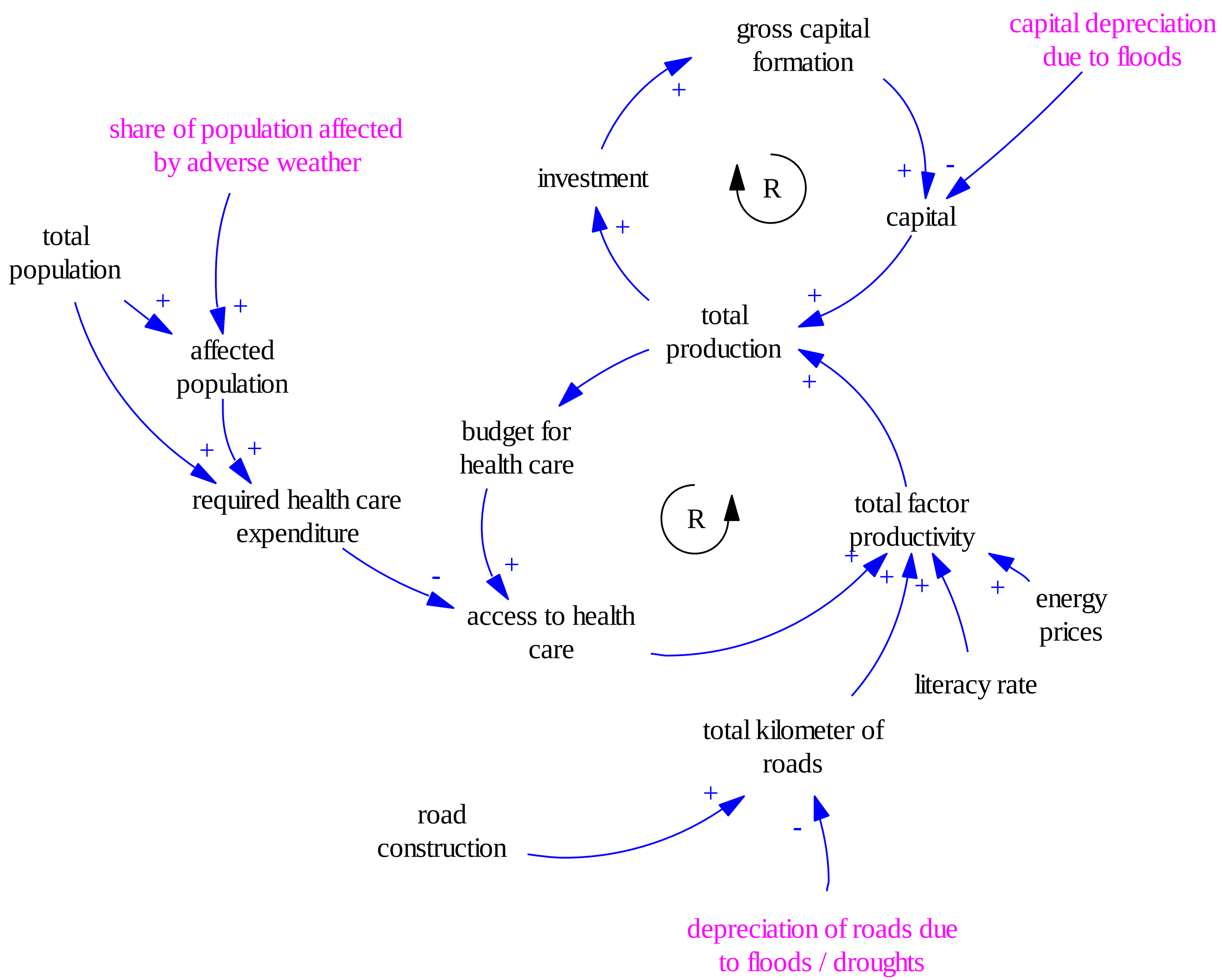
CLD Macroeconomy



CLD Macroeconomy



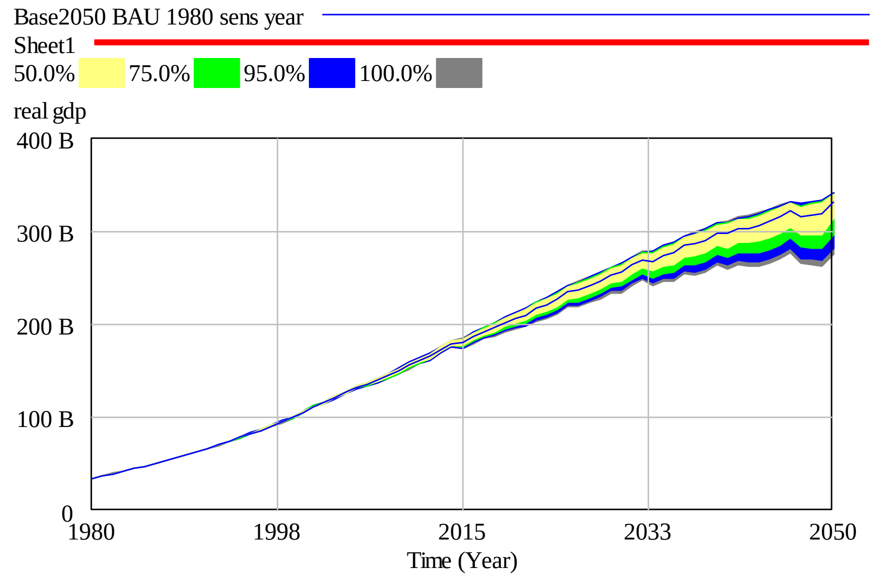
CLD Macroeconomy

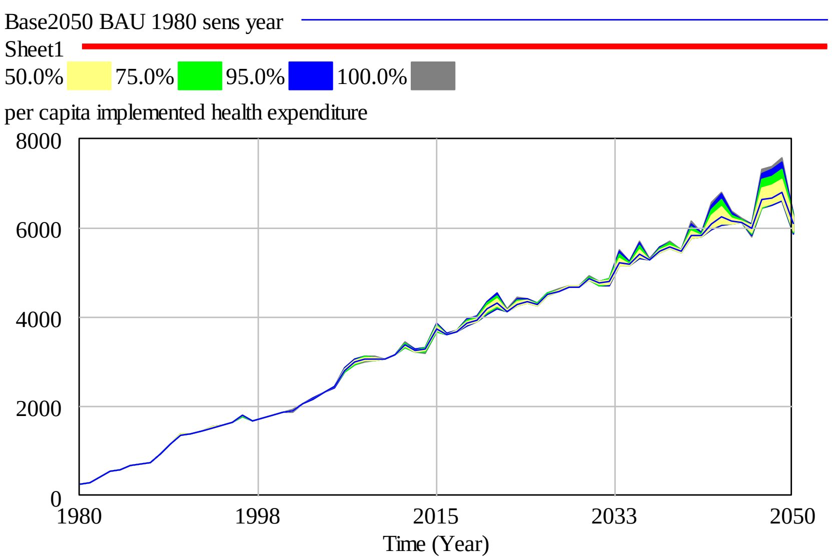


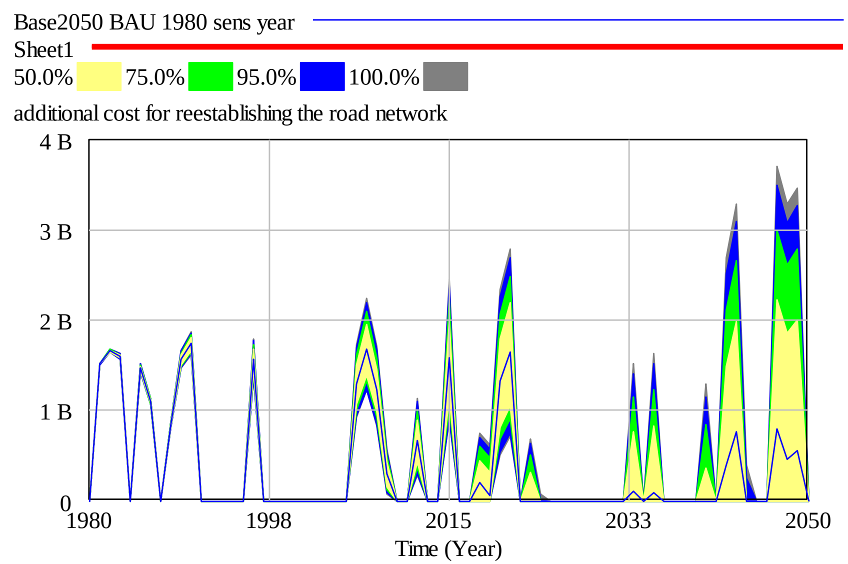
Second order impacts - GDP

GDP represented as labor, capital and productivity. Through the varying performance through all sectors, the confidence intervals for GDP increase over time.

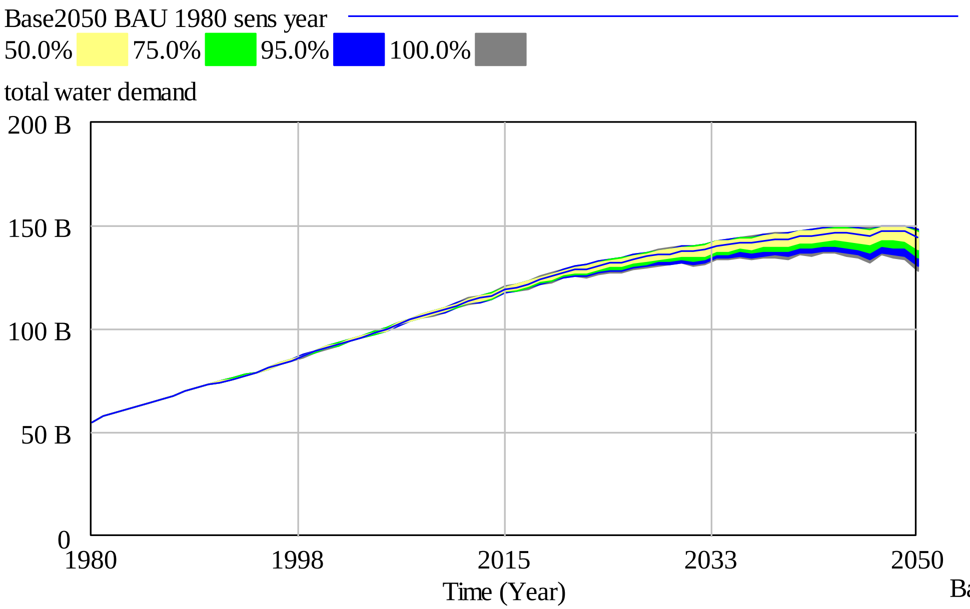
In addition, the costs for maintaining the road network and additional health care costs are added to government expenditures, and therewith decrease GDP even further.





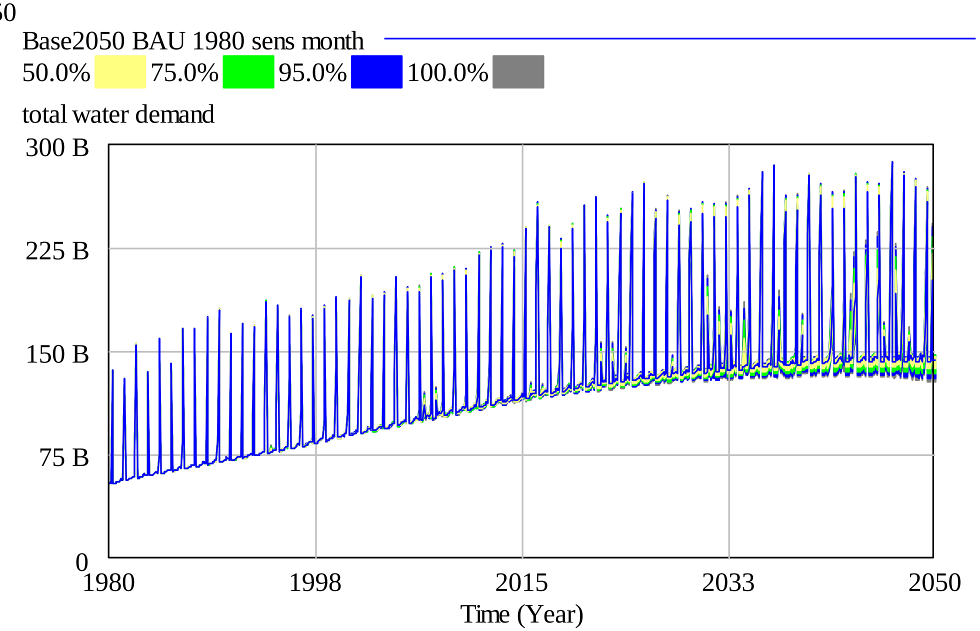


Monthly VS Annual time step



Due to the uncertainty about the amount of agriculture land and population, the range of total demand for water increases in the long run, BUT …

… using seasonal data allows for a more detailled planning of water demand, and has the potential to provide information about possible water scarcity during the dry season. Therefore it is possible to anticipate eventual shortages.



SEB data analysis (1)

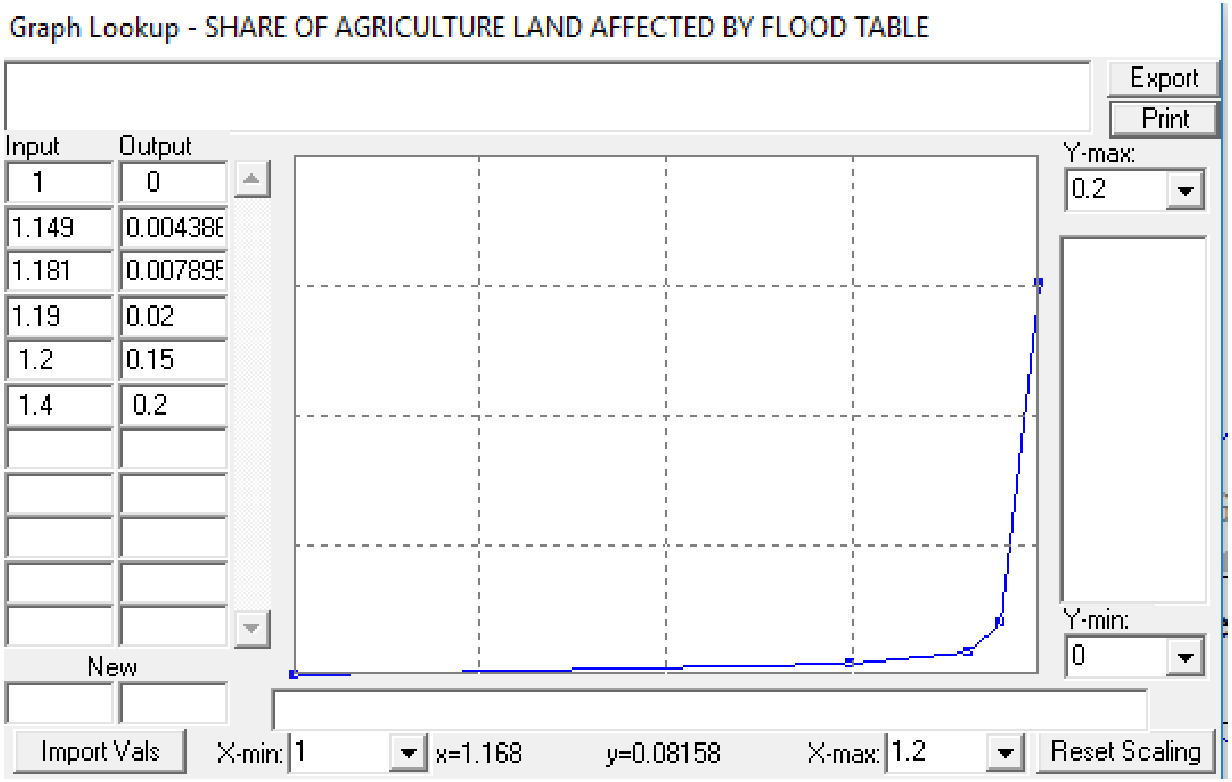
- The magnitude of adverse weather was estimated based on
  - Dataset with documented damages across 8 African countries providing information on e.g.
    - Affected population
    - Affected agriculture land
    - Loss of livestock
  - The respective stock value of the respective countries and years
    - Total population
    - Total agriculture land
    - Total livestock

SEB data analysis (2)

- The adverse weather indicators in the model are operationalized based on
  - Dataset with documented damages across African countries
  - Average monthly precipitation
- Thresholds for extreme events
  - Floods: 25% above average
  - Droughts: 25% below average
- Impacts of adverse weather are implemented as non-linear functions

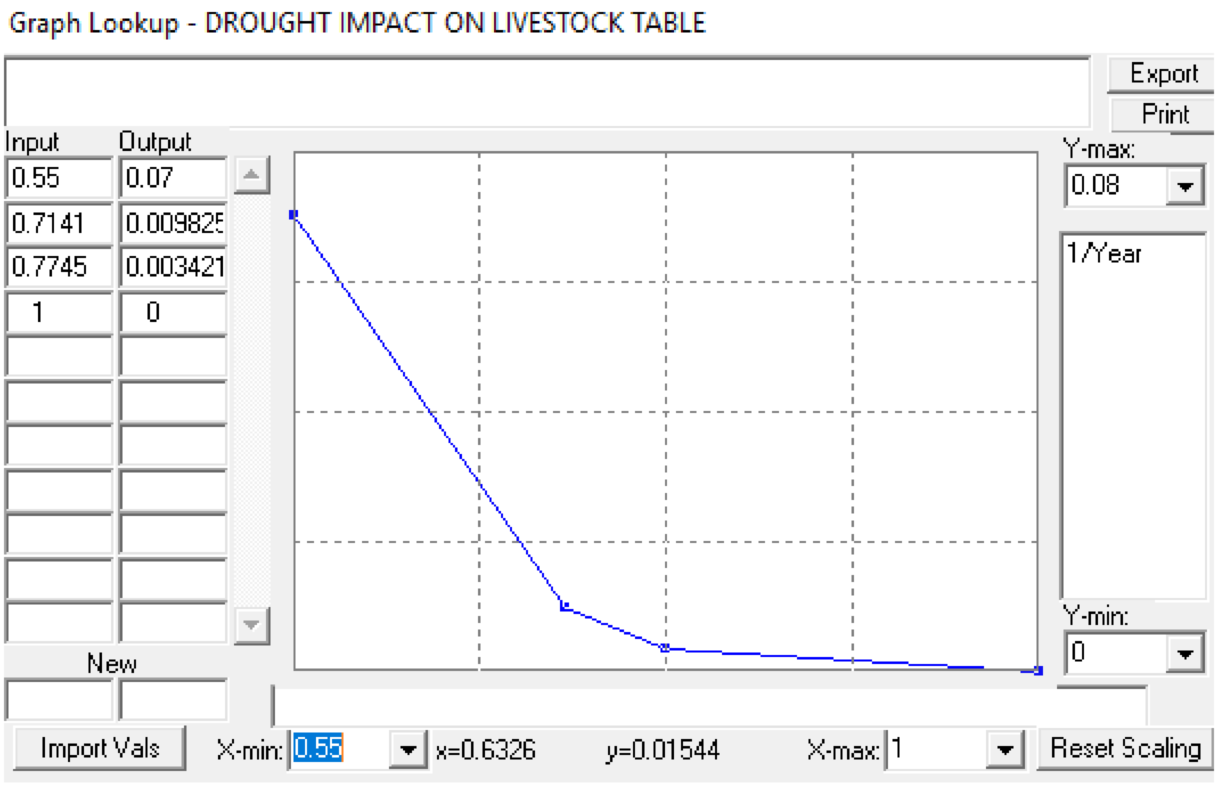
Impact of floods agriculture land

- The higher the flood indicator, the more agriculture land is affected



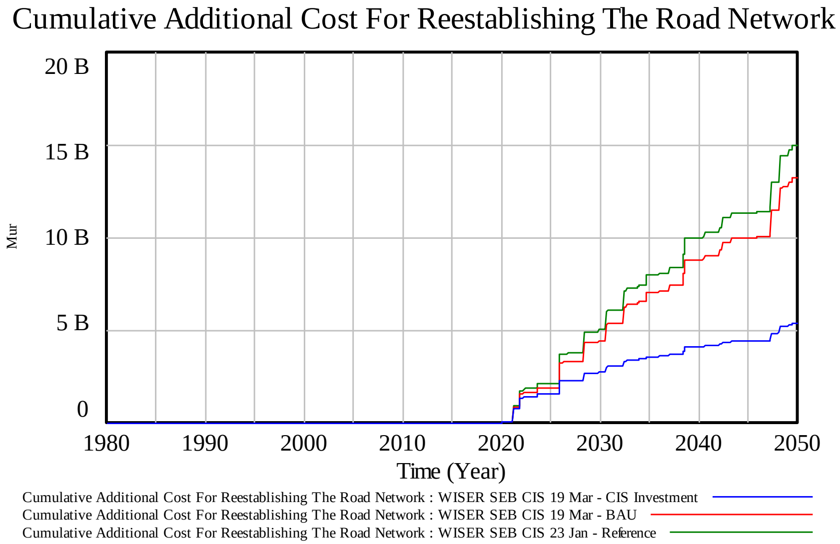
Impact of drought on livestock

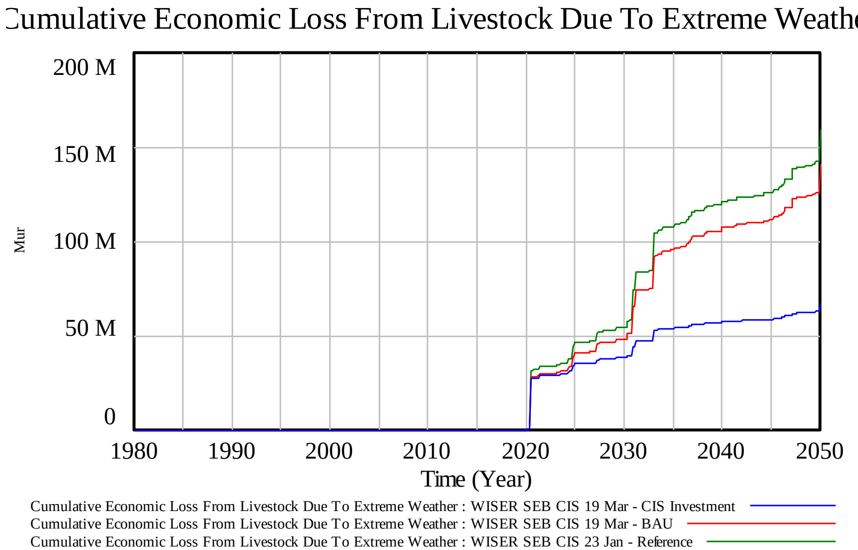
- The share of livestock increases exponentially depending on the strength of the drought



SEB of Climate Information Services

- Climate impacts from different scenarios accumulate over time
- The reference scenario (green line) serves to assess added benefits and avoided costs
- The difference between the reference and CIS scenarios are benefits obtained from CIS





SEB of CIS: Cost benefit ratio

- Example results for 30% and 100% coverage

Scenario	Total impacts (million USD)	Total SEBs (million USD)	Total investment (million USD)	Cost to benefit ratio
Reference (0% CIS coverage)				
Full climate impacts	9'160.55	-	-	-
BAU (30% CIS coverage)				
Impacts climate	8'159.32	1'001.23	208.31	4.81
CIS investment (100% coverage by 2035)				
CIS investment	3'027.19	6'133.36	845.14	7.26

Quality control: Validation of results

- The obtained simulation results were validated based on
  - Results obtained from the analysis of the dataset
    - Comparison of simulation results to the range of impacts obtained from data analysis
  - International reports
    - Assessment of whether the combined induced impacts produced by the model are conform with publications on climate impacts in Africa
  - Peer reviewed papers

Limitations (1)

- Use of average data obtained from a dataset covering 8 African countries
  - Customization of the tool to a country context requires more specific data, such as
    - Share of area affected
    - Local price assumptions on agriculture produce, livestock, roads, health care, etc.
- Impacts of adverse weather are estimated on monthly precipitation
  - Main cause of floods are dry spells followed by 2-3 days of heavy rain

Limitations (2)

- High level of aggregation for the assessment of impacts
  - Some impacts might be caused by a combination of factors, and require more detailed causal relationships
- At this stage, investments in CIS are based on a fraction of GDP, not on specific costs of interventions

Summary

- The model captures social, economic and environmental dynamics
- Including climate variations in the analysis has cascading effects through all sectors
- The performance of the system changes depending on the climate assumptions used
- Policy effectiveness has to be assessed using a variety of indicators, across sectors, actors, over time and space

Thank you!

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