

Technical workshop on analyzing the socio-economic utility of weather and climate information services for the food-energy-water Nexus in Africa

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KnowlEdge

Agenda

09:00-09:30 Welcome and introduction

Setting the scene, goals of the workshop and agenda

09:30-10:00 Introduction of System Dynamics (with emphasis on experience on modeling water, energy, agriculture)

Foundations of systems modeling, with an overview of feedback loops, delays and non-linearity

10:00-11:00 Introduction to climate adaptation and the Nexus concept

Overview of the concepts and brief interventions from participants on national work on climate adaptation and Nexus planning

11:00-11:15 Tea Break

11:15-12:30 Overview of the models (water, energy, agriculture)

Structure and scenarios, evolution from previous models

Agenda

12:30-14:00 **Lunch Break**

14:00-15:00 **Model applications**

Presentation of the parametrization and results for Mozambique, Uganda and Cameroon; comparative presentation, highlighting key features of each model

15:00-16:00 **Demonstration of the software and guided exercise**

- Overview of Vensim
- Running a pre-set scenario
- Changing model inputs for customized scenarios

16:00-16:30 **Tea Break**

16:30-17:30 **Open discussion and closing**

Validation on model structure (key indicators and data requirements)

Applicability of the models to different country context

Project overview – key concepts

- ‘Nexus thinking’ is an approach that recognizes the critical interdependence of food, energy and water in an increasingly resource constrained world.
- Understanding and improving how we manage and use these resources is a process full of uncertainty but it is needed, especially in the face of climate change.
- There is a critical need to equip both individuals and institutions with research, capacity building and new tools to plan for a better, and climate resilient future.

Project overview – key concepts

- New methods are needed that address a specific gap:
 - conventional forecasting tools and analyses are often comparatively static (mostly employing linear approaches) and
 - are narrowly focused on a sector or a specific set of thematic indicators.
- A systemic approach is instead required that:
 - considers social, economic and environmental indicators within a sector,
 - and link them across sectors to generate dynamic projections that
 - allow to estimate policy outcomes for all economic actors.

Project overview – key concepts

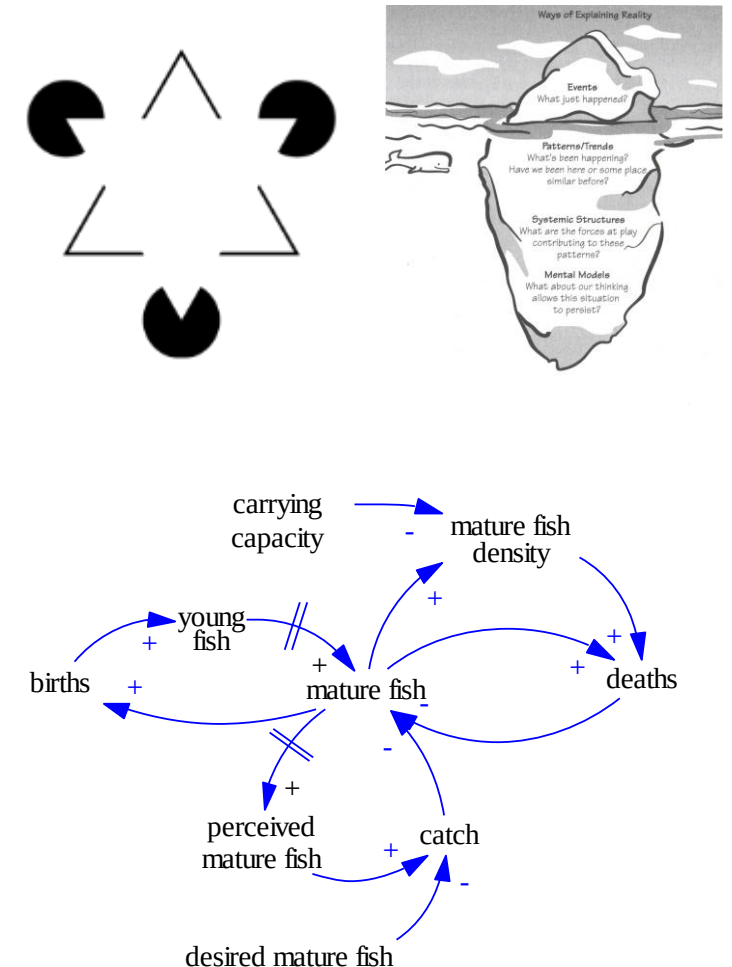
- This workshop is organized to discuss the application of a systems approach for the estimation of the Socio Economic Benefits (SEB) of climate information for the food, energy and water sectors in Africa. The work performed focuses on climate adaptation and includes the estimation of an integrated cost benefit analysis (CBA) of each intervention option simulated. The countries for which the models have been customized are Cameroon, Mozambique and Uganda. Inputs will be sought to validate the model, and to identify recommendations for future work and policy formulation at the country level.

Project overview – outcomes

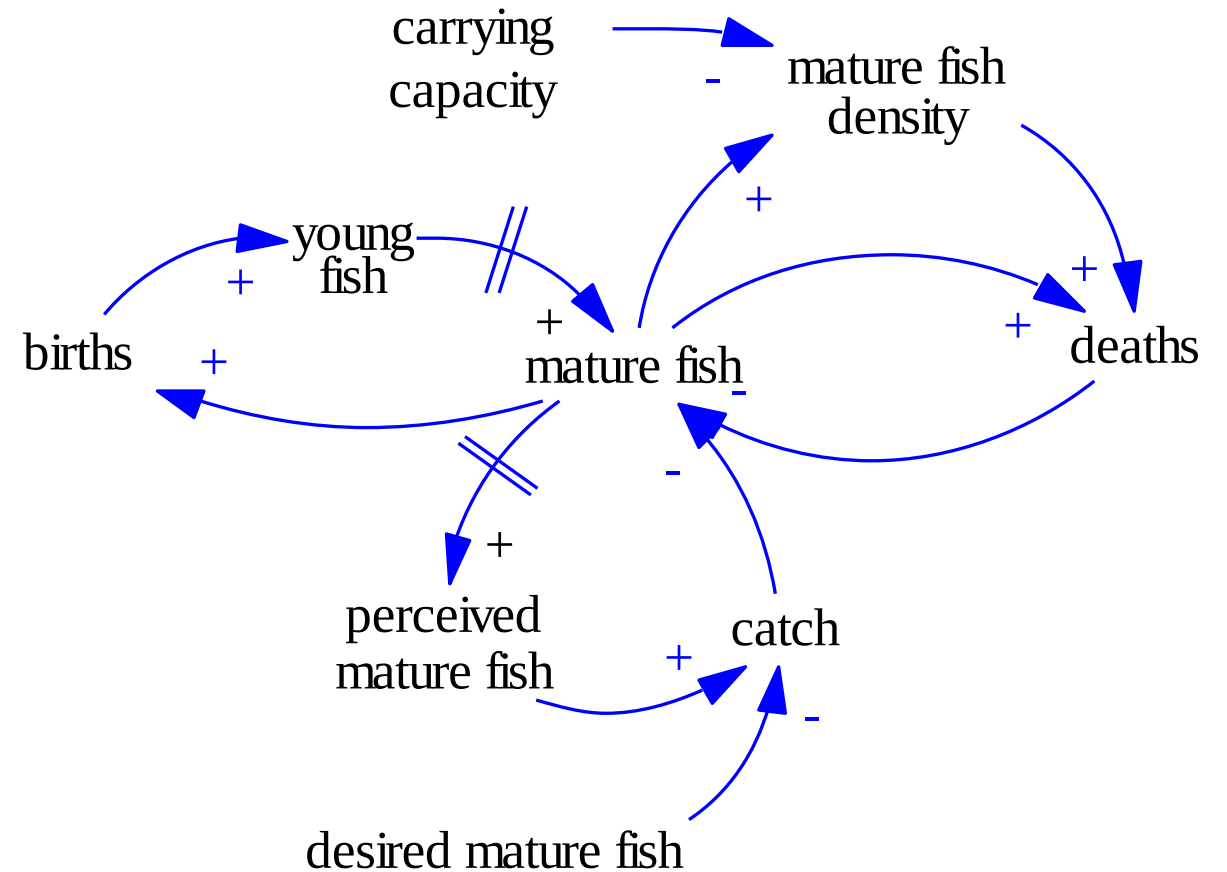
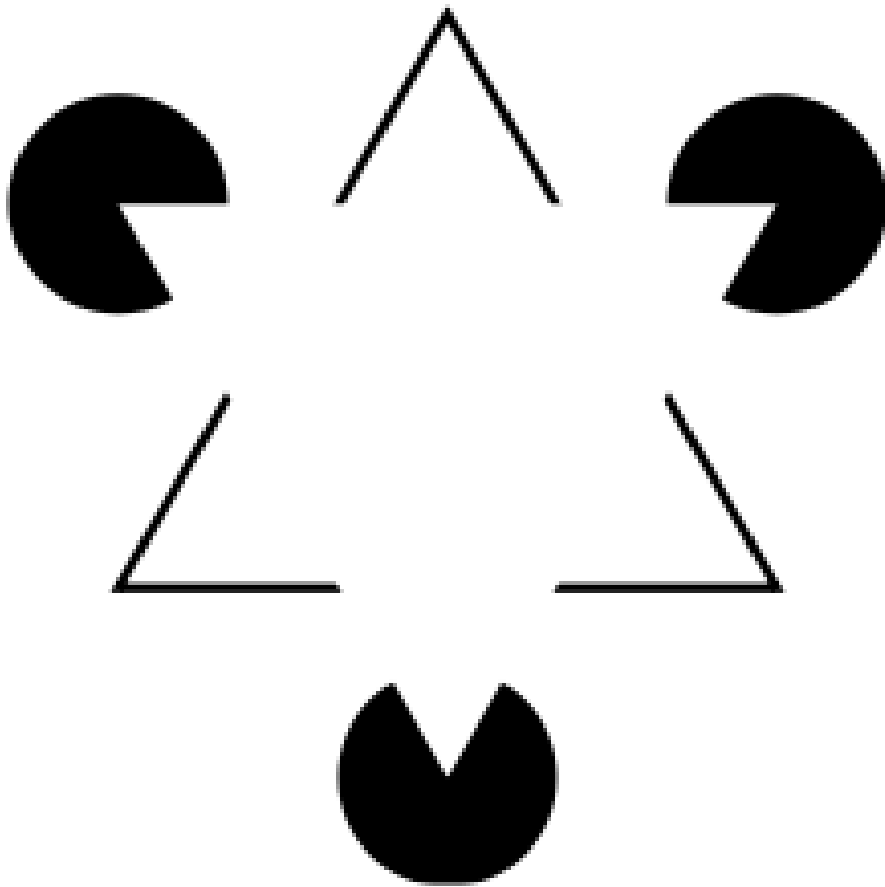
- Improved understanding of the Nexus concept
- Increased capacity to analyze the SEB of weather information
- Higher familiarity with systems models and with the software Vensim
- Improved familiarity with the Integrated Cost benefit Analysis, the economic method used to analyze policy interventions and investments
- Validation of the system dynamics models for food, energy and water, pilot and country level
- Compilation of recommendations for future work, and for policy intervention at the country level

1- Introduction to 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*).

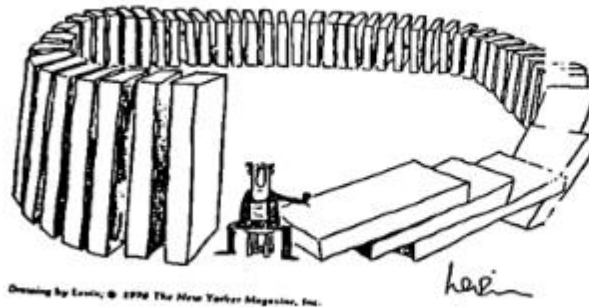


1- Introduction to System Dynamics

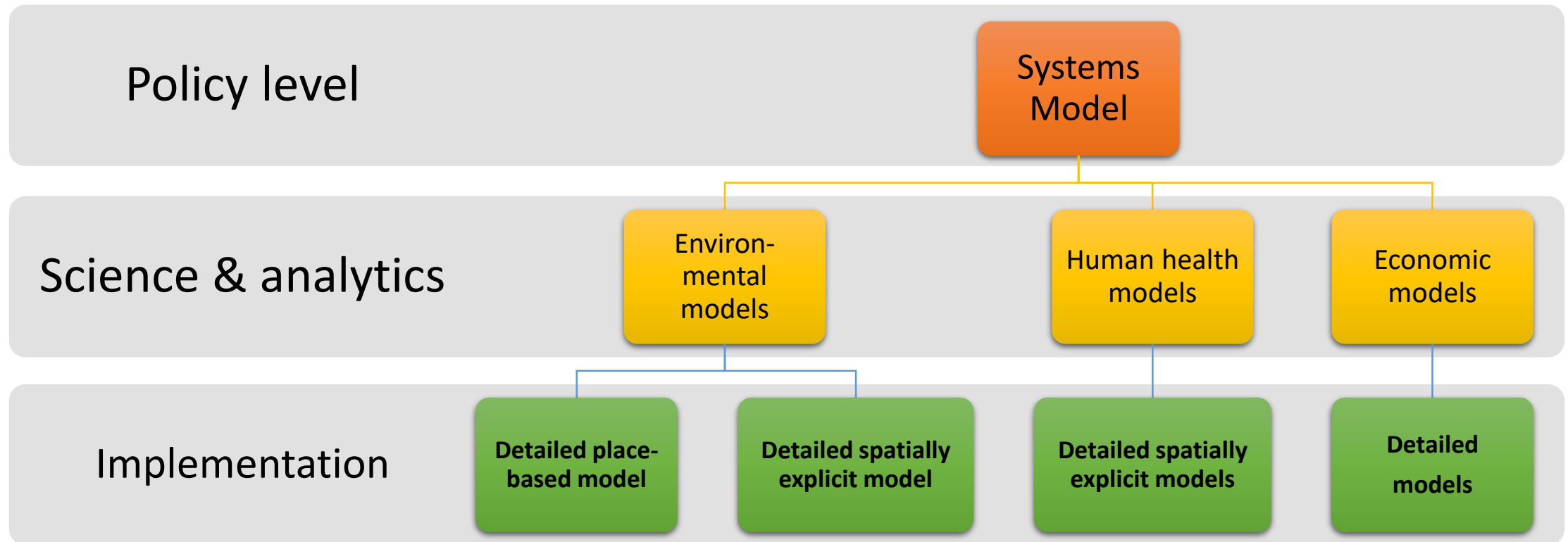
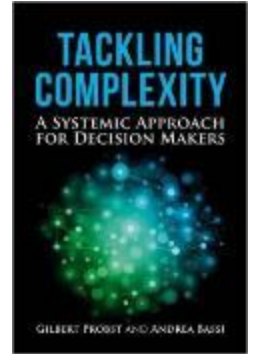


1- Introduction to System Dynamics

- Method for understanding interactions among:
 - Economic systems — companies, markets, etc.
 - Ecological systems — forests, watersheds, etc.
 - Social systems — communities, networks, etc.
- Reveals consequences of human interventions
 - Interventions may include new policies, technologies, business practices, etc.
 - Consequences may be intended or unintended
 - Examine consequences over a specified time period



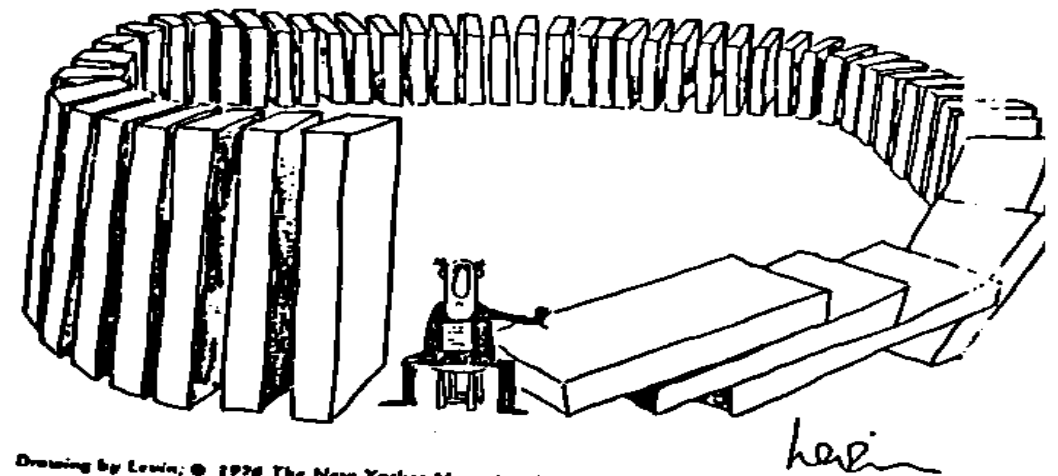
1- Introduction to System Dynamics



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

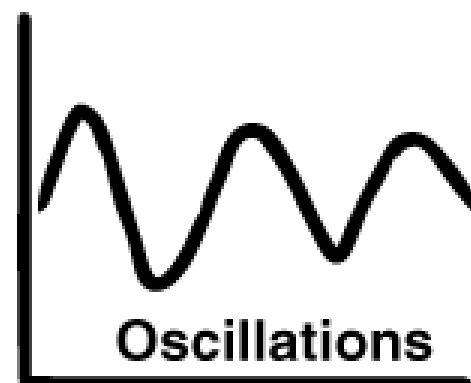
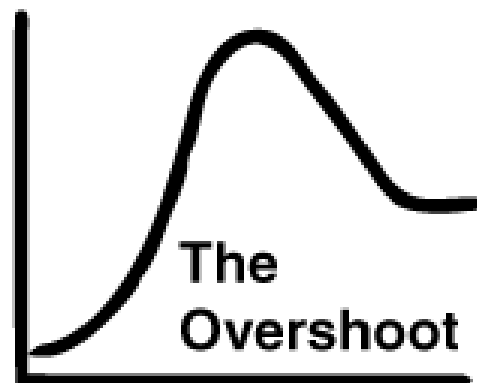
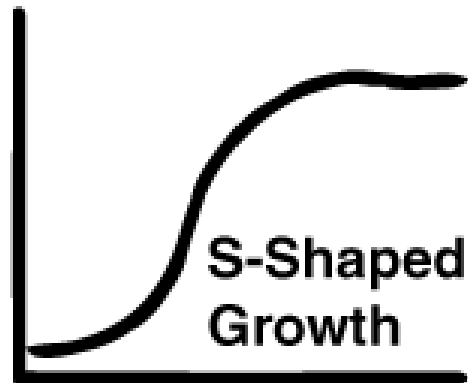
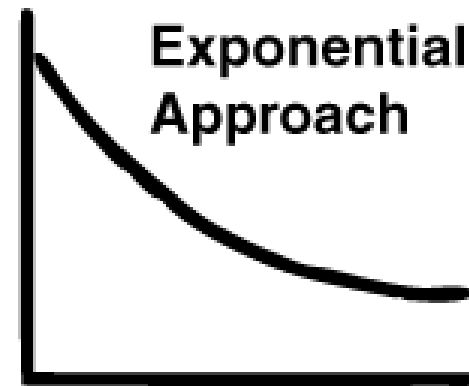
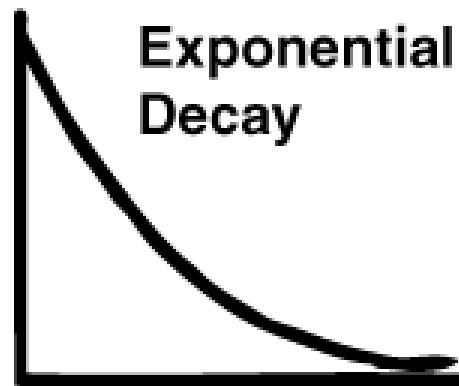
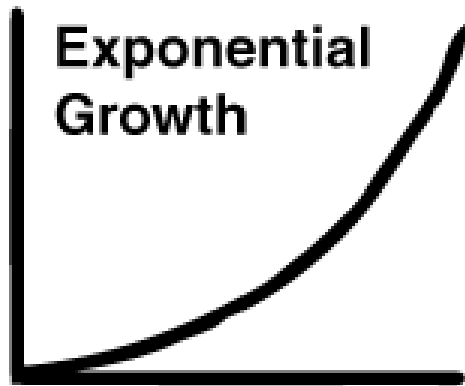
1- System Dynamics allows...

- 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; © 1996 The New Yorker Magazine, Inc.

1- System Dynamics allows...



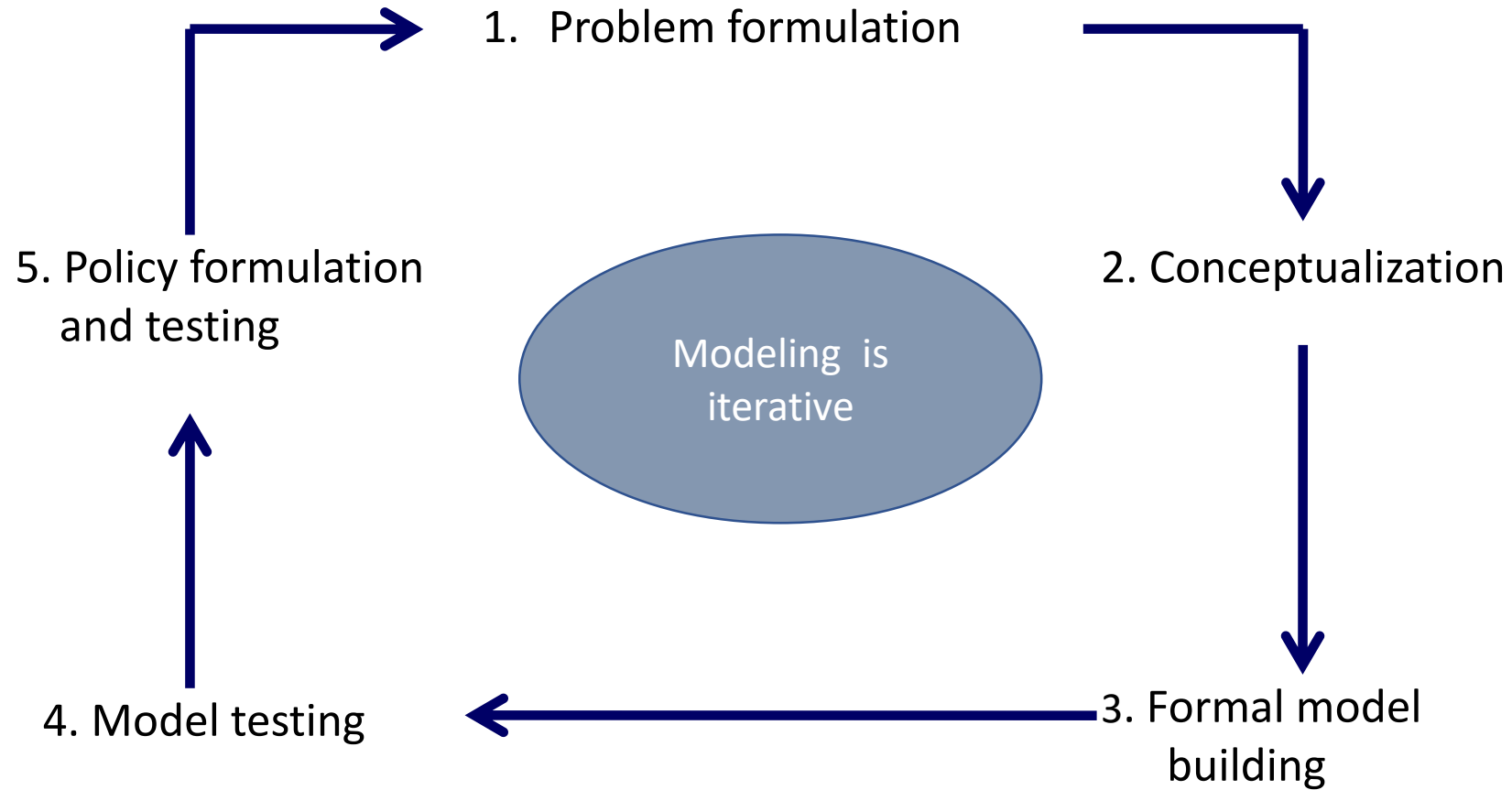
1- Added value compared to other tools?

- 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.

1- System Dynamics for the estimation of SEB

- 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

1- System Dynamics modeling process



1- 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

1- Reinforcing Loops

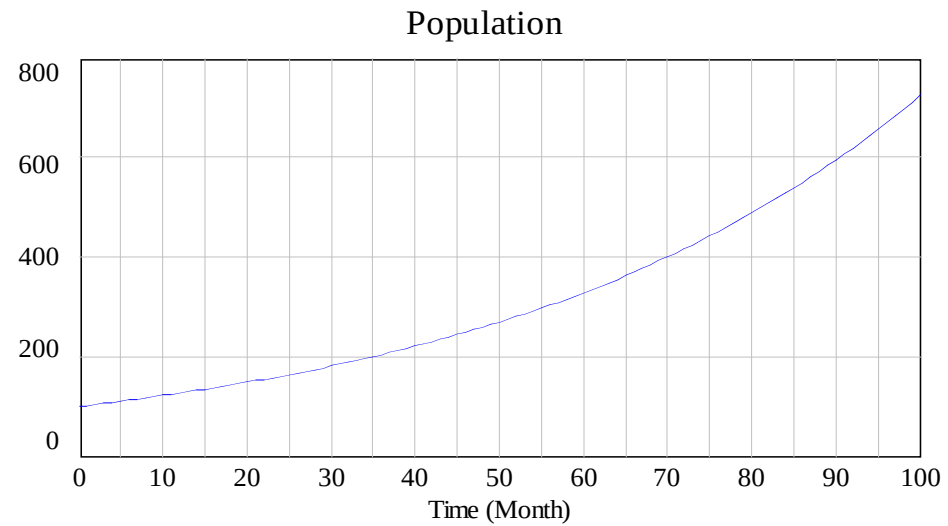
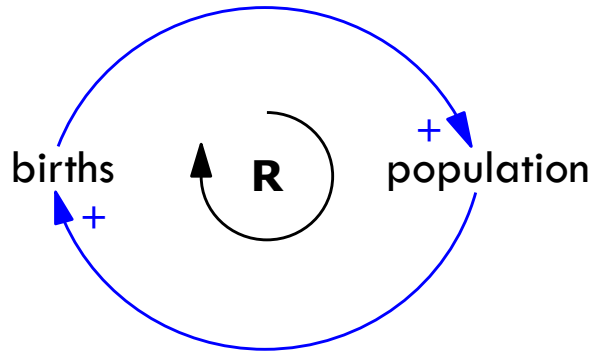
- Reinforcing loops tend to increase and amplify everything happening in the system (i.e. action - reaction).

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)

1- Reinforcing Loops

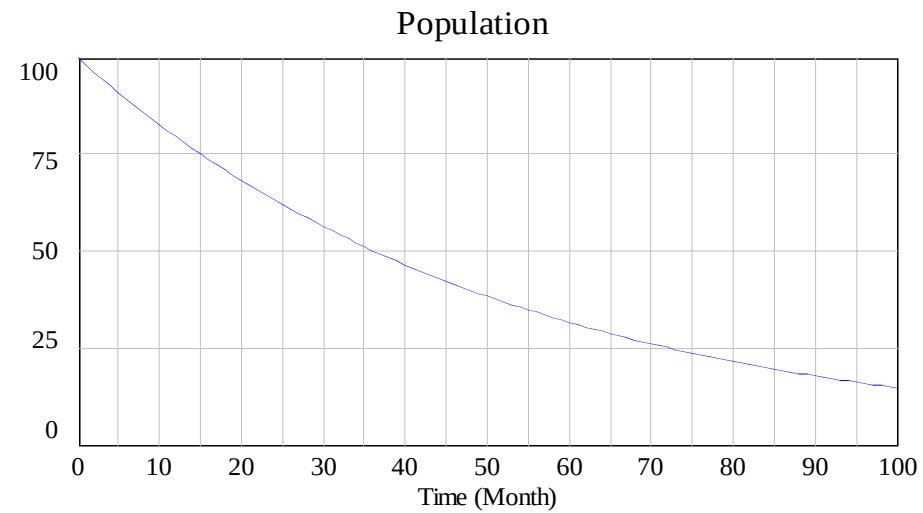
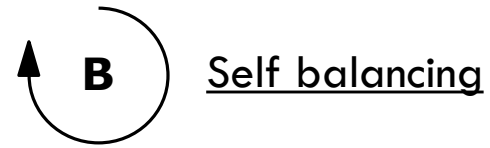
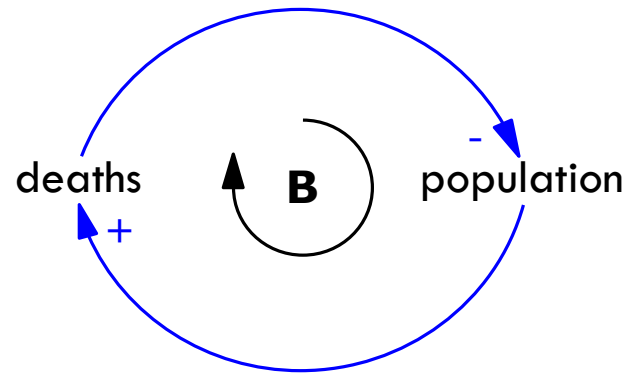


Population : Population1

1- Balancing Loops

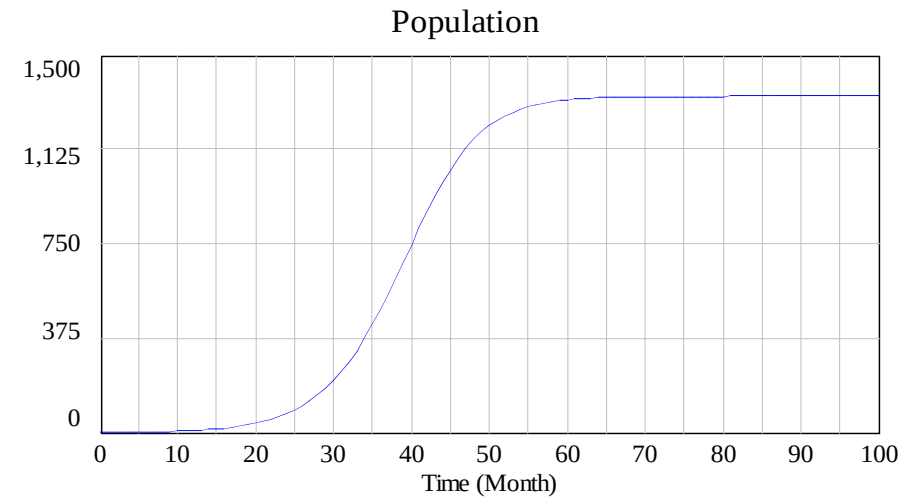
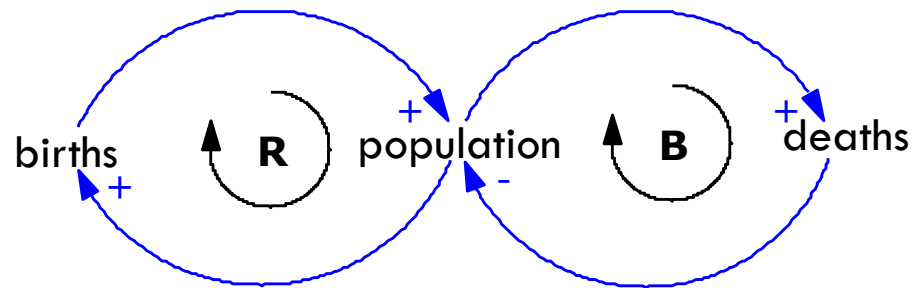
- Negative loops are counteractive and oppose change.
- Balancing loops represent a self limiting process, which aims at finding balance and equilibrium.

1- Balancing Loops



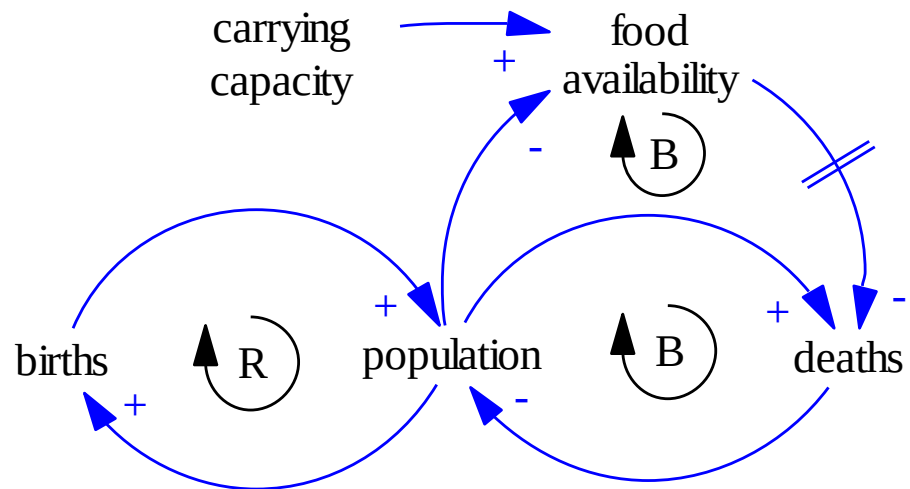
Population : Population

1- Combining Feedback Loops

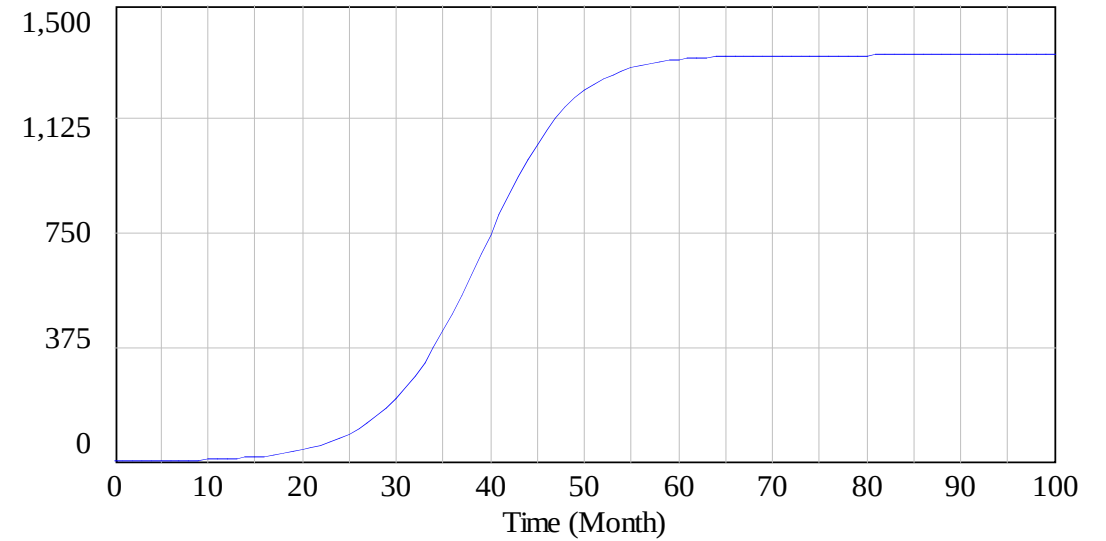


Population : Population

1- Combining Feedback Loops

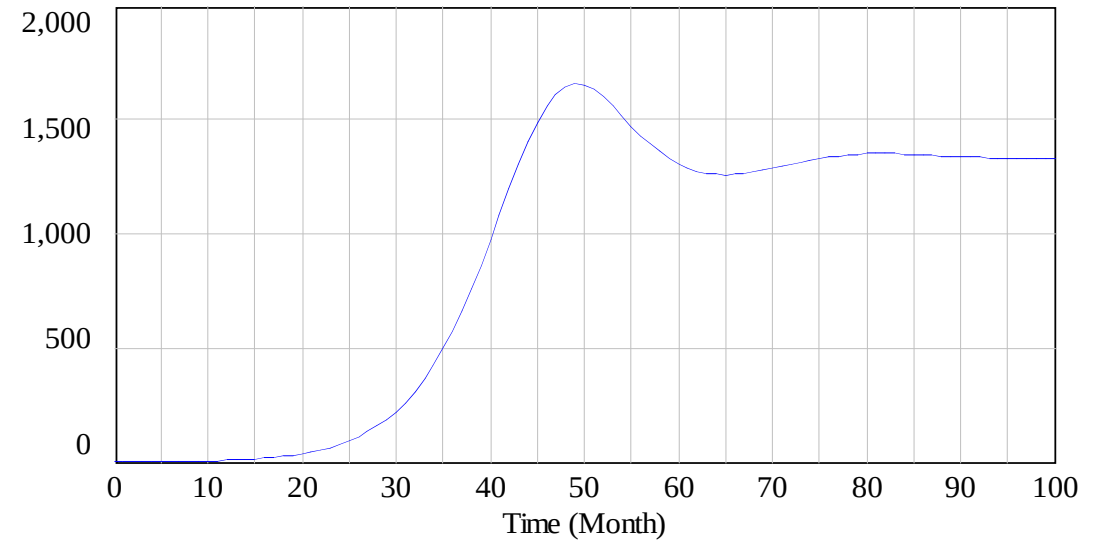


Population



Population : Population

Population



Population : Population

2- Introduction to Nexus planning and climate adaptation on national level

2- Land-use, Water and Economies Dependent on infrastructure



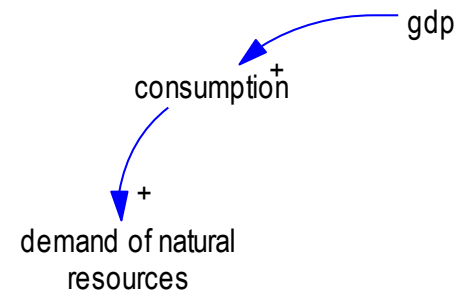
2- Land-use, Water and Economies Dependent on infrastructure

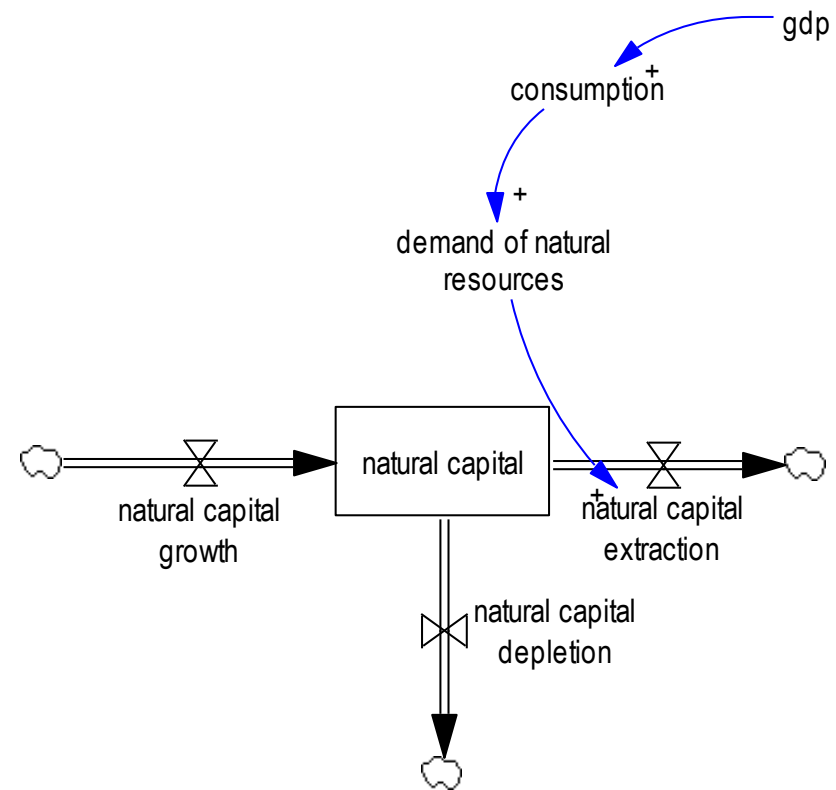


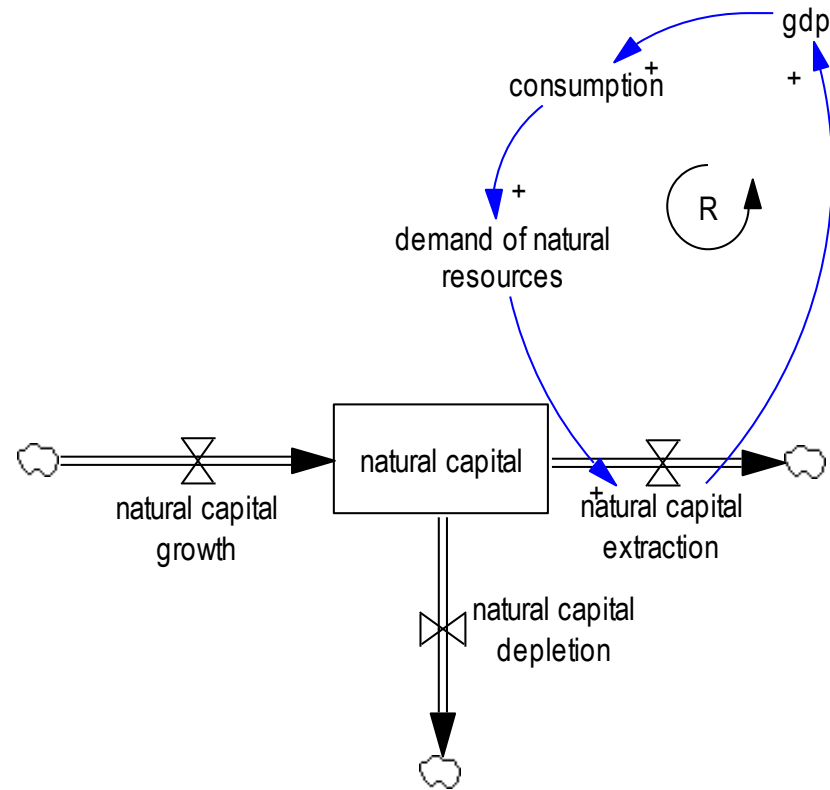
2- Using a systemic approach: informed by stakeholders, based on science

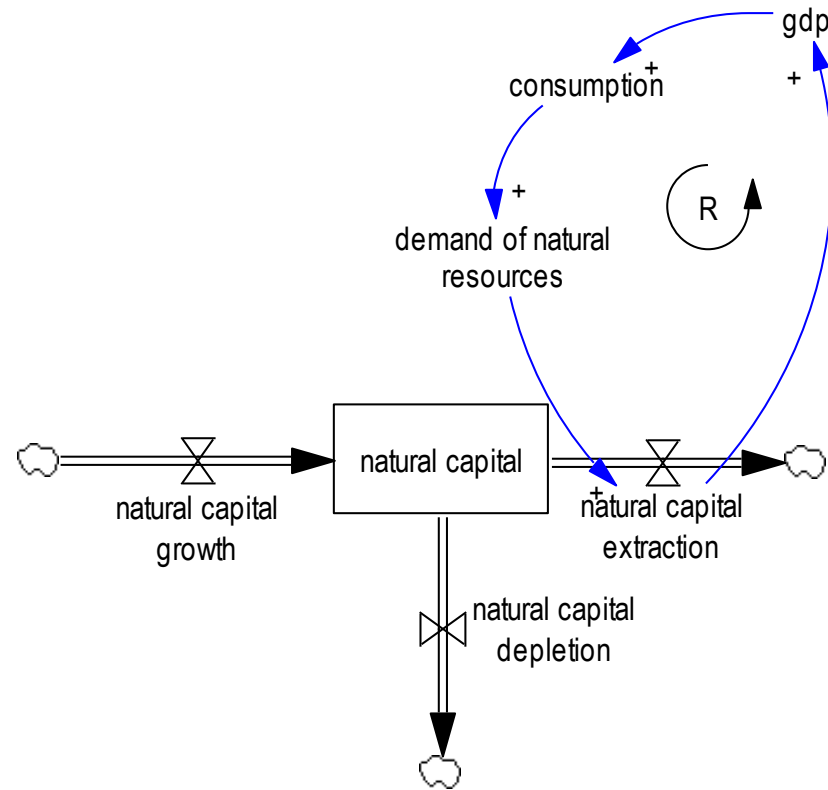
gdp

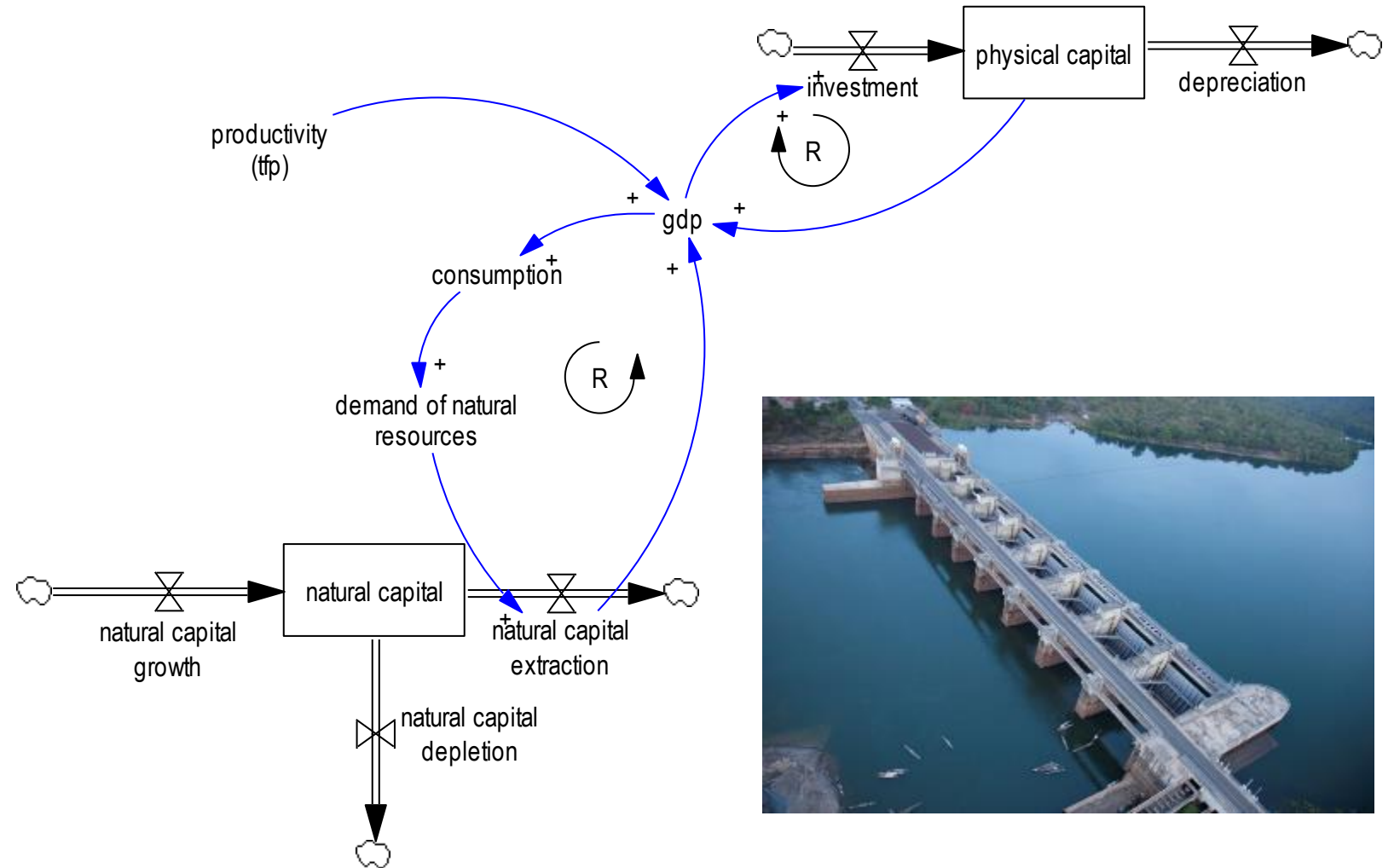


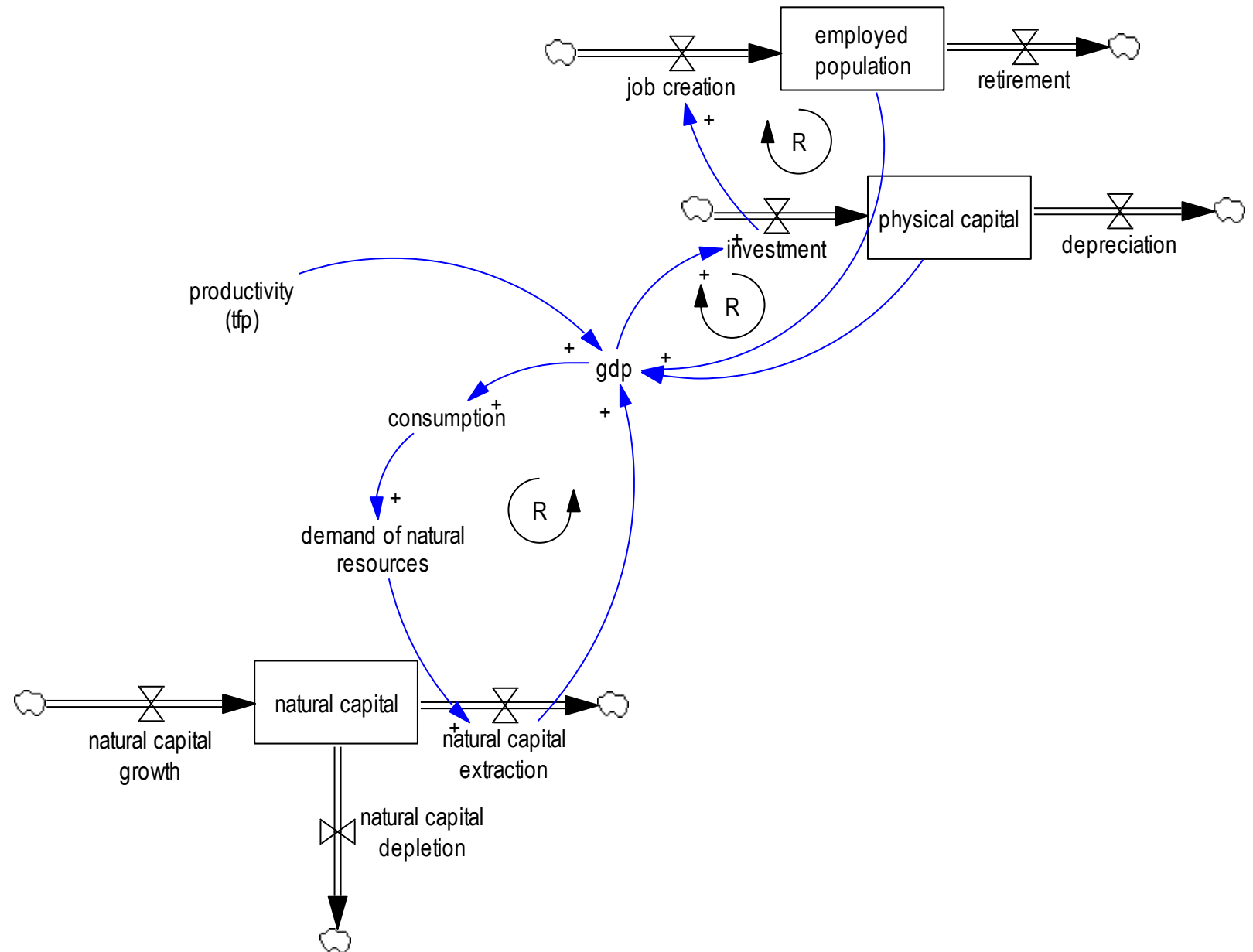


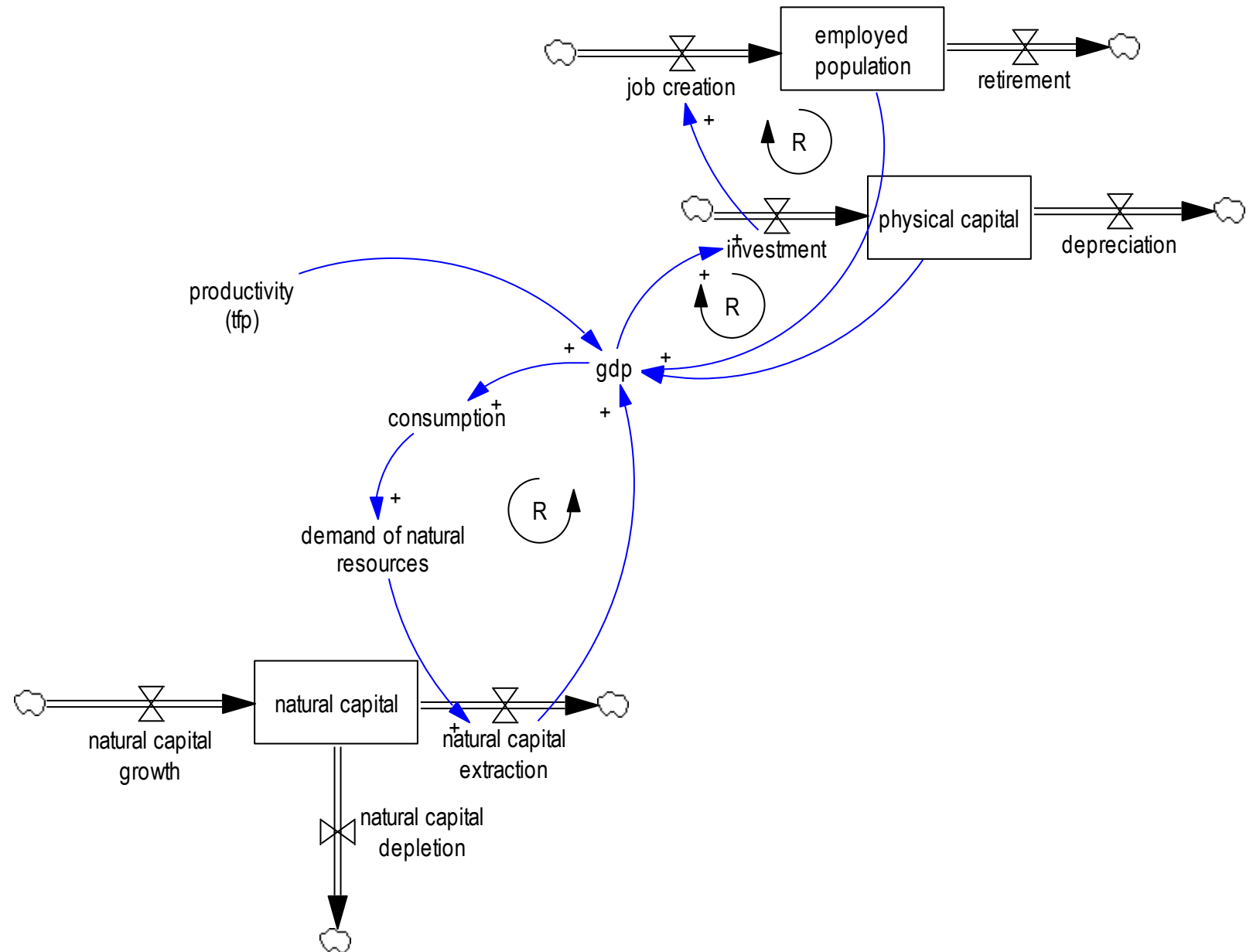


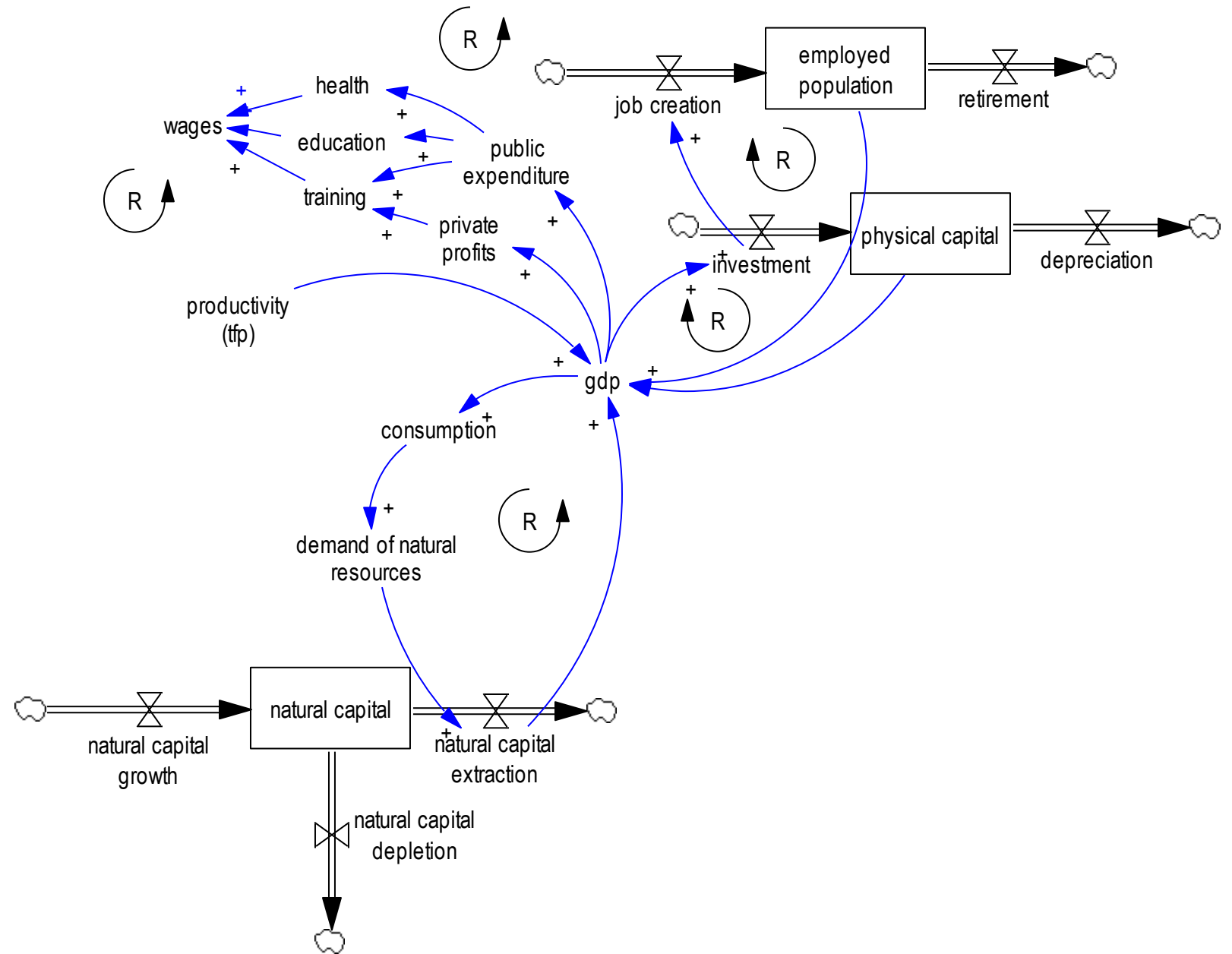


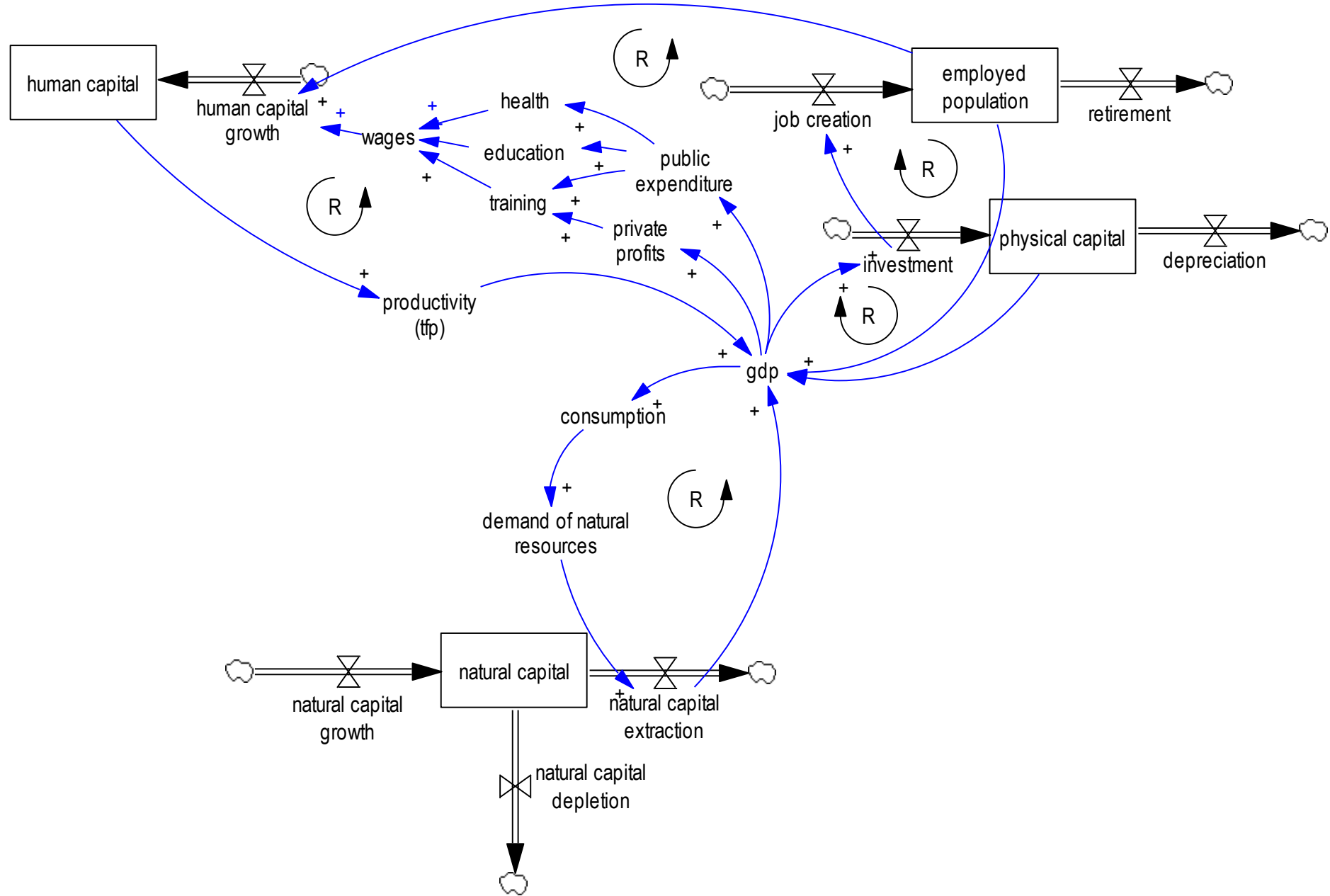


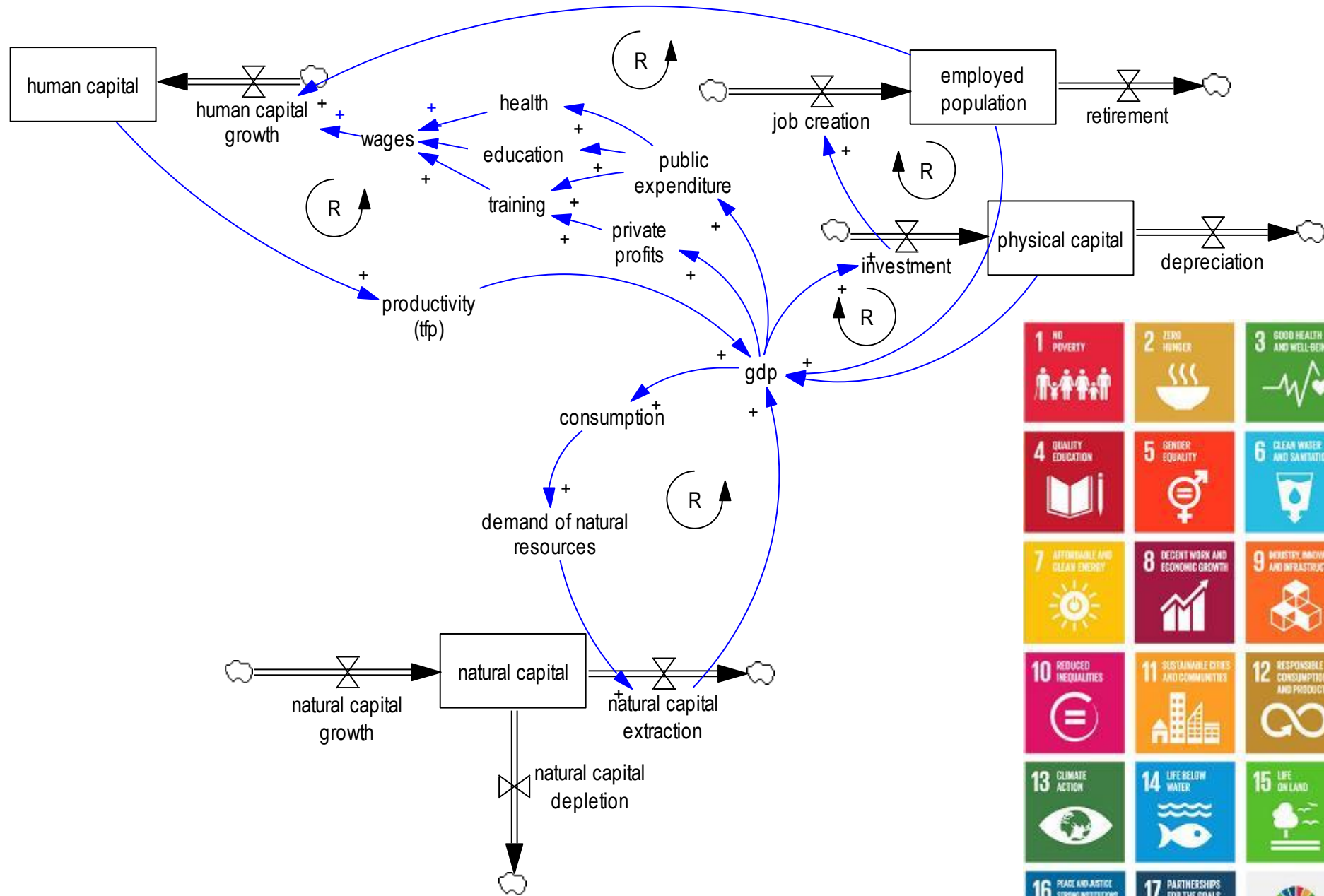


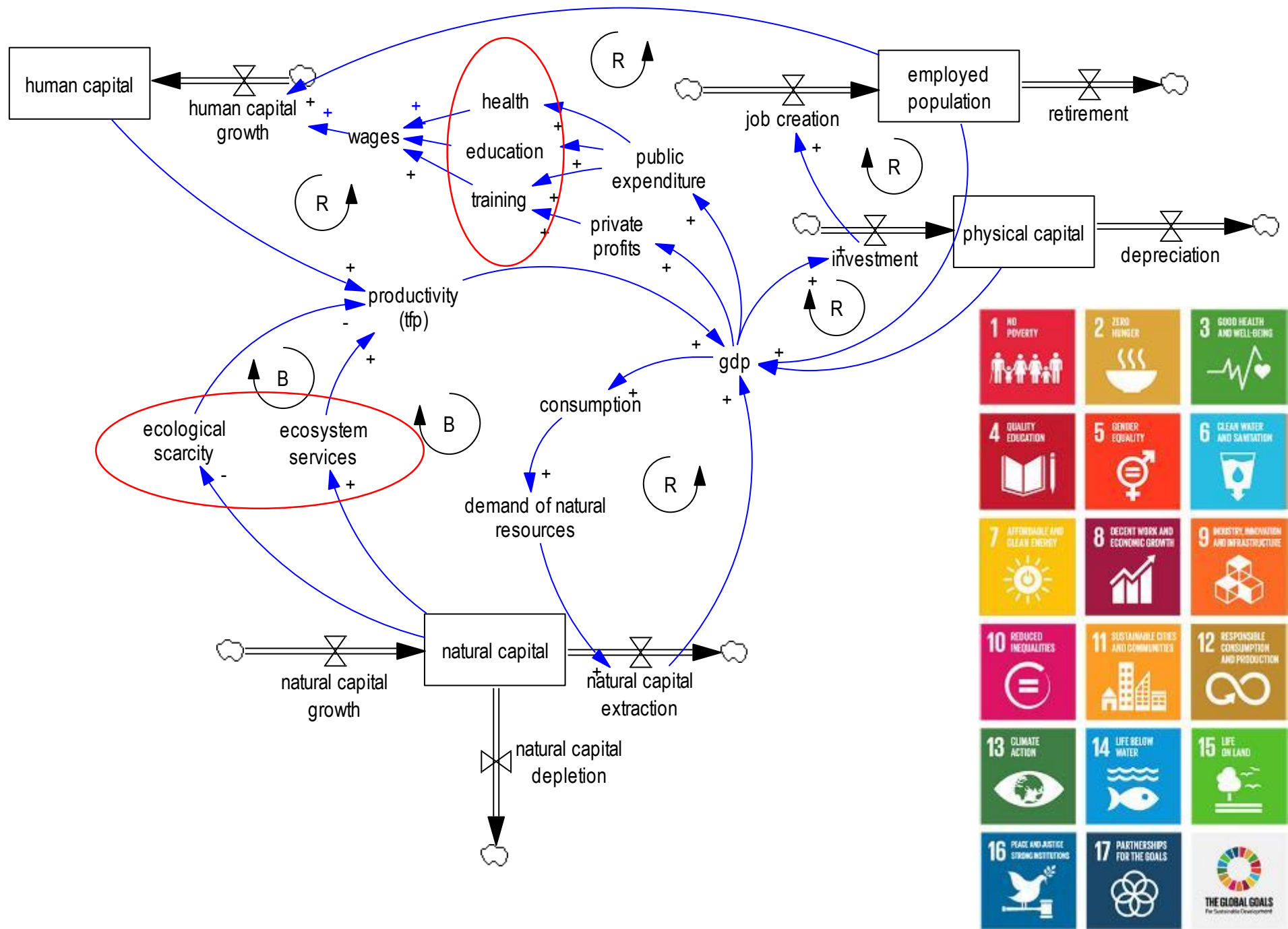


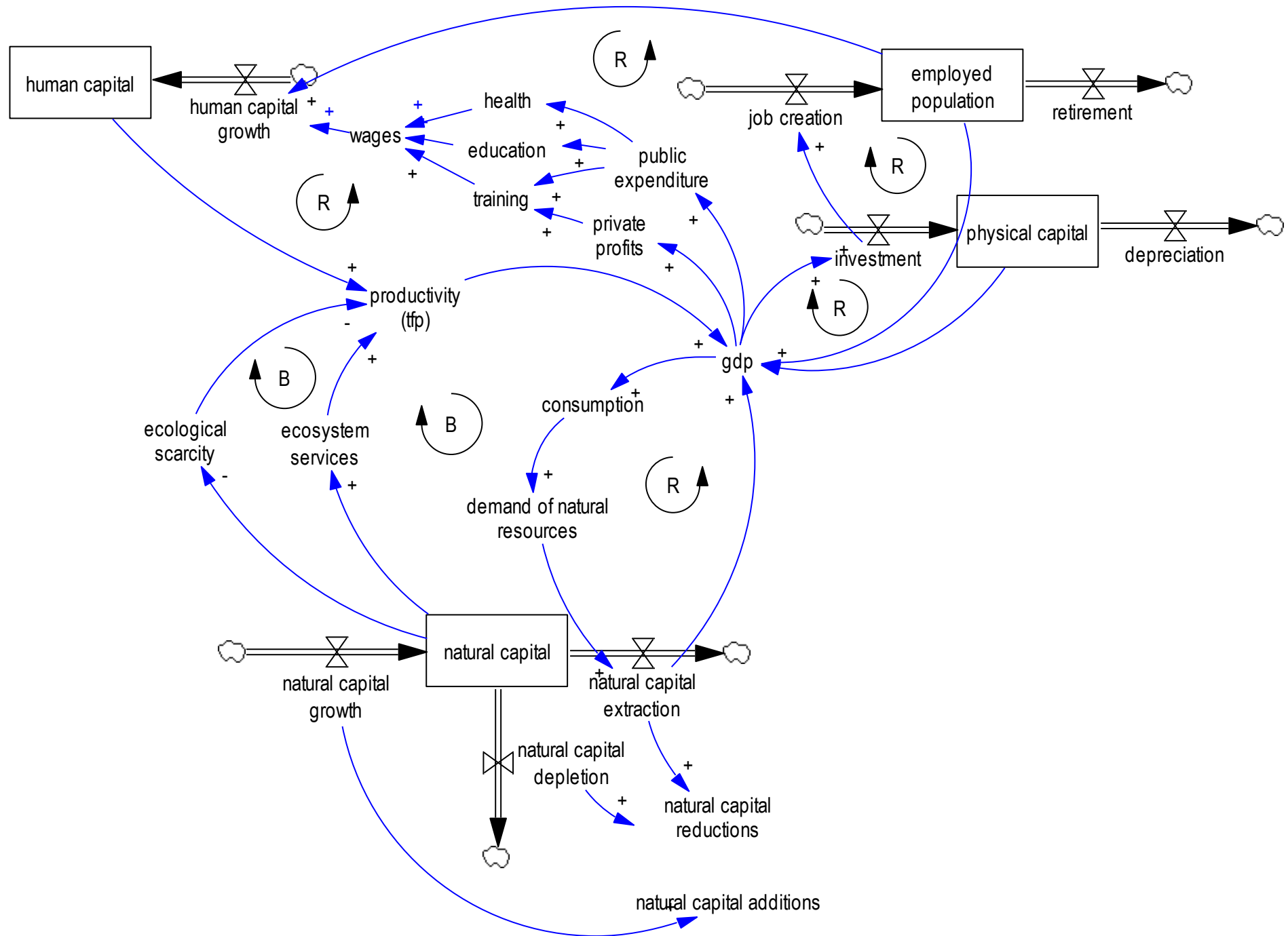


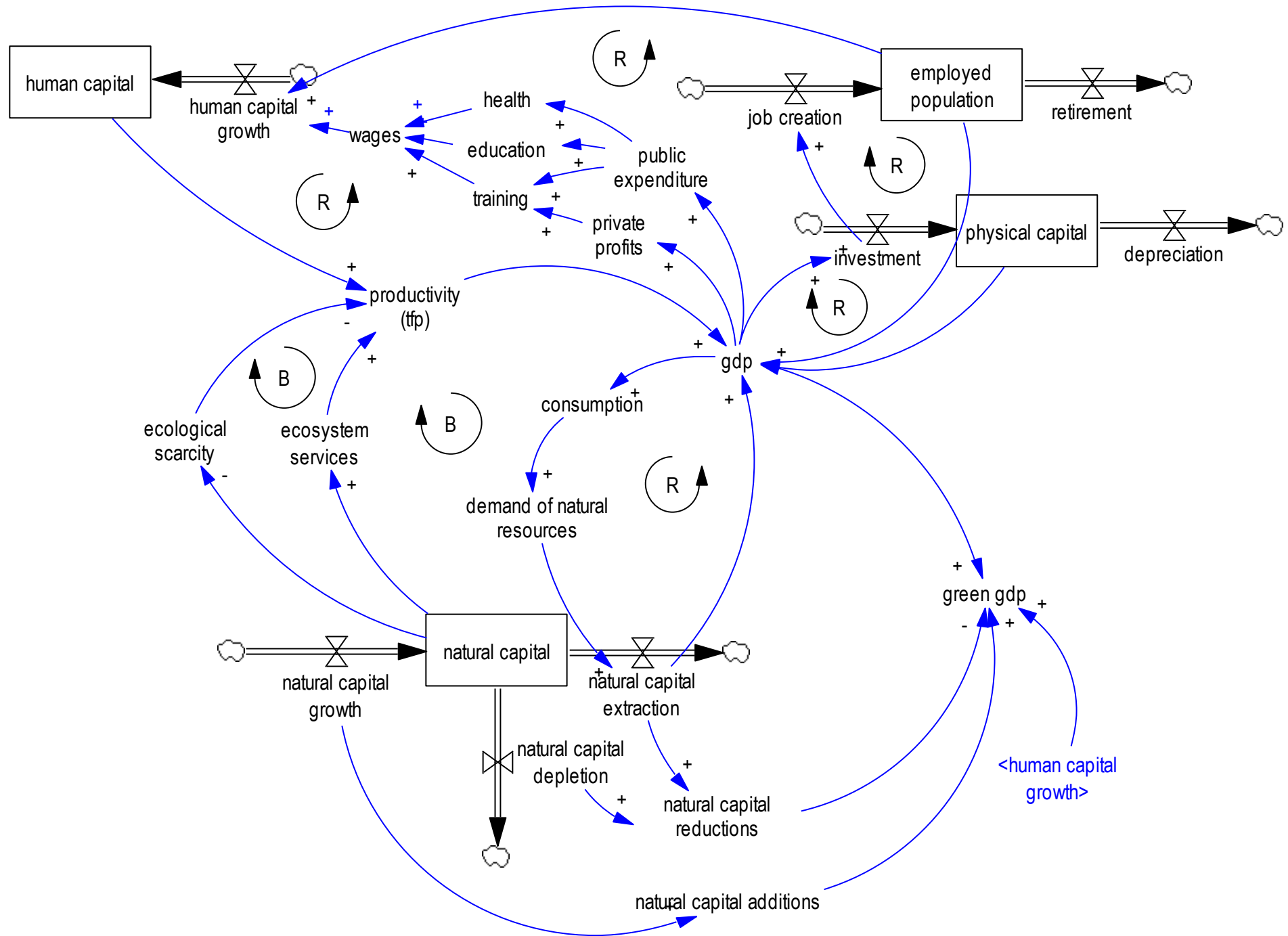




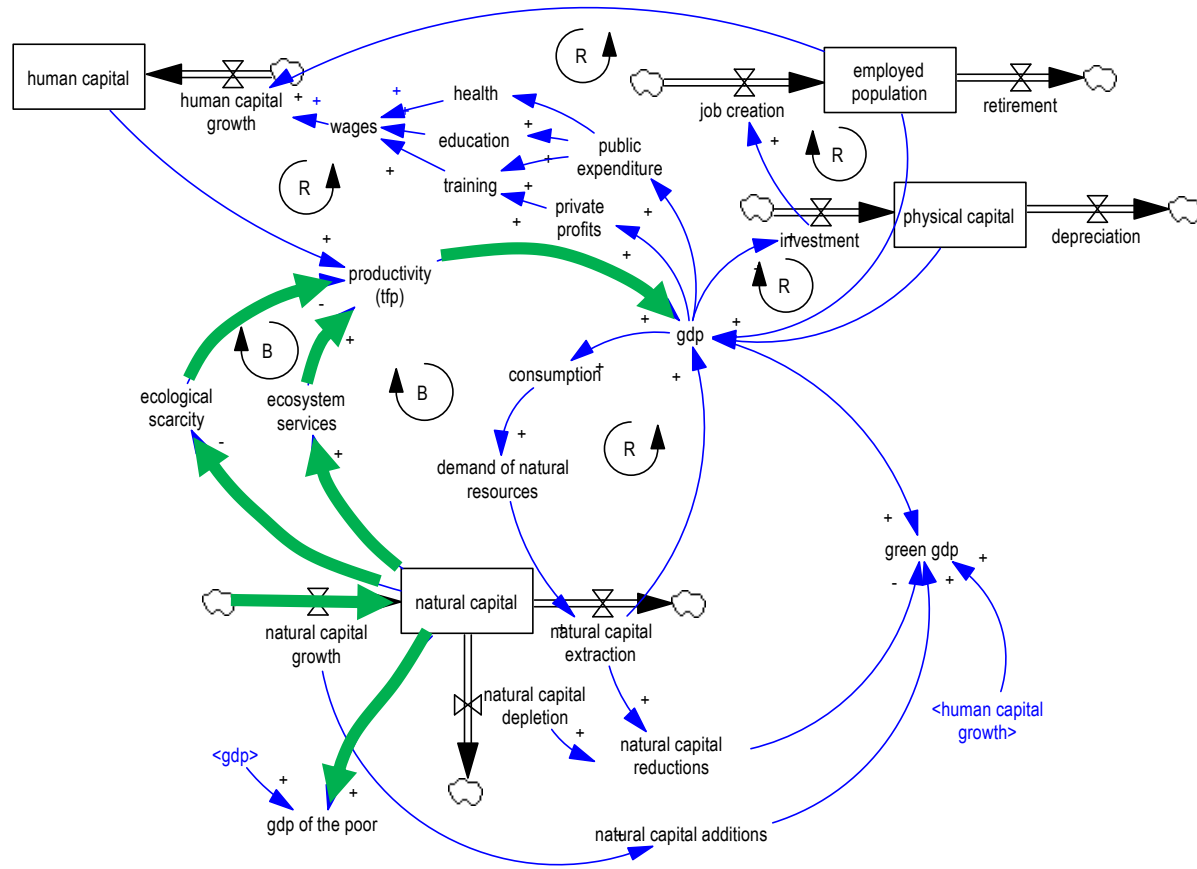




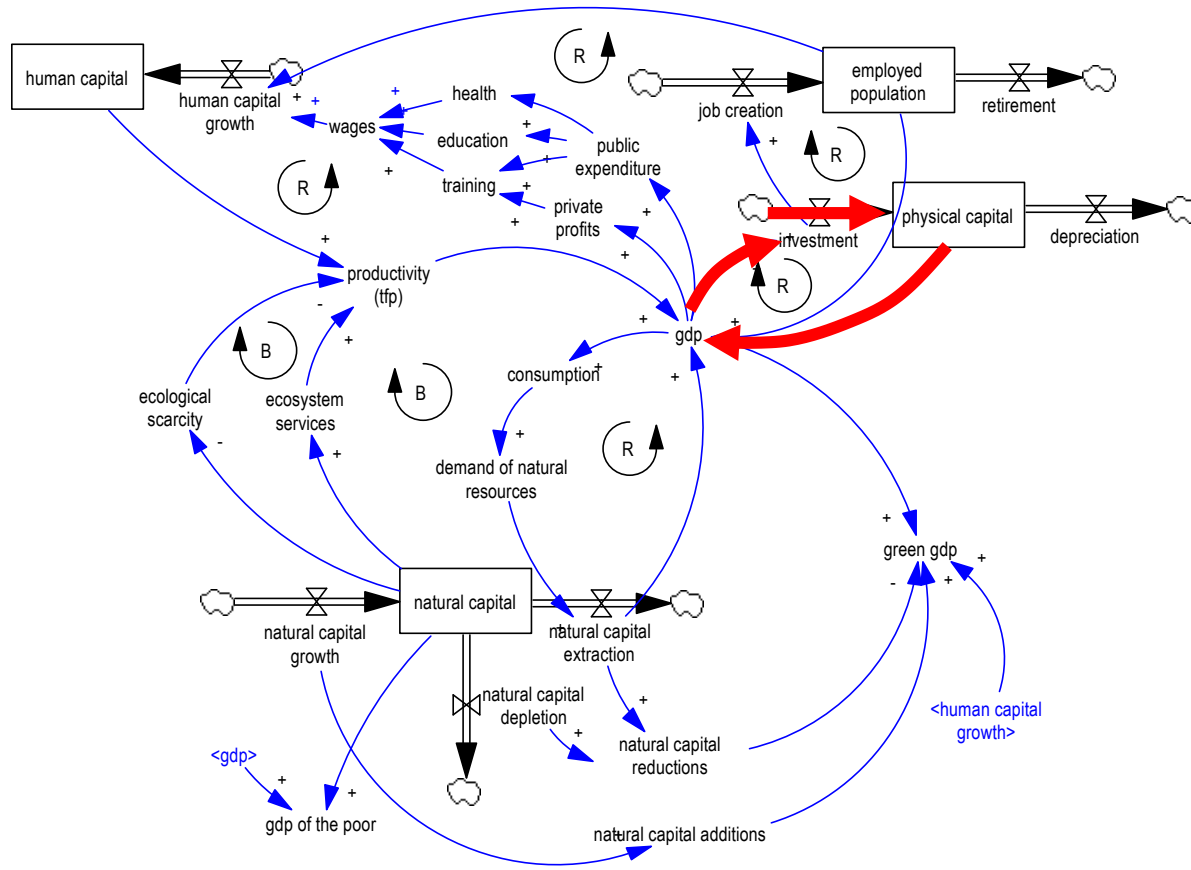




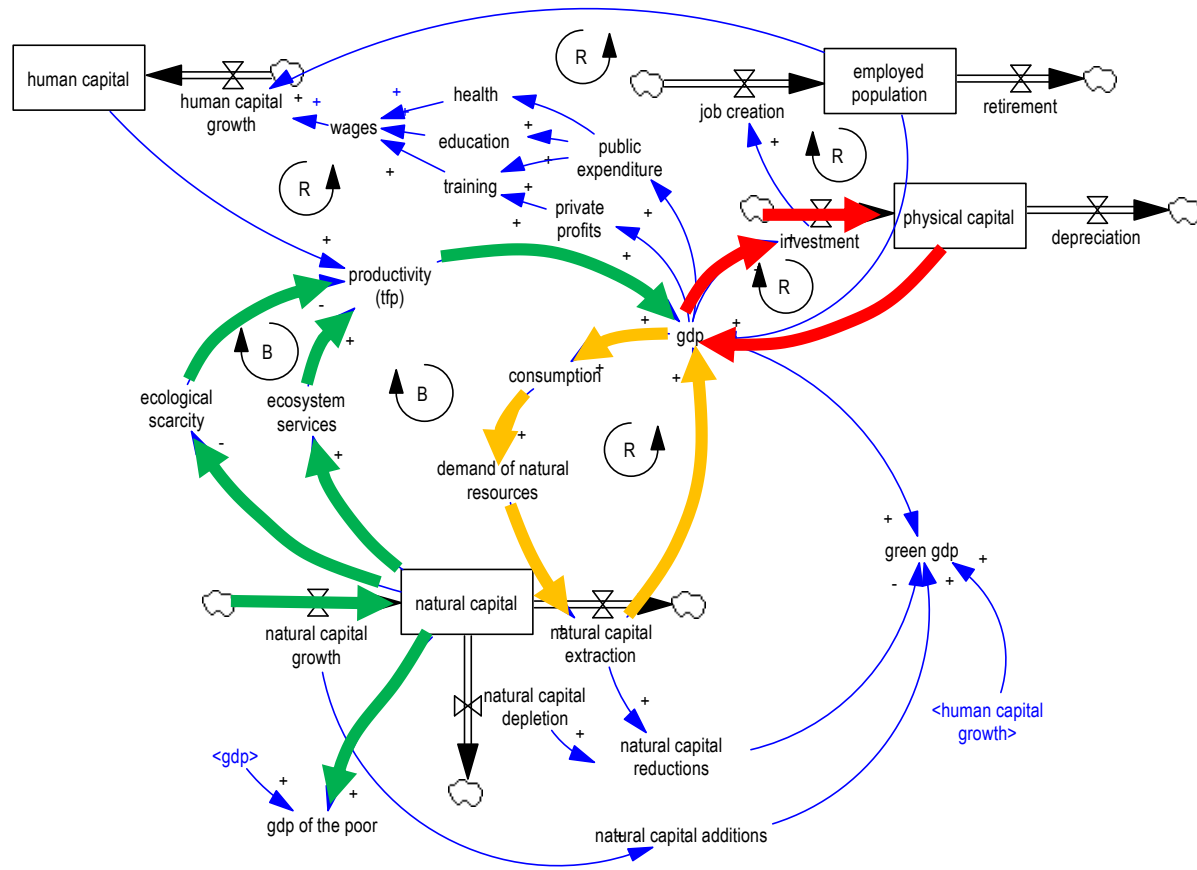
2- Systems analysis: value addition?



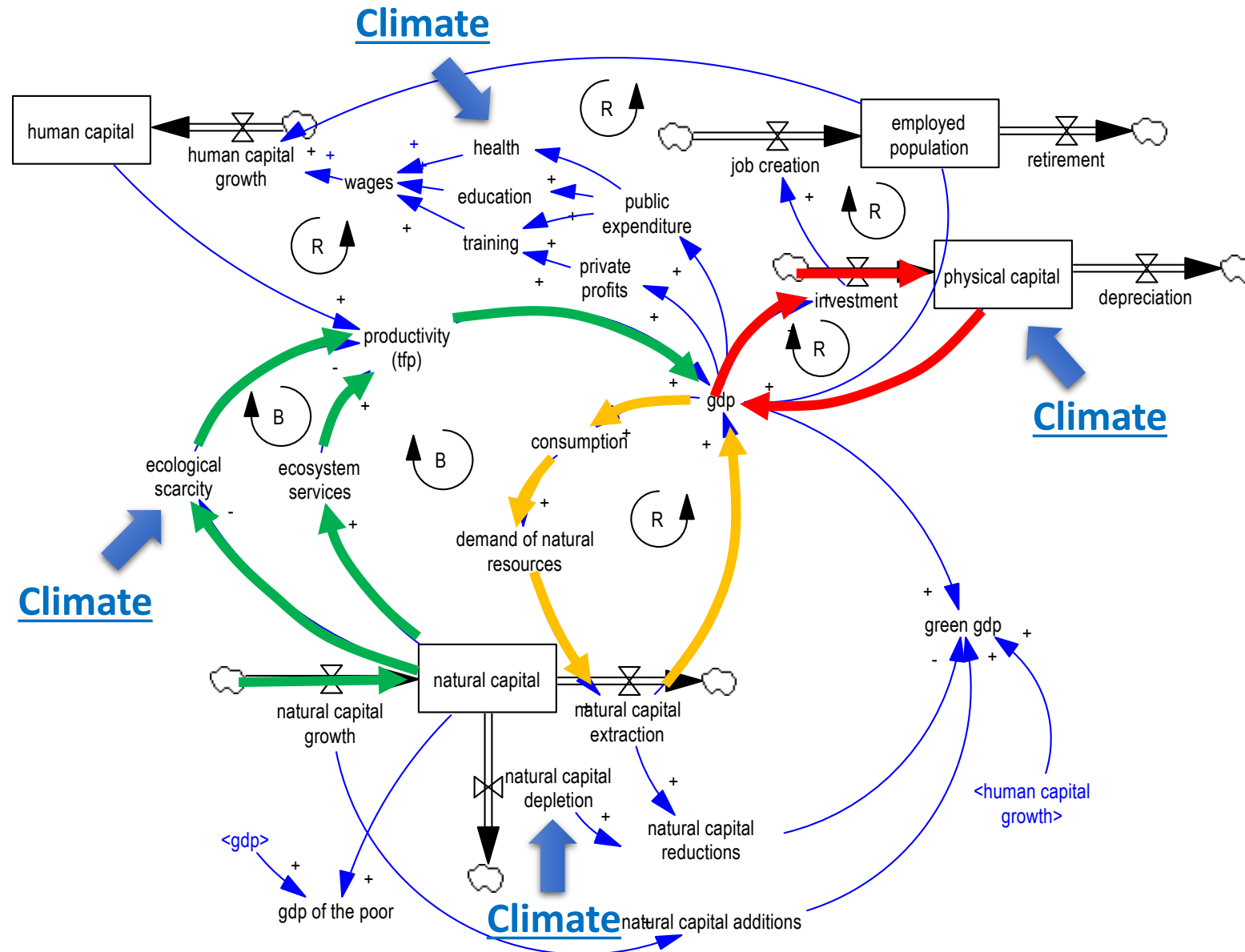
2- Systems analysis: value addition?



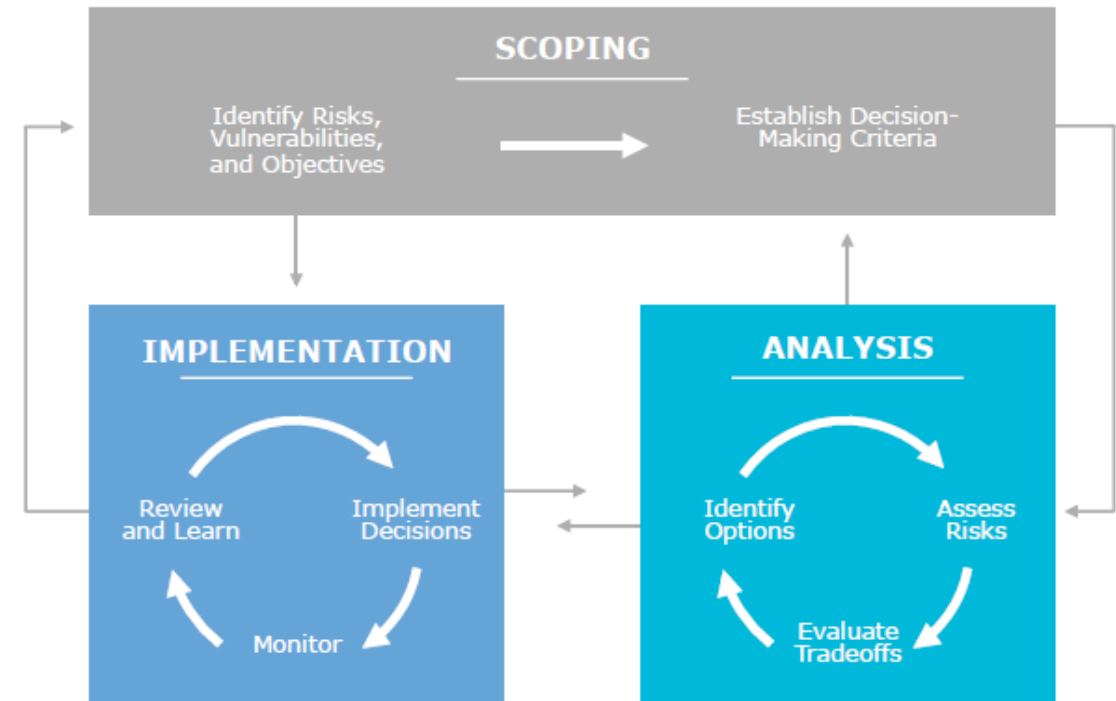
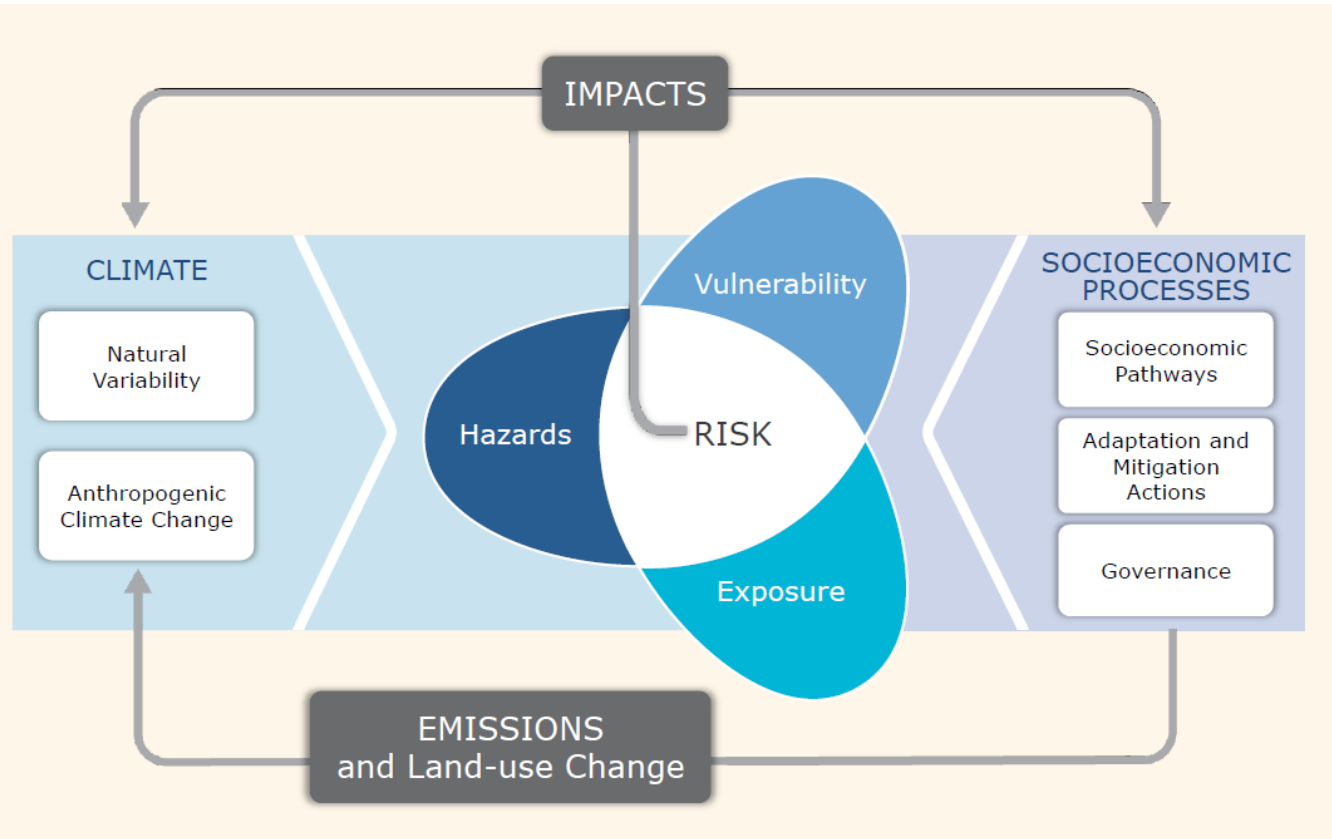
2- Systems analysis: value addition?



2- Systems analysis: climate impacts?



2- Vulnerability and adaptation in the Nexus

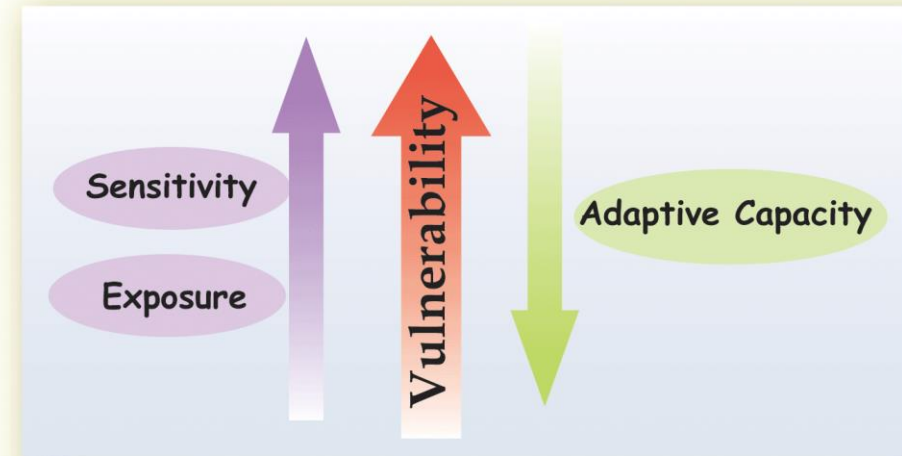


2- Some Questions to Begin Assessment of Vulnerability and Adaptation

- What is of concern?
 - Food production, water supply, health?
 - Concerns may not be expressed in climate terms
e.g., extreme temperature, but in consequences of climate for people
- Who may be affected?
- How far into the future is of concern?
 - Note concerns may focus on current risks,
which could be made worse by climate change
- For what purpose is the assessment to be used?
- What kind of output is needed?

2- Key concepts - vulnerability

- Vulnerability to climate change is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.
- Vulnerability is a function of three factors:
 - Exposure
 - Sensitivity
 - Adaptive capacity
- An assessment of vulnerability should consider all three factors
 - More exposure and sensitivity increase vulnerability
 - More adaptive capacity decreases vulnerability



2- Key concepts - exposure

- Exposure is what is at risk from climate change
 - Population
 - Resources
 - Property
- It is also the climate change that an affected system will face
 - Sea level
 - Temperature
 - Precipitation
 - Extreme events

2- Key concepts - sensitivity

- The degree to which a system is affected, either **adversely or beneficially**, by a given climate-related stimuli;
- **Direct** (e.g., reduction in crop yield caused by increased drought conditions), or **indirect** (e.g., damage to properties from coastal flooding caused by sea level rise);
- Generally, **primary** production systems (e.g., agriculture, forestry) are much more sensitive to climate variations, compared with most **secondary and tertiary** sectors (e.g., manufacturing and services)

2- Key concepts - adaptive capacity

- The ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences;
- Function of:
 - Wealth, technology, education, institutions, information, infrastructure and “social capital”
- *Having* adaptive capacity does not mean it is *used* effectively

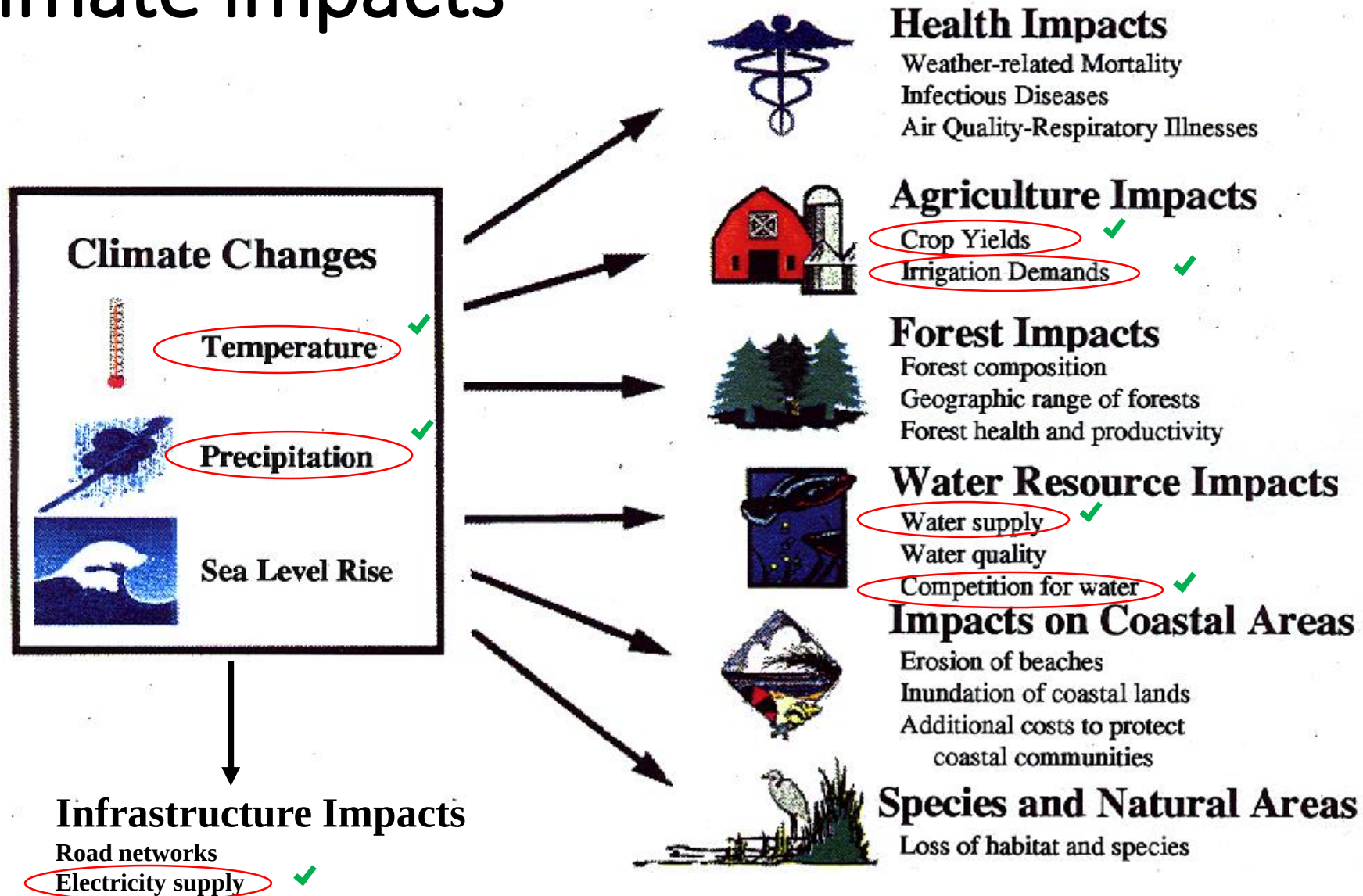
3- Overview of the models

- The UNECA SEB sectoral systems model was developed to analyze climate impacts in the water, energy and agriculture sector
- The model captures the linkages between the sectors and provides information about cross-sectoral impacts (e.g. agriculture and water)
- A Causal Loop Diagram (CLD) was developed for each of the sectors, highlighting the most important concepts and feedback loops

3- Evolution of the UNECA WISER model

- Previous versions of the UNECA WISER model were designed to assess the impact of adverse climate events on country level.
 - Includes individual sectors and their linkages to other sectors.
 - Focus of the assessment is macroeconomic performance.
 - Model inputs were not fully informed by empirical data (proof-of-concept).
 - The model outputs were calibrated to approximate historical developments.
- The UNECA WISER III model is designed to capture climate impacts at sectoral and inter-sectoral level (Nexus).
 - Assessment focuses on individual sectors and inter-sectoral impacts.
 - Model inputs are informed by empirical data.
 - Model outputs are calibrated according to historical data.
 - Application of the model to three countries: Uganda, Mozambique and Cameroon.

3- Climate impacts



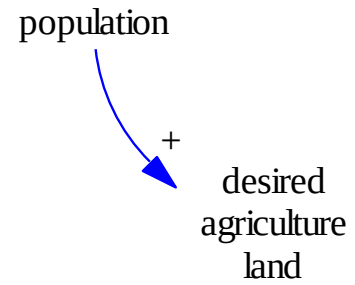
3- Overview of climate impacts

- The following climate impacts are considered in the UNECA WISER III model

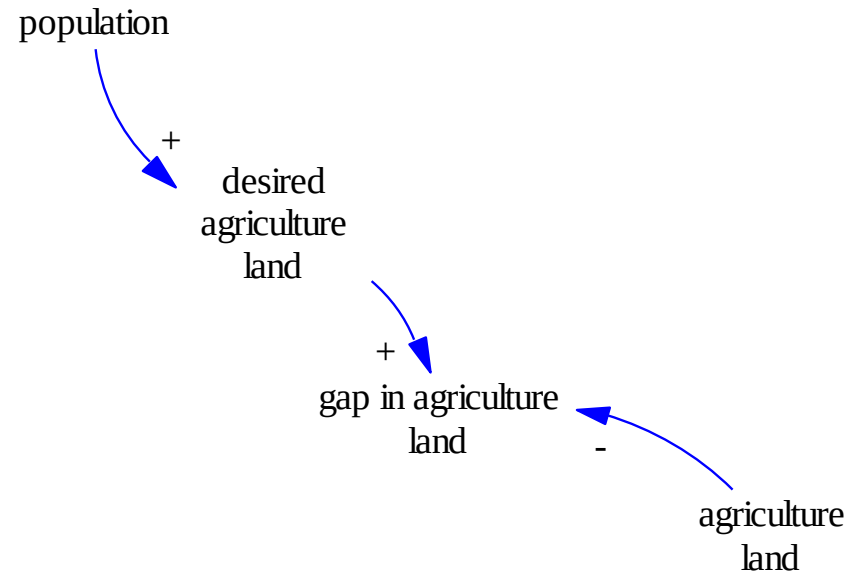
Climate impact	Floods	Droughts
Population affected by extreme events	X	X
Lifetime of agriculture land		X
Productive cropland	X	X
Load factor conventional	X	X
Load factor renewable	X	
Evapotranspiration rate		X
Damages to roads	X	

3- Structure of the agriculture sub-sector

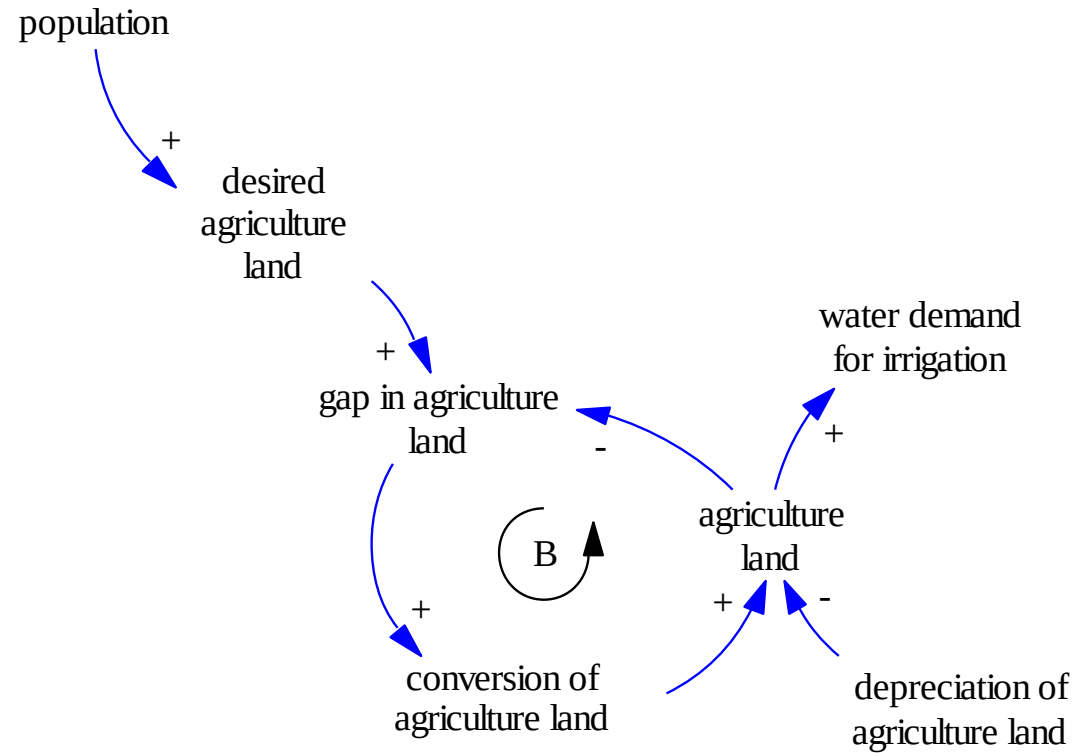
3- CLDs (1/3) - Agriculture



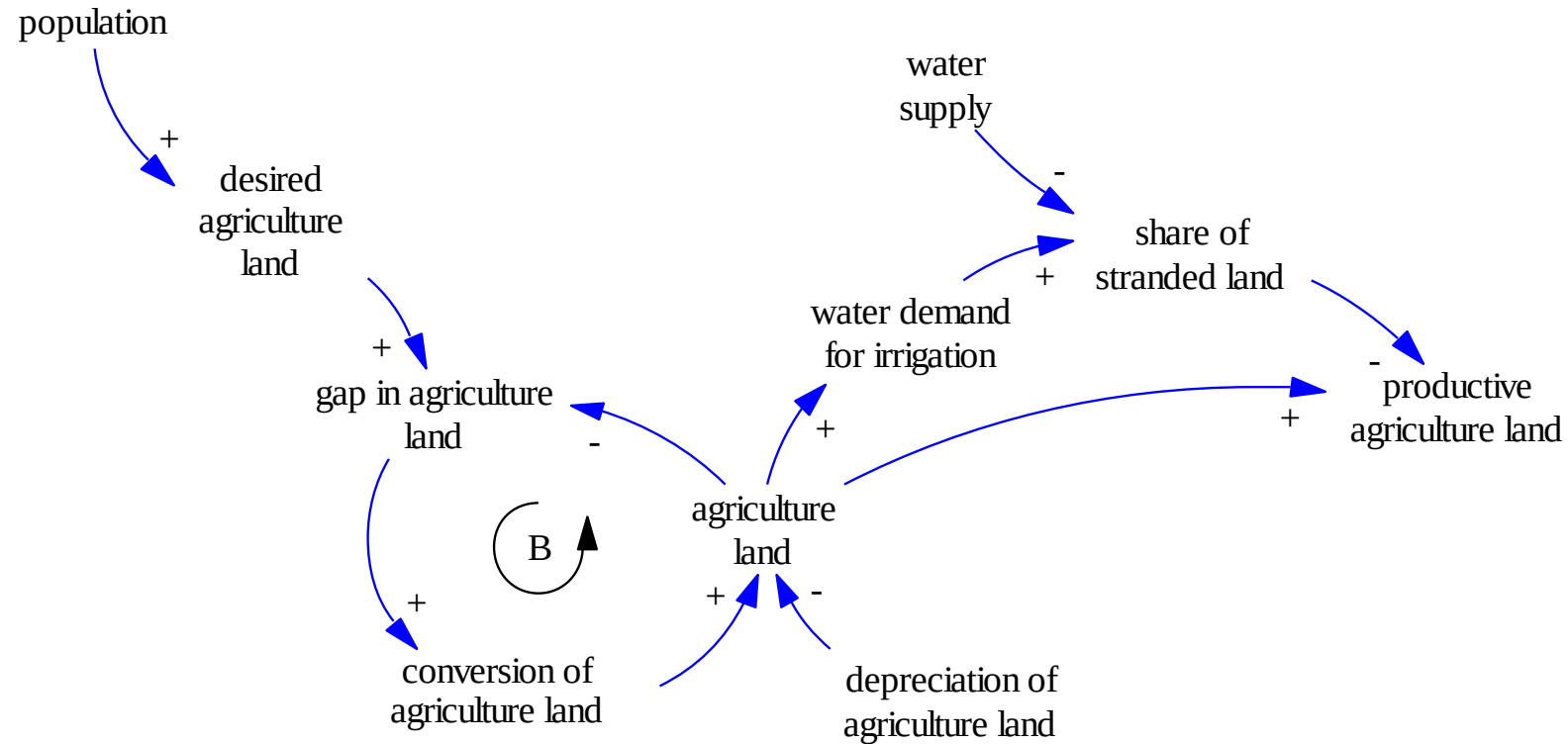
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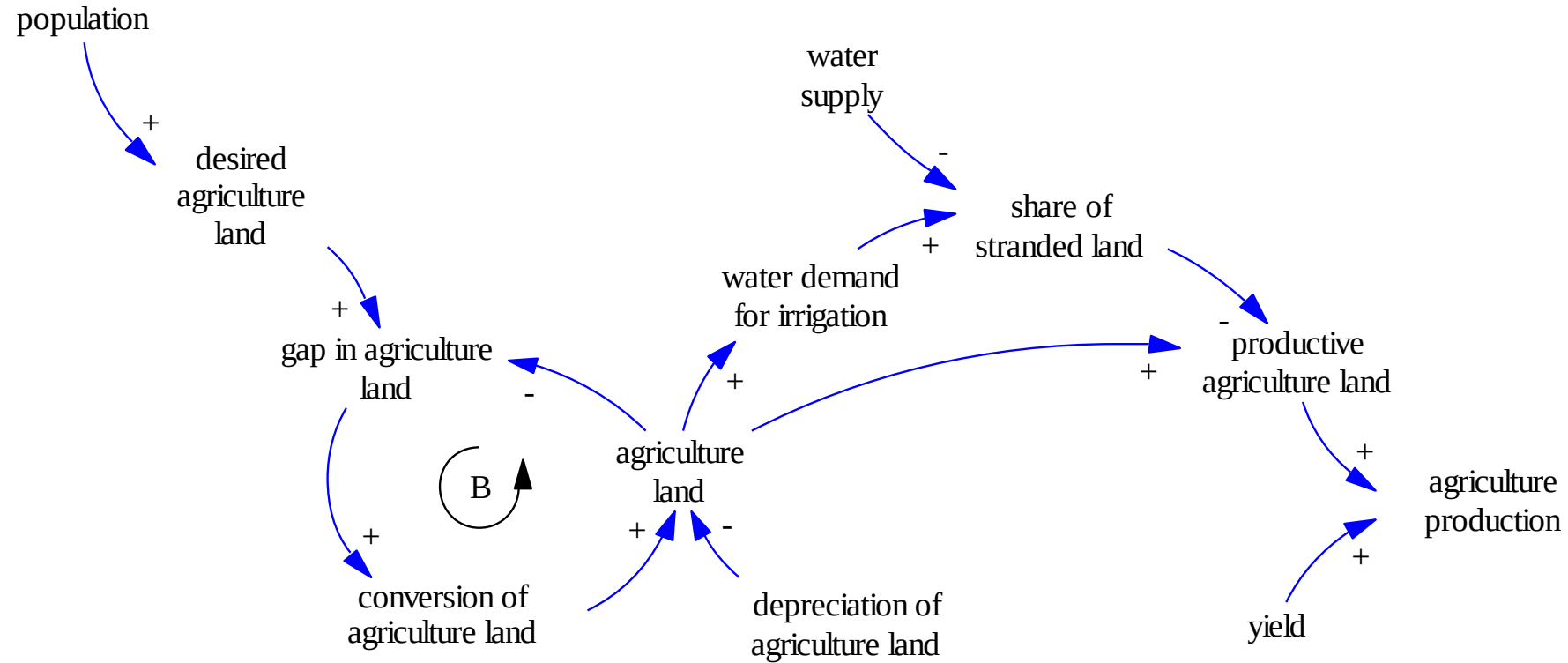
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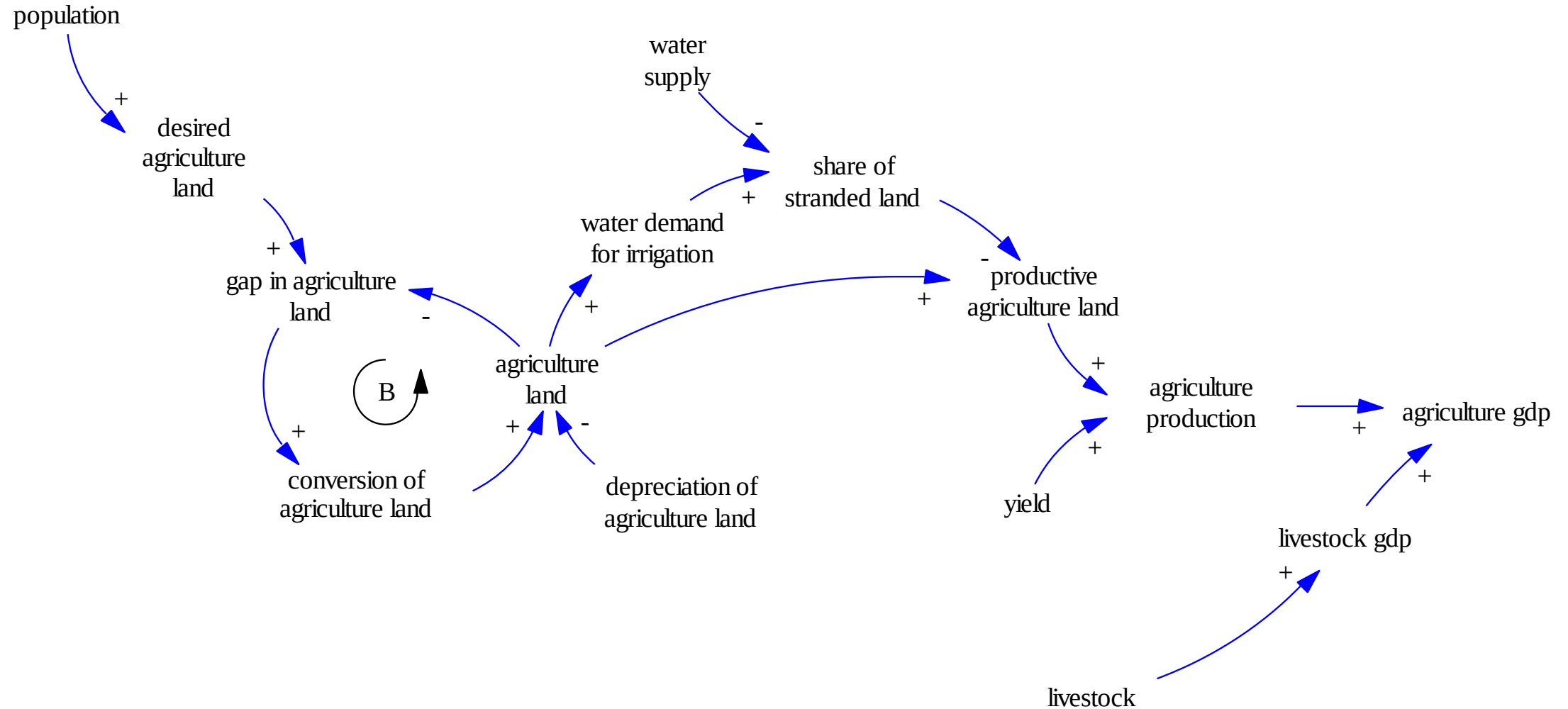
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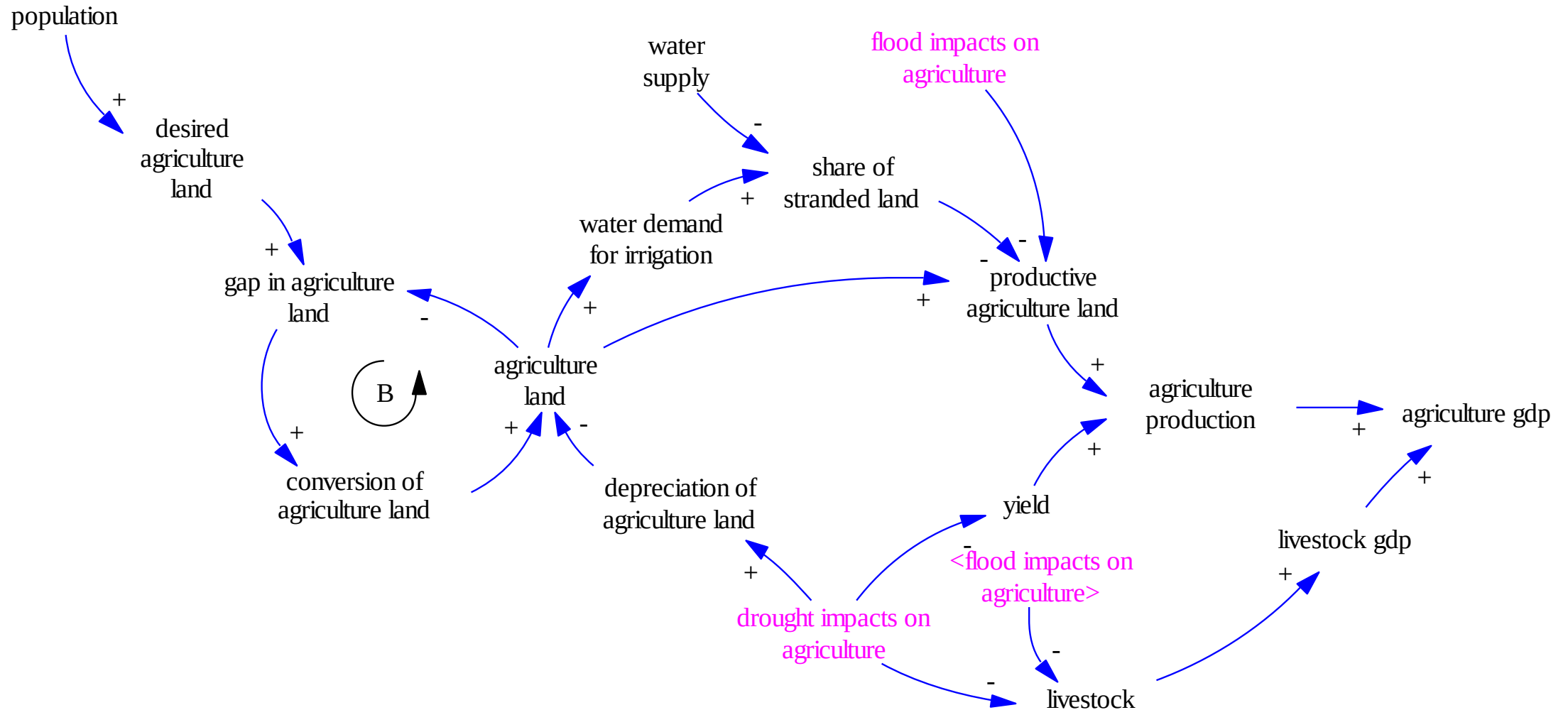
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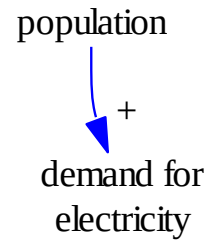


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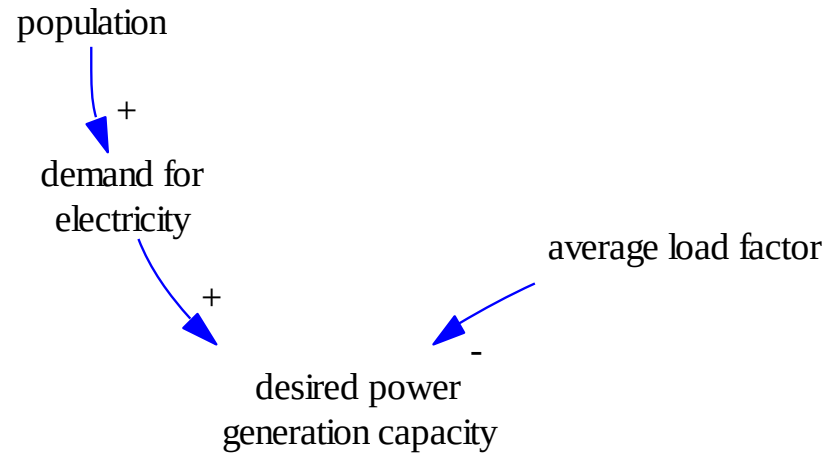


3- Structure of the energy sub-sector

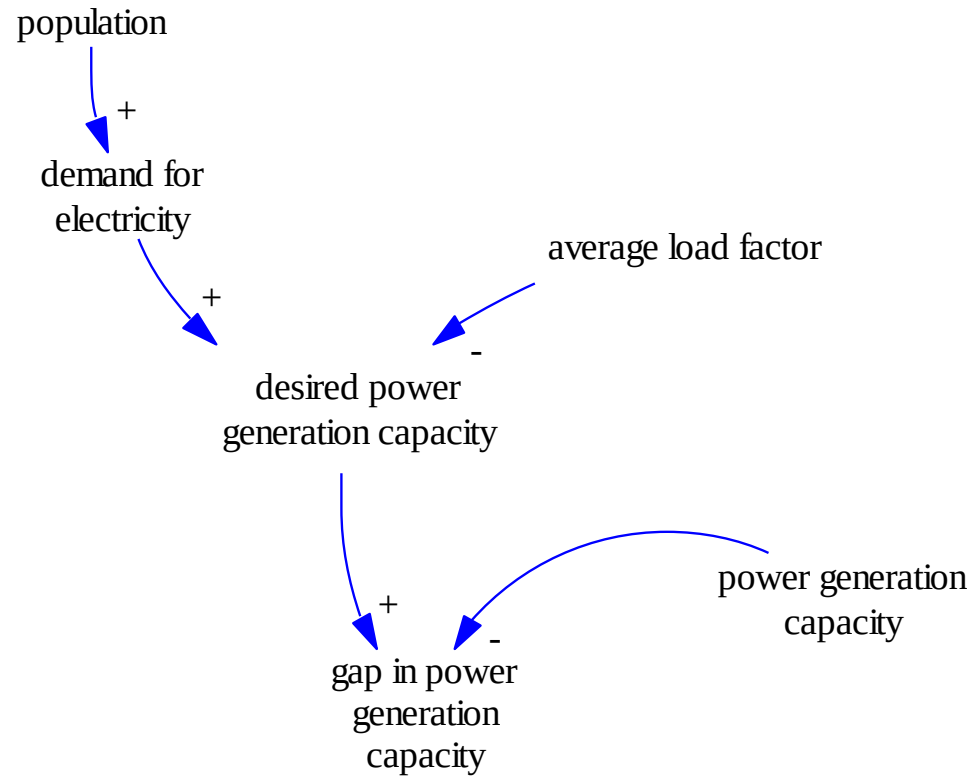
3- CLDs (2/3) - Energy



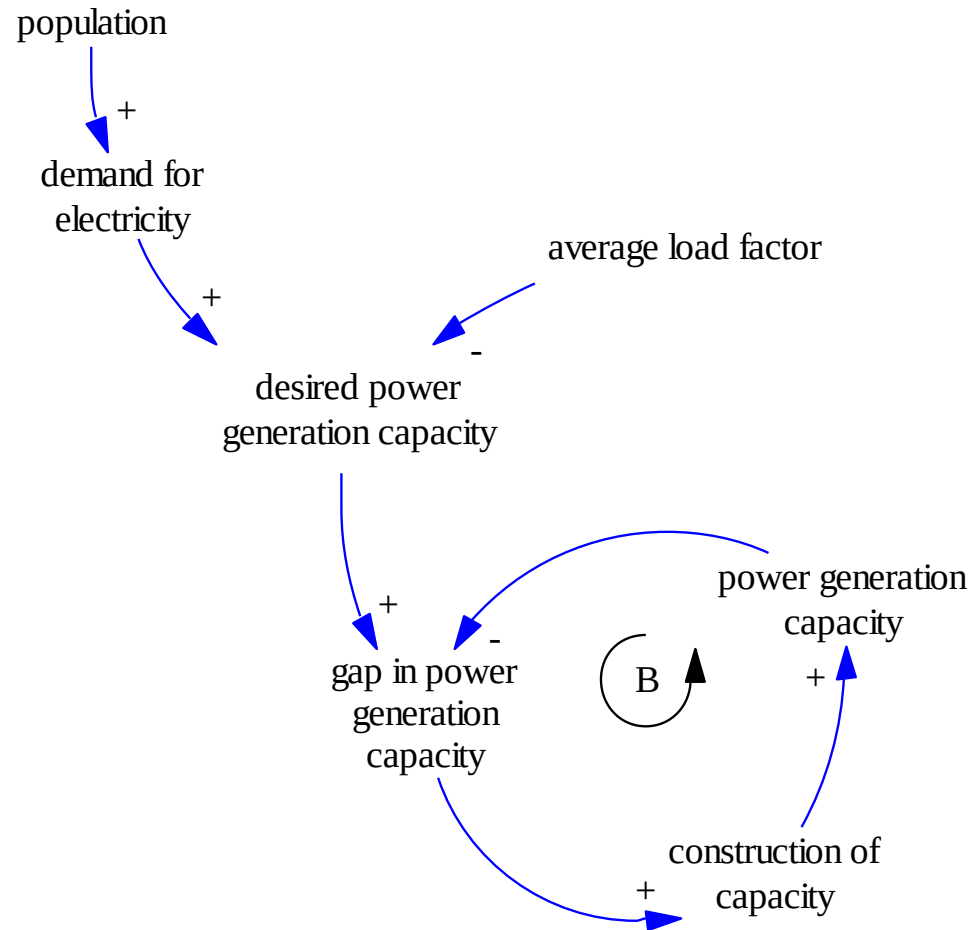
3- CLDs (2/3) - Energy



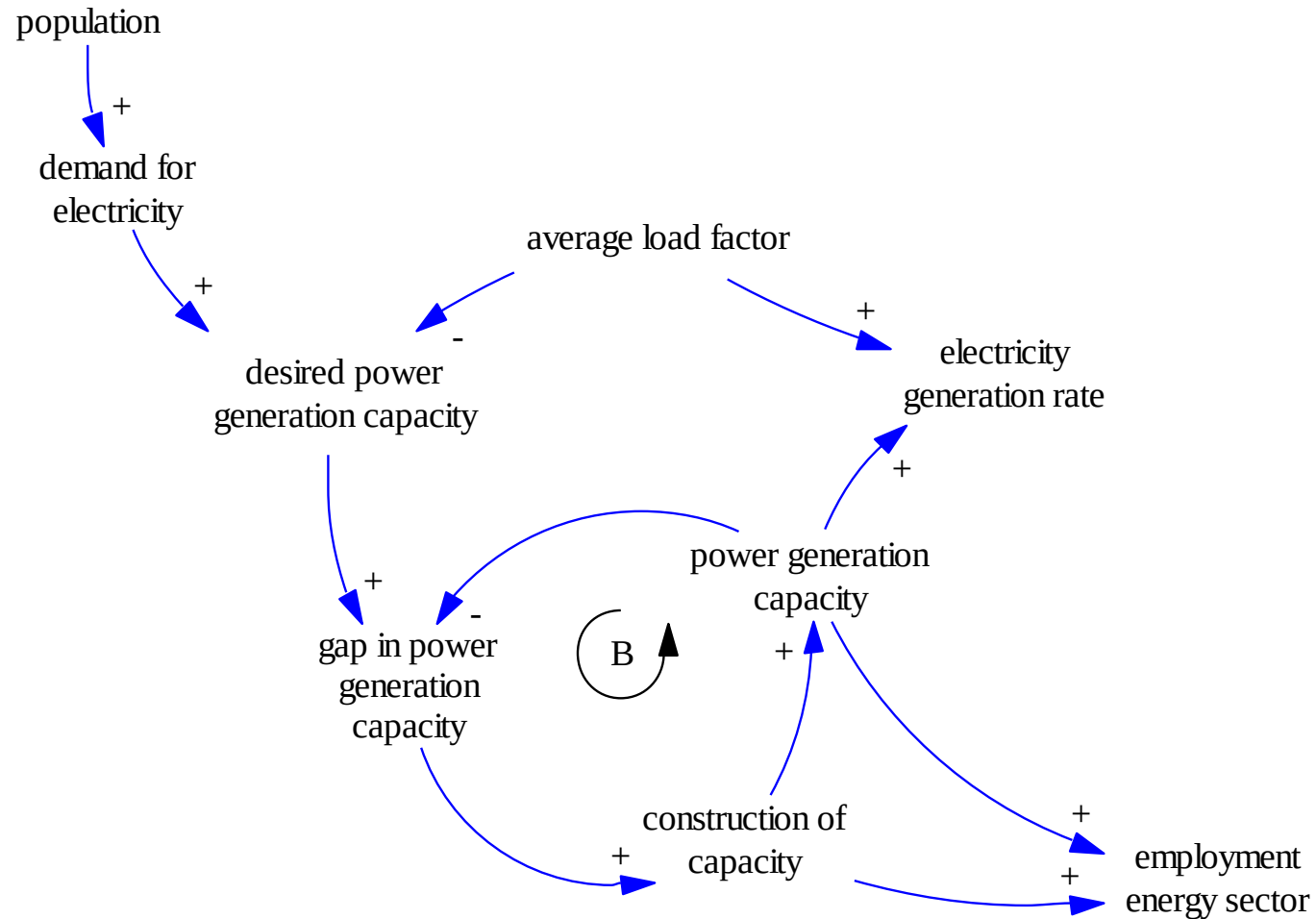
3- CLDs (2/3) - Energy



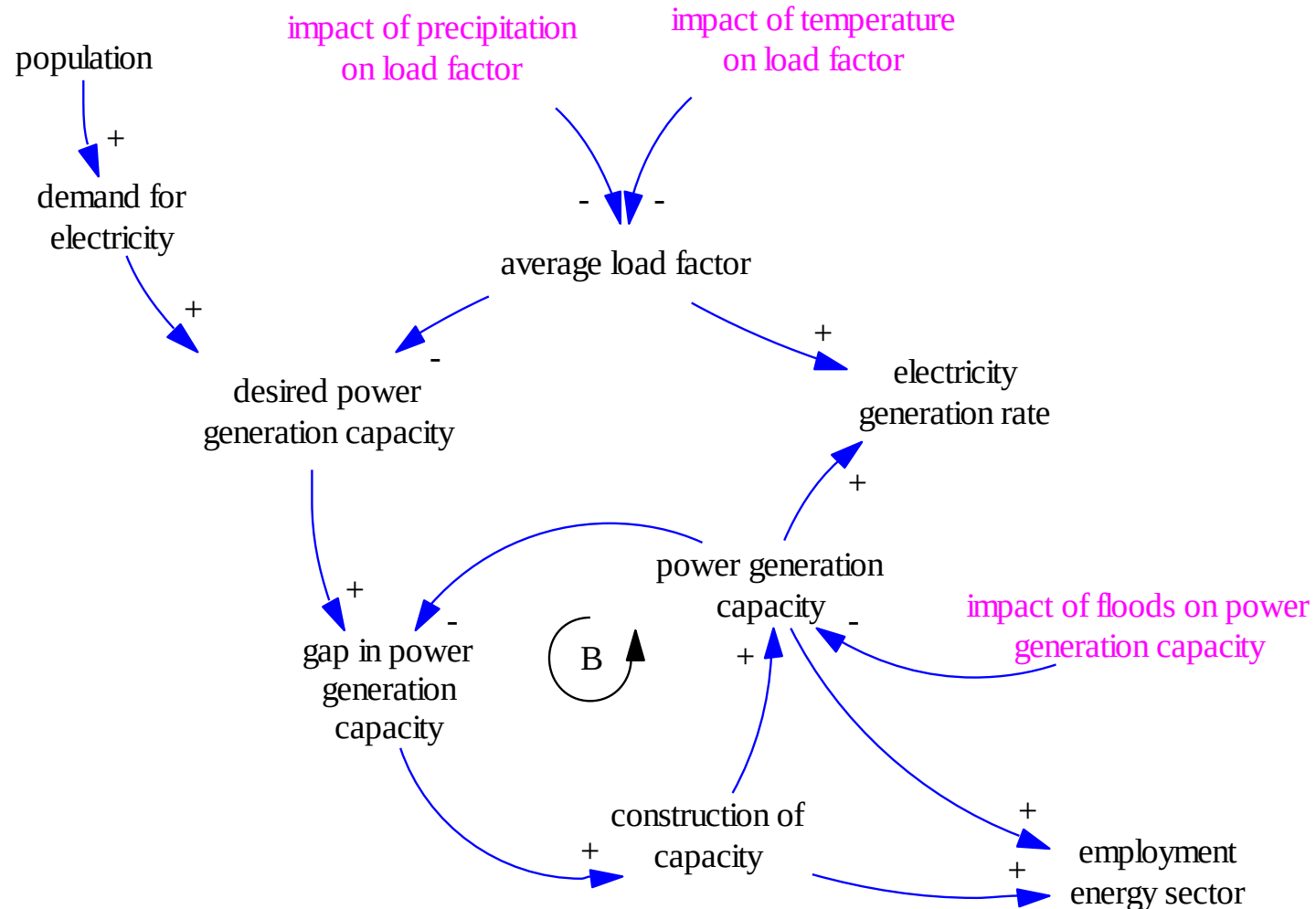
3- CLDs (2/3) - Energy



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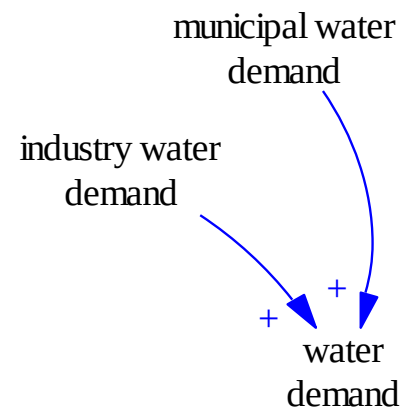


3- CLDs (2/3) - Energy

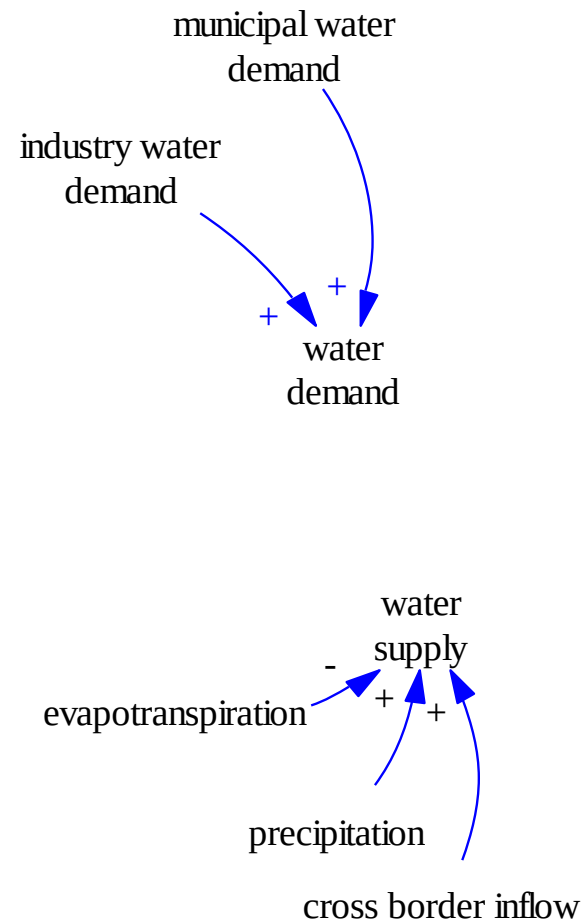


3- Structure of the water sub-sector

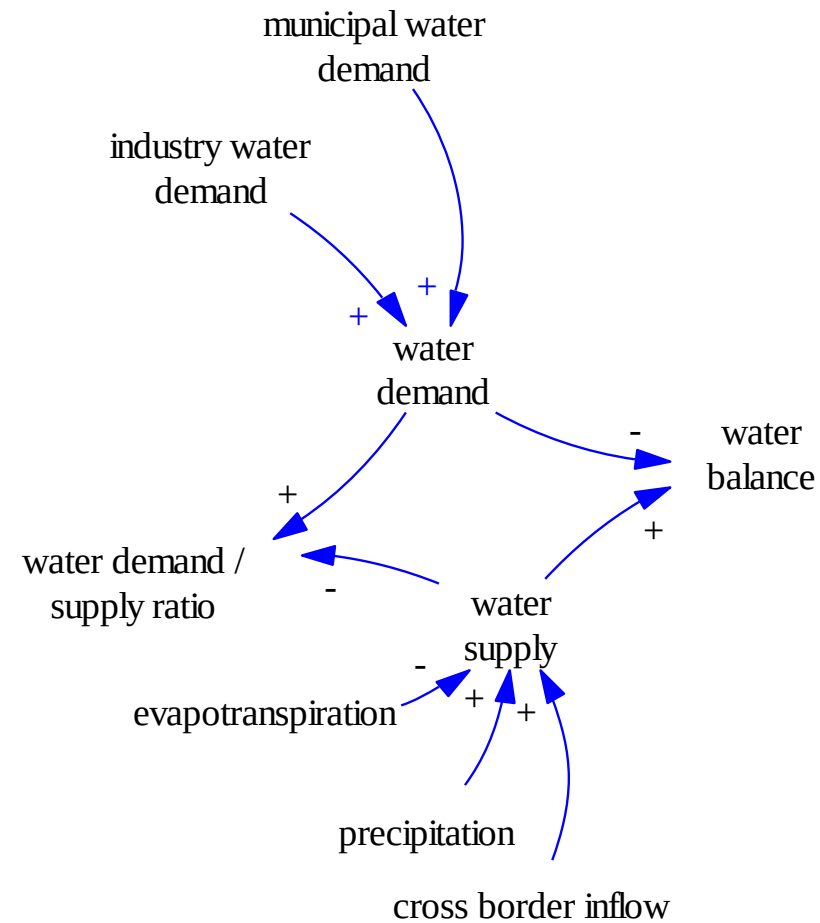
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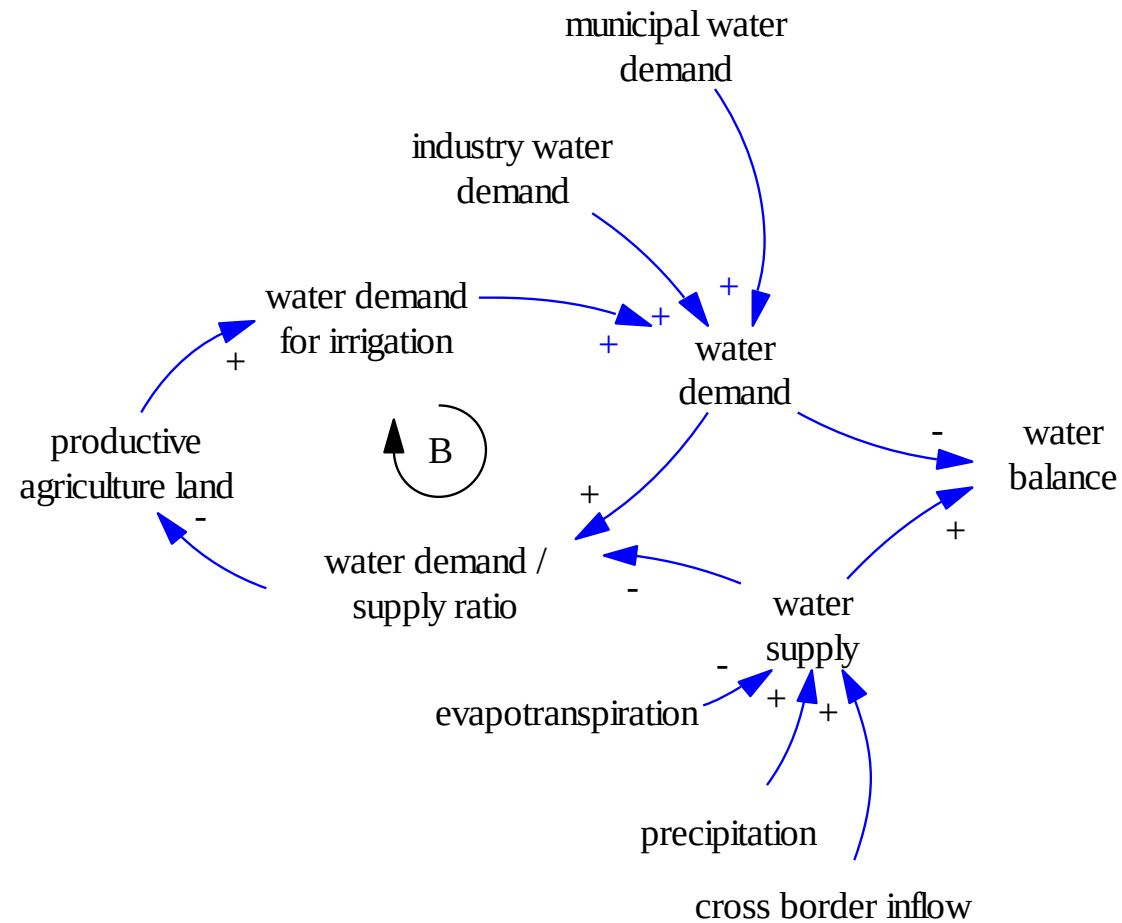
3- CLDs (3/3) - Water



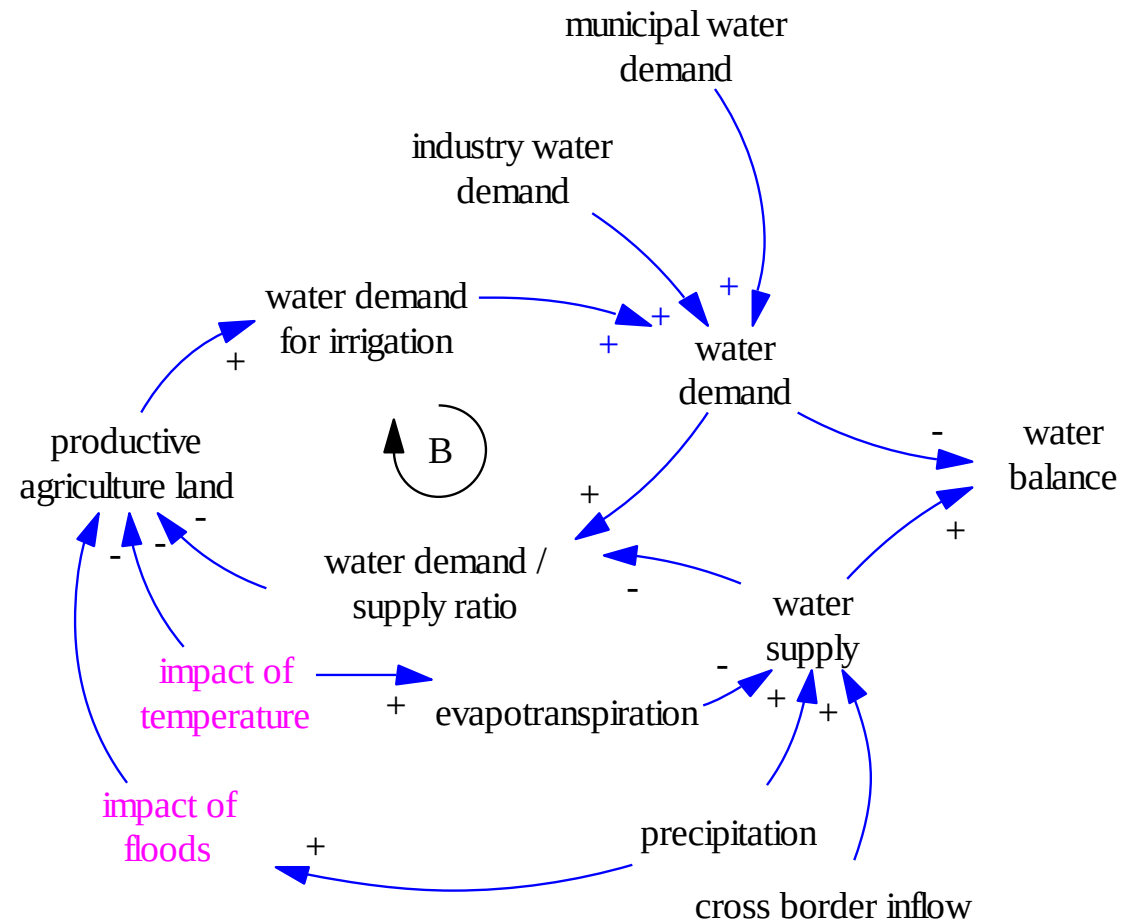
3- CLDs (3/3) - Water



3- CLDs (3/3) - Water



3- CLDs (3/3) - Water



3- Simulated scenarios and assumptions

Five scenarios were simulated for each country

<u>Scenario</u>	<u>Climate impacts</u>	<u>Description</u>
Business as usual (BAU)	No	The BAU scenario assumes the continuation of past and current trends. There are neither climate impacts nor adaptation measures in the BAU scenario. It serves as a baseline for assessing sectoral climate impacts.
Climate scenario	Yes	The Climate scenario uses the same assumptions as the BAU scenario. It includes sectoral impacts of floods and droughts, but no adaptation measures. It is used to assess the net impacts of climate events without interventions.
Adaptation scenarios		
Climate Agriculture	Yes	The Climate Agriculture scenario represents the agriculture adaptation scenario. It assumes the implementation of 10% sustainable agriculture by 2030, which benefits production, employment and sectoral value added.
Climate Energy	Yes	The Climate Energy scenario represents the energy adaptation scenario. It assumes a 15% increase in renewable power generation capacity by 2025 compared to the BAU scenario.
Climate Water	Yes	The Climate Water scenario represents the adaptation scenario of the water sector. It assumes a 30% implementation of drip irrigation, which benefits total water consumption and dampens climate impacts on agriculture.

3- Assumptions BAU scenario

- The BAU model projections are based on the following assumptions on GDP and Population growth.

Variable	Country	Value 2016	Value 2050	Source
GDP growth rate	Mozambique	4.5%	4.5%	Assumption
	Uganda	3.0%	3.0%	
	Cameroon	4.2%	4.2%	
Population growth rate	Mozambique	2.82%	2.12%	(UNDESA, 2018)
	Uganda	3.32%	2.26%	
	Cameroon	2.63%	1.18%	

3- Assumptions adaptation scenarios

- The adaptation scenarios are based on the following assumptions by sector.

Sector	Value 2018	Value 2025
Agriculture (all countries)		
Share of organic farming	0%	25%
Additional productivity organic farming	10%	
Additional value added organic farming	10%	
Additional labor organic farming	10%	
Energy		
Share of renewable energy		
Cameroon	70.0%	85.0%
Uganda	90.0%	100.0%
Mozambique	82.6%	97.6%
Water		
Share of drip irrigation	0%	30%
Efficiency conventional irrigation	25%	
Efficiency drip irrigation	82%	

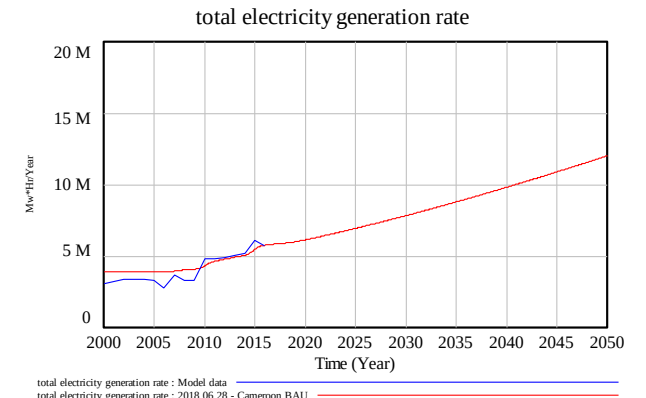
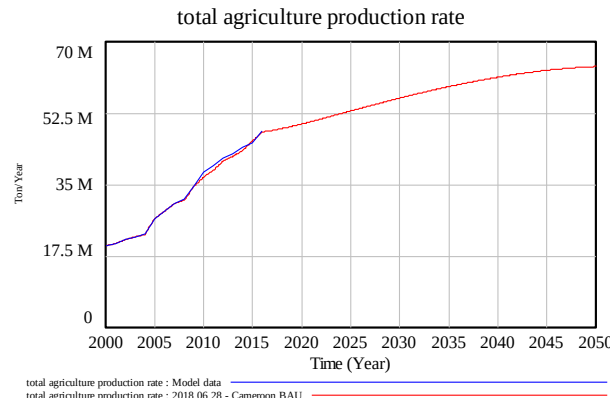
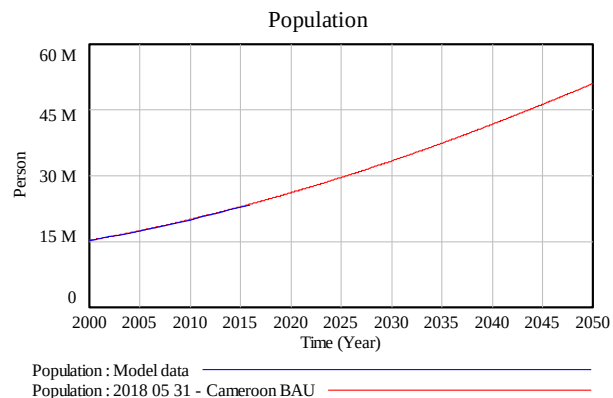
4- Model customizations to Mozambique, Uganda and Cameroon

4- Methodology for calibration and analysis

- System Dynamics was utilized for the socioeconomic assessment. It integrates the outputs from CROPWAT and SWAT and utilizes them to estimate bio-physical impacts.
- CROPWAT was utilized to estimate the specific water consumption and irrigation requirement by crop type.
- SWAT was utilized to calibrate water supply in the SD model, together with data on rainfall.

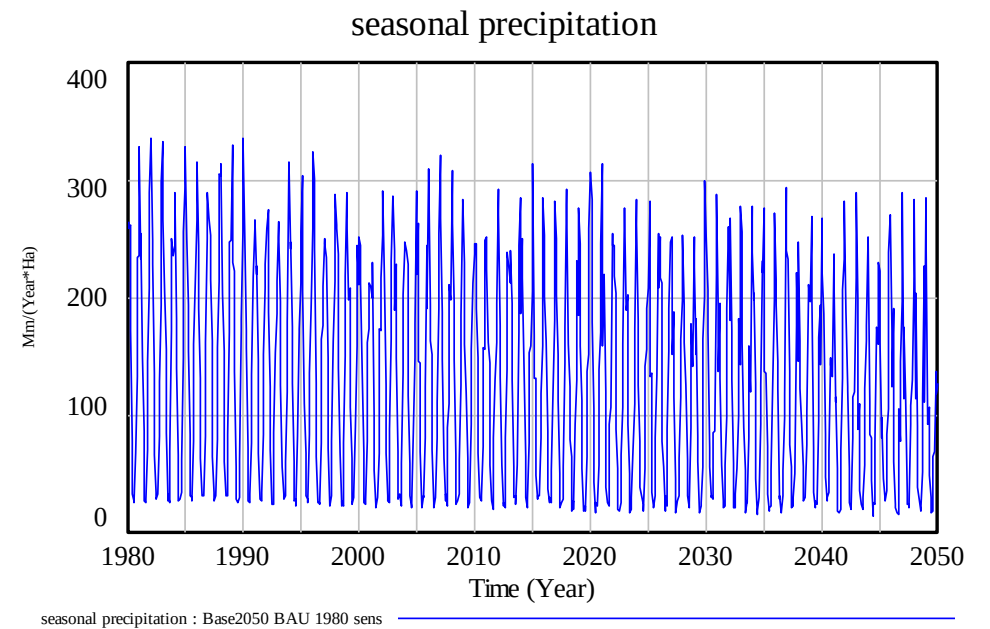
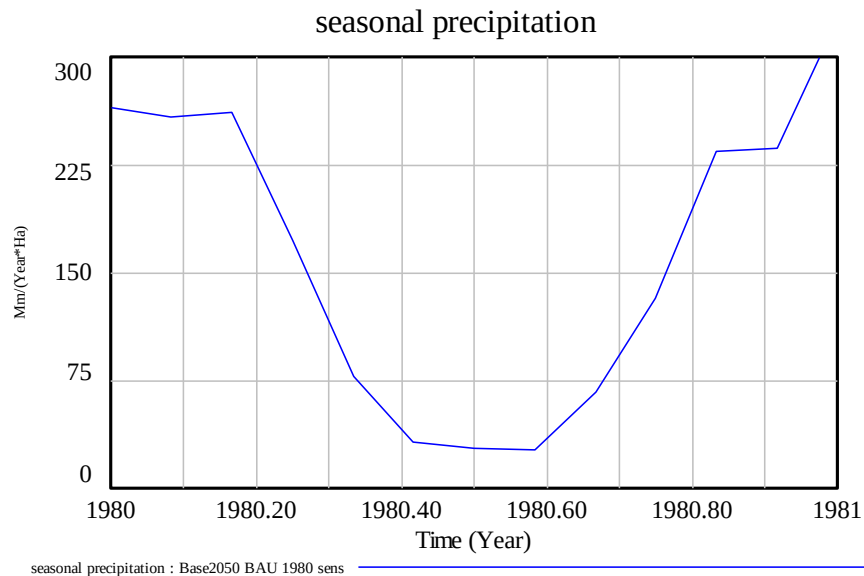
4- Data sources and validation

- The models are calibrated based on historical data. Among the data sources included are
 - National statistics
 - World Bank Data and World Development Indicators (WDIs)
 - UN databases on population and climate impacts (UNDP, UNDESA)
 - Other sources, such as papers from scientific journals and technical reports
- The validation of model projections is conducted by comparing model outputs to historical data.

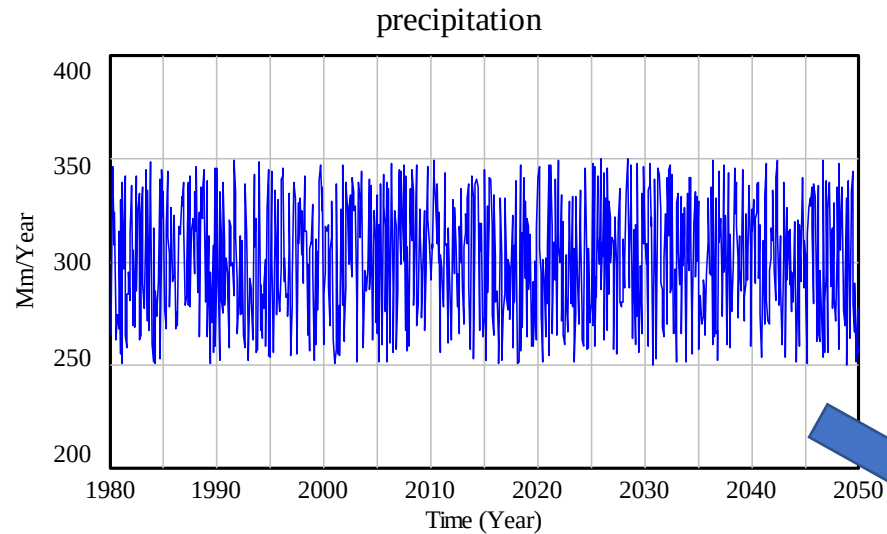


4- Calibration of precipitation

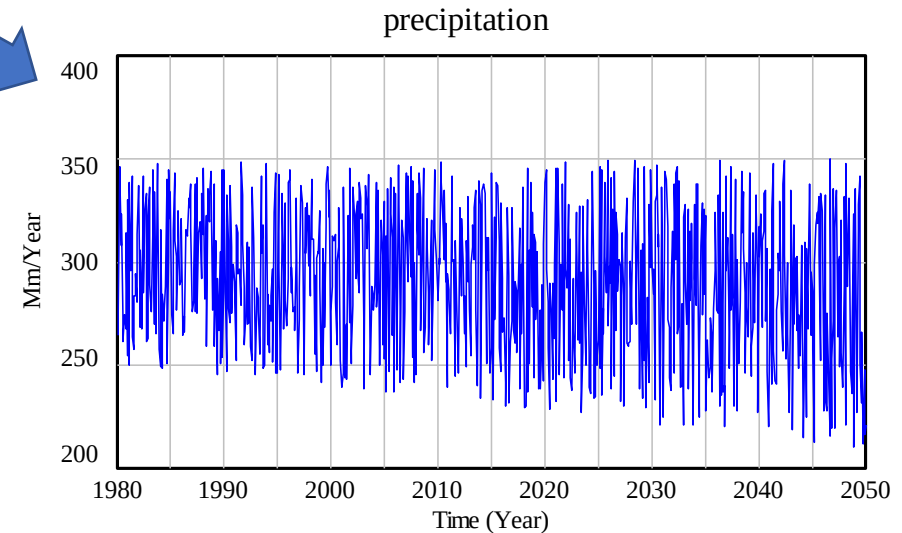
- The annual rainfall is distributed over the year to capture seasonal patterns and their cascading effects.



4- Climate variability and trends



precipitation : Base2050 BAU month sens



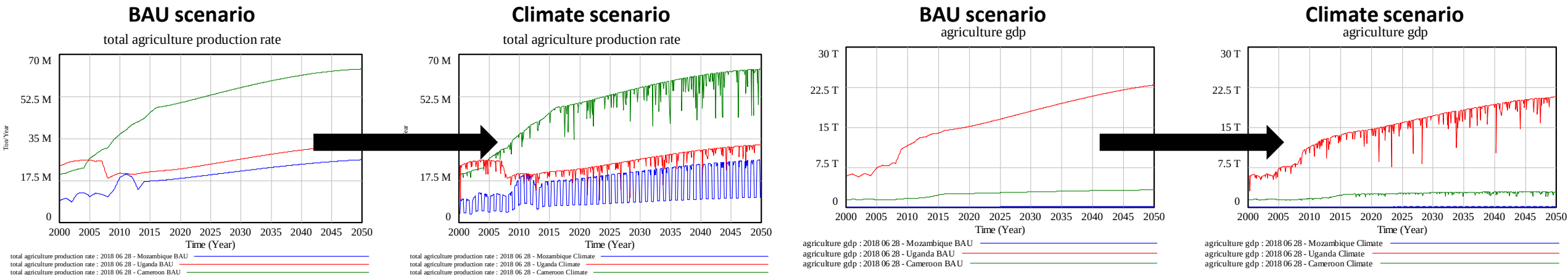
precipitation : Base2050 Weather month

4- Results

- The analysis compares sectoral performance
 - ...of the BAU to the Climate scenario to assess climate impacts.
 - ...of the Climate to the Adaptation scenarios to assess intervention effectiveness.
- Climate impacts have a proportional impact on sectoral performance, hence the bigger the sector, the stronger the impacts.
- Results at the sectoral level are presented and compared for Mozambique, Uganda and Cameroon.
- Total investments and benefits are compared using an integrated Cost-Benefit Analysis (CBA) approach.

4- Results – Climate scenario – Agriculture (1/2)

- The amount of cropland remains unaffected assuming that cropland is re-established once destroyed by climate events.
- Agriculture production is affected by the lack of water during the dry season, which reduces productivity per hectare and hence the quantity produced.
- Agriculture GDP in the climate scenario declines as a consequence of reduced production.



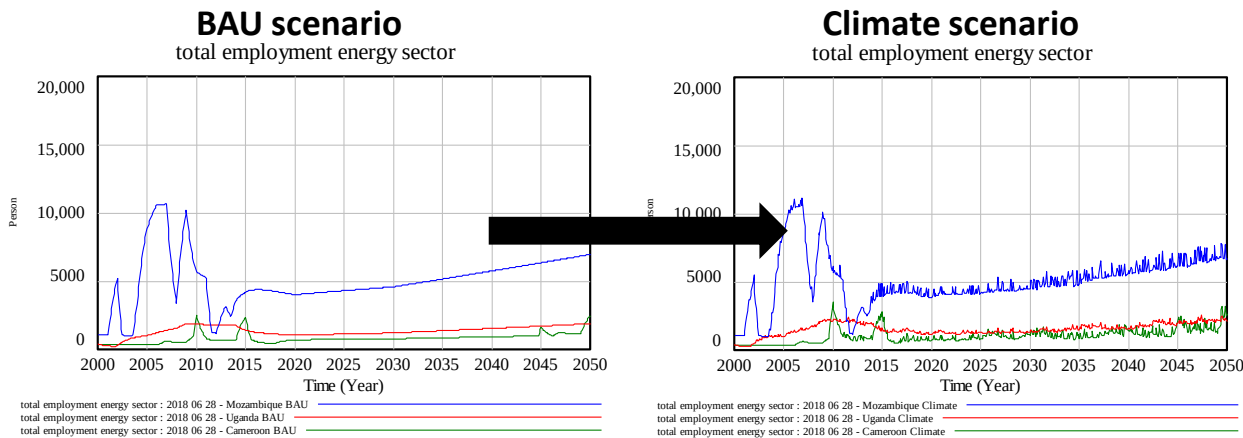
4- Results – Climate scenario – Agriculture (2/2)

- Climate impacts on agriculture GDP are the most pronounced for Mozambique due to water scarcity during the dry period. Reductions range from 23.3% to 25.7%.
- Reductions in agriculture GDP for Uganda and Cameroon range between 4.7% to 12.4% and 3.4% to 14.2% respectively.
- The strength of impacts on the Cameroonian agriculture sector increase over time. The underlying reasons are decreasing annual precipitation and population growth.

Agriculture GDP	Unit	2018	2020	2025	2030	2040	2050
Mozambique Climate	bn MZN	84.66	87.95	94.89	101.23	111.23	120.95
Mozambique BAU	bn MZN	111.47	114.73	123.73	132.91	149.70	160.66
Climate vs BAU	%	-24.0%	-23.3%	-23.3%	-23.8%	-25.7%	-24.7%
Uganda Climate	bn Ush	13'970.07	14'353.52	15'871.60	17'107.79	18'339.91	20'658.28
Uganda BAU	bn Ush	14'808.81	15'255.66	16'652.21	18'147.35	20'935.51	22'852.44
Climate vs BAU	%	-5.7%	-5.9%	-4.7%	-5.7%	-12.4%	-9.6%
Cameroon Climate	bn CFA	2'464.57	2'524.08	2'614.70	2'748.34	2'784.98	2'803.36
Cameroon BAU	bn CFA	2'559.26	2'612.64	2'760.03	2'903.77	3'141.51	3'267.16
Climate vs BAU	%	-3.7%	-3.4%	-5.3%	-5.4%	-11.3%	-14.2%

4- Results – Climate scenario – Energy (1/2)

- Climate damages to capacity are the highest in Cameroon, which has the most established energy sector. Damages are second highest for Uganda, and the lowest for Mozambique.
- Employment in the electricity sector shows stronger fluctuations. This is caused by higher construction employment from replacing capacity damaged during climate events.



Country	Cumulative damage to capacity	Total economic damage	Economic damage over 30 years
Unit	MW	bn LCU	bn LCU / Year
Mozambique	387	34.4	1.15
Uganda	1'315	7'409.7	246.99
Cameroon	3'826	3'228.4	107.61

4- Results – Climate scenario – Energy (2/2)

- Electricity production in the Climate scenario is affected by climate events. The use factor for thermal capacity is sensitive to high temperatures and the lack of water for cooling.
- Due to the high share of renewables, climate impacts on electricity generation are the least pronounced for Mozambique.
- Climate impacts cause electricity generation in Uganda and Cameroon to be between 0.6% and 1.6% lower than in the BAU scenario.

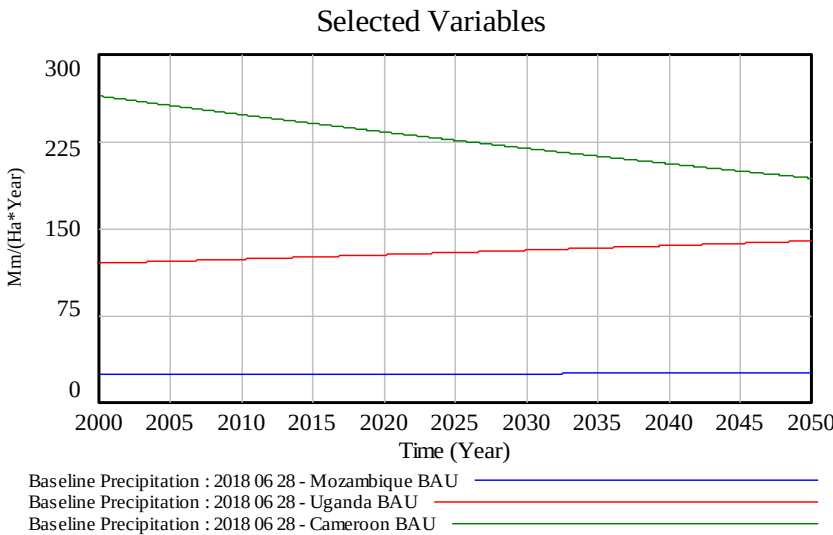
Electricity generation	Unit	2018-2020	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
Mozambique Climate	TWh	18.19	20.08	23.10	26.40	30.05	33.97	38.09
Mozambique BAU	TWh	18.19	20.09	23.09	26.42	30.06	33.96	38.10
Climate vs BAU	%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%
Uganda Climate	TWh	3.94	4.40	5.17	6.00	6.90	7.87	8.89
Uganda BAU	TWh	3.99	4.47	5.23	6.07	6.98	7.97	9.02
Climate vs BAU	%	-1.4%	-1.6%	-1.1%	-1.2%	-1.2%	-1.3%	-1.5%
Cameroon Climate	TWh	5.94	6.48	7.26	8.17	9.16	10.23	11.31
Cameroon BAU	TWh	6.00	6.52	7.37	8.29	9.28	10.34	11.44
Climate vs BAU	%	-1.0%	-0.6%	-1.6%	-1.4%	-1.4%	-1.0%	-1.2%

4- Results – Water (1/2) – BAU vs Climate

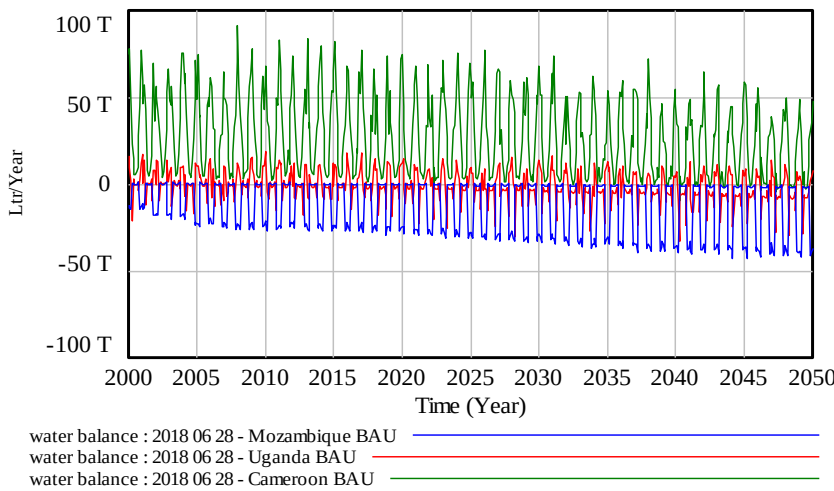
- The scenarios assume a change in average monthly precipitation based on historical trends.
 - An increasing trend in is assumed for Uganda and Mozambique, while average monthly precipitation in Cameroon is assumed to decline.
- Due to low precipitation values, water stress is the highest in Mozambique. Uganda and Cameroon experience increasing water stress over time.
 - In Uganda, agriculture expansion and population growth increase water stress, despite increasing annual precipitation.
 - Cameroon is projected to experience water stress from 2030, when water demand starts exceeding water supply. This is caused by the combination of increasing anthropogenic pressures and decreasing precipitation.

4- Results – Water (1/2) – BAU vs Climate

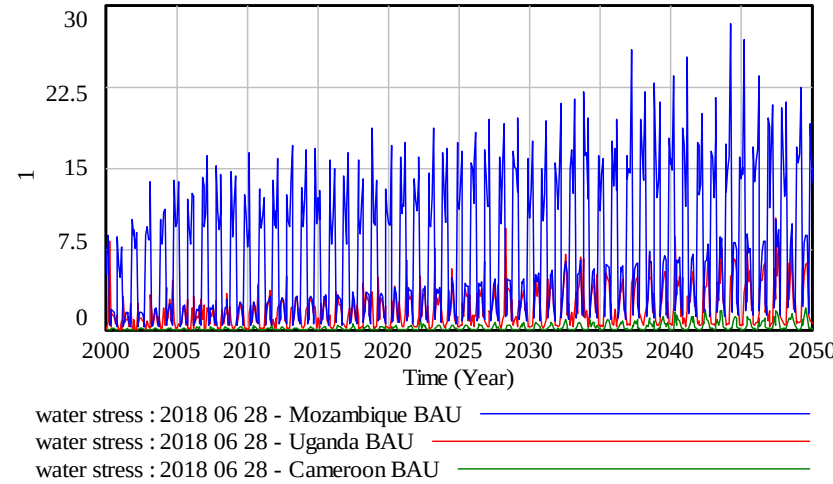
Average monthly precipitation



water balance



water stress



4- Results – Water (2/2) – BAU vs Climate

- Increasing annual precipitation elevates Mozambique's water balance by 56.7% in 2050 compared to the BAU scenario.
- The projections indicate that agriculture expansion in Uganda could cause severe water scarcity from 2020, despite a slight increase in annual precipitation.
- All three countries show a declining water balance over time.
 - The projections indicate a worsening trend for Mozambique and future challenges in for Uganda and Cameroon.
 - Cameroon's water balance is projected to remain positive until 2030, after which it starts declining due to agriculture expansion and decreasing precipitation.

Water balance	Unit	2018-2020	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
Mozambique Climate	mn m3	-10'978.7	-11'856.1	-13'157.8	-14'149.2	-15'371.7	-16'349.0	-17'205.1
% change to 2018	%	0.0%	8.0%	19.8%	28.9%	40.0%	48.9%	56.7%
Uganda Climate	mn m3	448	-259	-2'174	-2'177	-2'389	-4'369	-4'258
% change to 2018	%	0.0%	-157.7%	-585.1%	-585.9%	-633.1%	-1074.9%	-1050.1%
Cameroon Climate	mn m3	25'946	28'218	28'186	24'417	23'170	20'346	19'036
% change to 2018	%	0.0%	8.8%	8.6%	-5.9%	-10.7%	-21.6%	-26.6%

4- Cumulative climate impacts

- The relative strength of climate impacts depends on the size and vulnerability of the respective sectors in their country context.
- Overall, cumulative losses from climate events are the highest in Cameroon, followed by Uganda and Mozambique.
 - Cumulative losses from agriculture are the highest in Cameroon, while cumulative additional water demand to maintain production is highest for Uganda.

Sector	Unit	Mozambique	Uganda	Cameroon
<u>Agriculture</u>				
Total production	mn Tons	-8.9	-25.9	-51.2
Additional water demand	mn m3	270.1	114'615.1	87'114.7
<u>Energy</u>				
Power generation capacity	MW	1'684.5	6'404.4	9'089.7
Electricity production	mn MWh	-0.1	-2.5	-3.3
<u>Water</u>				
Water resources internally produced	mn m3	-72'249	-377'674	-1'596'445
Water balance	mn m3	90'595	64'219	3'698'844

4- Assessment of SEBs from CIS

Investments 

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*

4- Results of the integrated CBA – BAU vs Climate (1/2)

- The analysis reveals that climate hazards cause significant additional costs across the three countries.
 - Cumulative losses between 2018 and 2050 range from USD 7.3 billion in Mozambique to USD 53.5 billion in Cameroon.
- The projections indicate significant damages to power generation capacity and losses from crop production. This assumes that no adaptation measures are taken.

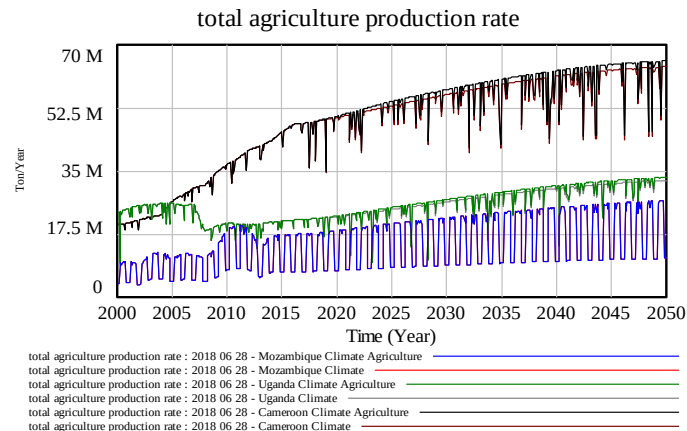
Category	Unit	Mozambique	Uganda	Cameroon
Value added				
Agriculture GDP	mn USD	-6'201.54	-9'897.41	-14'899.45
Climate vs BAU	%	-12.1%	-13.7%	-16.7%
Livestock GDP	mn USD	-43.55	-201.55	-369.85
Climate vs BAU	%	-21.9%	-43.0%	-70.7%
Investments and costs				
Electricity				
Investments	mn USD	3'728.23	12'688.93	18'652.83
Conventional	mn USD	667.83	1'680.25	5'877.30
Renewable	mn USD	3'060.41	11'008.68	12'775.53
Avoided costs				
O&M cost power generation	mn USD	-27.18	18.79	25.37
Conventional	mn USD	-5.47	6.44	17.79
Renewable	mn USD	-21.71	12.35	7.58
Added benefits				
Labor income energy	mn USD	2'694.84	21.59	12.26
Net benefits	mn USD	-7'262.1	-22'546.0	-33'514.6
Exchange rate	LCU / USD	59.3	3,756.0	562.5

4- Results of the integrated CBA – BAU vs Climate (2/2)

Category	Unit	Mozambique	Uganda	Cameroon
<u>Value added</u>				
Agriculture GDP	mn USD	-6'201.54	-9'897.41	-14'899.45
Climate vs BAU	%	-12.1%	-13.7%	-16.7%
Livestock GDP	mn USD	-43.55	-201.55	-369.85
Climate vs BAU	%	-21.9%	-43.0%	-70.7%
<u>Investments and costs</u>				
<u>Electricity</u>				
Investments	mn USD	3'728.23	12'688.93	18'652.83
Conventional	mn USD	667.83	1'680.25	5'877.30
Renewable	mn USD	3'060.41	11'008.68	12'775.53
<u>Avoided costs</u>				
O&M cost power generation	mn USD	-27.18	18.79	25.37
Conventional	mn USD	-5.47	6.44	17.79
Renewable	mn USD	-21.71	12.35	7.58
<u>Added benefits</u>				
Labor income energy	mn USD	2'694.84	21.59	12.26
Net benefits	mn USD	-7'262.1	-22'546.0	-33'514.6
Exchange rate	LCU / USD	59.3	3,756.0	562.5

4- Results – Adaptation scenario – Agriculture (1/2)

- Organic farming practices increase agriculture production by 4.5% to 5.06%.
- After full implementation in 2025, agriculture GDP is projected to increase by 4.4% in Mozambique and Uganda, and by 4.7% in Cameroon.
 - Due to impacts in the livestock sector, the increase in agriculture GDP is disproportional to the increase in crop production.
- The net benefits of implementing organic farming at USD 100 per hectare are negative for all three countries.
 - Premium prices for organic produce could serve as instrument to ensure at least break even. The required premium ranges between 10.2% in Cameroon to 29% in Mozambique.



Investments	Unit	Mozambique	Uganda	Cameroon
Organic farming	bn USD	6.51	6.73	6.25
Added benefits				
Agriculture GDP	bn USD	2.24	3.66	6.12
Total net benefits	bn USD	-4.27	-3.07	-0.13

Policy measure	Unit	Mozambique	Uganda	Cameroon
Required cost per ha	USD / Ha / Year	34.5	54.3	97.9
Required premium price	%	29.0%	18.4%	10.2%

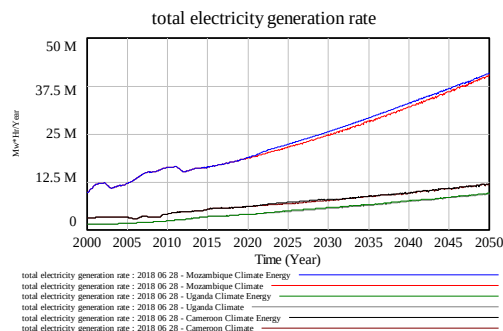
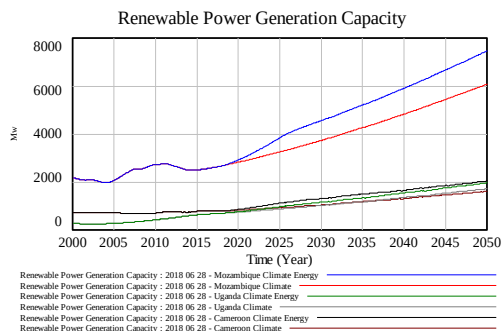
4- Results – Adaptation scenario – Agriculture (2/2)

- The use of organic farming practices increases agriculture GDP between 4.4% and 4.7% from 2025
- By 2050, this translates into additional value added of
 - Mozambique: 90.4 million USD / year
 - Uganda: 243.3 million USD / year
 - Cameroon: 233.6 million USD / year

Agriculture GDP	Unit	2018	2020	2025	2030	2040	2050
Mozambique Adaptation	bn MZN	84.91	89.29	99.01	105.66	116.13	126.31
Mozambique Climate	bn MZN	84.66	87.95	94.89	101.23	111.23	120.95
Adaptation vs Climate	%	0.3%	1.5%	4.3%	4.4%	4.4%	4.4%
Uganda Adaptation	bn Ush	14'009.23	14'569.83	16'558.18	17'853.01	19'144.57	21'572.26
Uganda Climate	bn Ush	13'970.07	14'353.52	15'871.60	17'107.79	18'339.91	20'658.28
Adaptation vs Climate	%	0.3%	1.5%	4.3%	4.4%	4.4%	4.4%
Cameroon Adaptation	bn CFA	2'471.40	2'561.11	2'725.47	2'866.30	2'910.05	2'934.75
Cameroon Climate	bn CFA	2'464.57	2'524.08	2'614.70	2'748.34	2'784.98	2'803.36
Adaptation vs Climate	%	0.3%	1.5%	4.2%	4.3%	4.5%	4.7%

4- Results – Adaptation scenario – Energy (1/2)

- The transition to renewable capacity reduces physical damages to capacity, and hence contributes to energy security.
 - Although less capacity is damaged, the total value of damages increases due to higher replacement cost for renewable capacity.
- Generation capacity in MW increases in all three countries as result of lower efficiency of renewable generation.
 - The transition towards renewable energy increases employment for both construction and maintenance.



	Adaptation scenario		Climate scenario		Difference	
Total damages to capacity	MW	mn USD	MW	mn USD	MW	mn USD
Mozambique	1'254	2'931	1'292	2'815	-38	116
Uganda	6'812	13'825	7'025	13'777	-213	48
Cameroon	7'622	16'636	8'122	16'353	-500	282

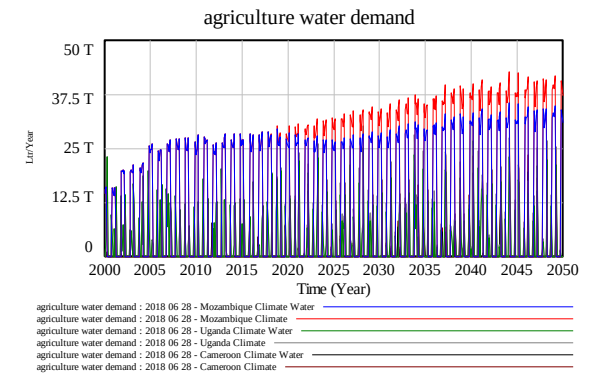
4- Results – Adaptation scenario – Energy (2/2)

- Additional investments in renewable capacity are the highest in Mozambique, followed by Cameroon and Uganda.
 - Mozambique has the largest electricity sector of the three countries and needs to replace more capacity than Uganda and Cameroon.
 - Due to the existing share of renewables, investments are the lowest in Uganda.
- All three countries experience benefits from improved access to energy and additional employment in the energy sector.

Investments	Unit	Mozambique	Uganda	Cameroon
Renewable capacity	mn USD	75'153	9'119	15'768
Investment	mn USD	73'693	9'008	15'298
O&M cost	mn USD	1'460	111	470
Avoided cost				
Conventional capacity	mn USD	27'594	4'440	8'778
Investment	mn USD	26'298	4'309	8'279
O&M cost	mn USD	1'297	131	498
Added benefits				
GDP from access to energy	mn USD	17'115	20'775	25'393
Labor income	mn USD	20'986	5.1	1.4
Total Net benefits	mn USD	-9'458	16'100	18'404

4- Results – Adaptation scenario – Water (1/2)

- After 2025, the introduction of drip irrigation reduces irrigation water demand by 16.7%.
- Additional investments in the range of USD 6.0 billion and USD 6.7 billion are required to realize the ambition.
- Estimated annual water savings:
 - Mozambique: 871.9 billion m³ / year
 - Uganda: 226.9 billion m³ / year
 - Cameroon: 48.1 billion m³ / year
- If water savings are used to irrigate additional cropland, the total amount of cropland could be increased by between 12.8% and 14.4%.



4- Results – Adaptation scenario – Water (2/2)

- Implementing irrigation reduces irrigation water demand by 16.7%.
- Cumulative water savings between 2018 and 2050
 - Mozambique: 27.9 trillion m3
 - Uganda: 7.3 trillion m3
 - Cameroon: 1.5 trillion m3
- It is difficult to assess the value of the obtained water savings.
 - Water efficiency could be driven by the need to ensure minimum environmental flows, provide more water for population and livestock, or to increase agriculture land productivity.

Water demand for irrigation	Unit	2018-2020	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
Mozambique Adaptation	mn m3	11'219.15	10'931.26	11'105.33	11'769.28	12'589.44	13'143.52	13'578.99
Mozambique Climate	mn m3	11'469.74	12'228.40	13'329.00	14'125.89	15'110.27	15'775.31	16'297.97
Adaptation vs Climate	%	-2.2%	-10.6%	-16.7%	-16.7%	-16.7%	-16.7%	-16.7%
Uganda Adaptation	mn m3	3'281.86	3'006.64	3'597.41	3'408.91	2'701.96	3'800.94	2'721.96
Uganda Climate	mn m3	3'356.94	3'354.79	4'317.73	4'091.49	3'242.99	4'562.01	3'266.99
Adaptation vs Climate	%	-2.2%	-10.4%	-16.7%	-16.7%	-16.7%	-16.7%	-16.7%
Cameroon Adaptation	mn m3	520.43	419.11	216.01	702.53	793.74	850.04	1'041.58
Cameroon Climate	mn m3	534.67	461.86	259.26	843.20	952.68	1'020.24	1'250.14
Adaptation vs Climate	%	-2.7%	-9.3%	-16.7%	-16.7%	-16.7%	-16.7%	-16.7%

4- Integrated CBA – Adaptation scenario (1/2)

- Implementing adaptation measures yields net benefits for Uganda and Cameroon, but incurs losses for Mozambique.
 - The net results for Mozambique are negative due to low value-added agriculture production and high transition costs of the energy sector.
- The analysis indicates that increased energy access yields the highest benefits in terms of GDP.

Category	Unit	Mozambique	Uganda	Cameroon
Investment				
Renewable energy	mn USD	91'209	10'344	20'940
Investments	mn USD	73'693	9'008	15'298
O&M cost	mn USD	17'516	1'335	5'642
Organic agriculture	mn USD	6'506	6'731	6'248
Irrigation	mn USD	6'439	6'669	5'987
Investments in drip irrigation	mn USD	4'599	4'766	4'218
O&M irrigation	mn USD	1'840	1'904	1'768
Total investment and costs	mn USD	104'153	23'744	33'174
Avoided costs				
Conventional energy	mn USD	41'857	5'880	14'260
Investments	mn USD	26'298	4'309	8'279
O&M cost	mn USD	15'559	1'570	5'981
Total avoided costs	mn USD	41'857	5'880	14'260
Added benefits				
Labor income energy	mn USD	20'986	5	1.4
Agriculture GDP	mn USD	2'242	3'657	6'116
GDP from access to energy	mn USD	1'731	14'279	112'842
GDP from additional land	mn USD	5'652	6'998	10'037
Total added benefits	mn USD	30'611	24'940	128'996
Net benefits	bn LCU*	-31'685	7'075	110'082

4- Integrated CBA – Adaptation scenario (2/2)

Category	Unit	Mozambique	Uganda	Cameroon
<u>Investment</u>				
Renewable energy	mn USD	91'209	10'344	20'940
Investments	mn USD	73'693	9'008	15'298
O&M cost	mn USD	17'516	1'335	5'642
Organic agriculture	mn USD	6'506	6'731	6'248
Irrigation	mn USD	6'439	6'669	5'987
Investments in drip irrigation	mn USD	4'599	4'766	4'218
O&M irrigation	mn USD	1'840	1'904	1'768
Total investment and costs	mn USD	104'153	23'744	33'174
<u>Avoided costs</u>				
Conventional energy	mn USD	41'857	5'880	14'260
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GDP from additional land	mn USD	5'652	6'998	10'037
Total added benefits	mn USD	30'611	24'940	128'996
Net benefits	bn LGU*	21'685	7'075	110'022

4- The Food-Water-Energy Nexus – Insights

- The analysis shows that including climate impacts in simulations has significant impacts on sectoral performance and costs
- Adaptation to climate change, to improve resilience, holds potential for both reducing the impacts of climate change and improve the baseline
- The simulation of adaptation measures indicated not only the potential to reduce costs, but the possibility to generate net benefits
- What is most interesting in the context of the nexus approach is that several synergies emerge when linking together the agriculture, energy and water models

4- The Food-Water-Energy Nexus – Synergies

- The following synergies between sectoral adaptation measures have been revealed
 - Organic farming practices increase the resilience of the sector to climate impacts. They benefit agriculture productivity, which contributes to food security. Higher labor requirements increase employment and labor income, and support poverty alleviation.
 - Implementing drip irrigation reduces water stress by lowering irrigation water demand. The implementation of drip irrigation reduces pressures on water resources, makes water available for other purposes, and increases the resilience of the agriculture sector.
 - Increasing renewable power generation, increases access to energy and contributes to energy security. This results in higher total factor productivity and hence higher GDP growth. In addition, higher labor requirements of renewables generate employment and labor income, and support poverty alleviation.

4- Summary

- The model captures sectoral performance on social, economic and environmental
- Including climate variations in the analysis has cascading effects through all sectors
- The performance of the system changes depending on its resilience to climate impacts
- The analysis indicates net benefits from implementing adaptation measures.
 - However, policy effectiveness has to be assessed considering the local context; across sectors, actors, over time and space

4- Policy recommendations

1. Incentivize the use of systemic planning, across sectors and including social, economic and environmental indicators of performance.
2. Use a multi-stakeholder approach, to ensure that all key indicators are considered and that policies are formulated and implemented effectively
3. Support the development of new quantitative models that implement knowledge integration across disciplines, and fully account for climate science
4. Increase investment in the collection, processing and use of weather information, including early warning systems
5. Invest in Climate Information Services, also to disseminate information in a timely manner
6. Require the preparation of integrated economic analysis

Thank you!

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