System of
Environmental
Economic
Accounting

Introduction to ecosystem services and biophysical modelling for ecosystem accounting

Online course of the Regional Training Programme on the SEEA Experimental Ecosystem Accounting

24 September 2019

Dr. Andrea M. Bassi
Senior Affiliate, International Institute for Sustainable Development (IISD)
Founder and CEO, KnowlEdge Srl
Extraordinary Associate Professor, Stellenbosch University

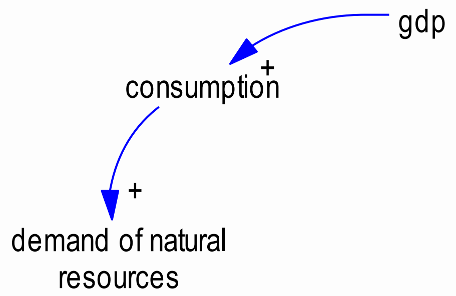
United Nations

Overview

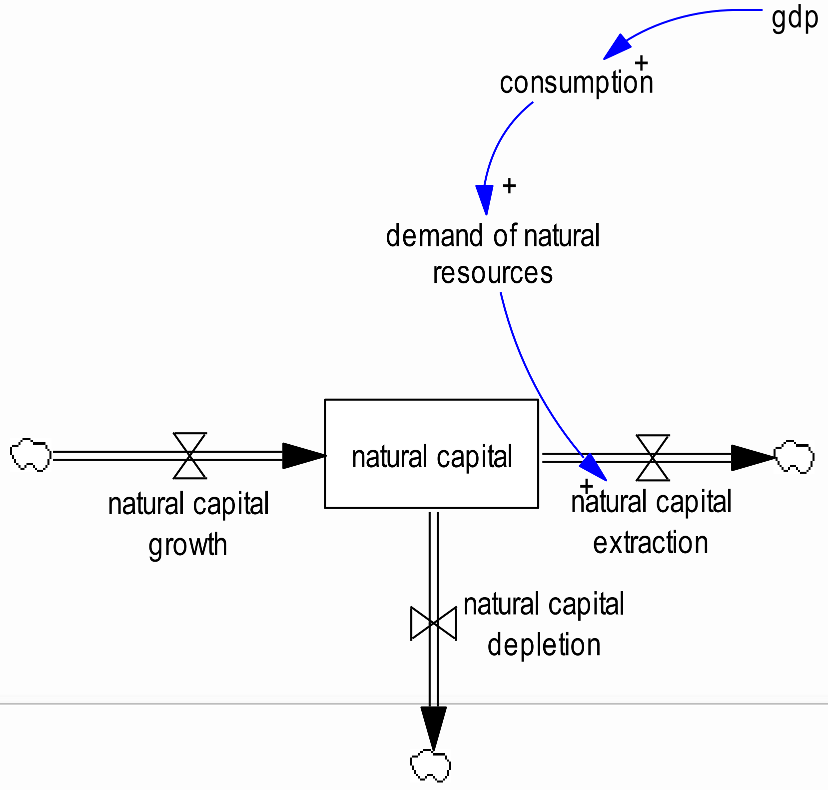
- Sustainable development, an integrated approach
- Introduction to ecosystem services
- Models for the estimation of ecosystem services
- What model to use?
- Example

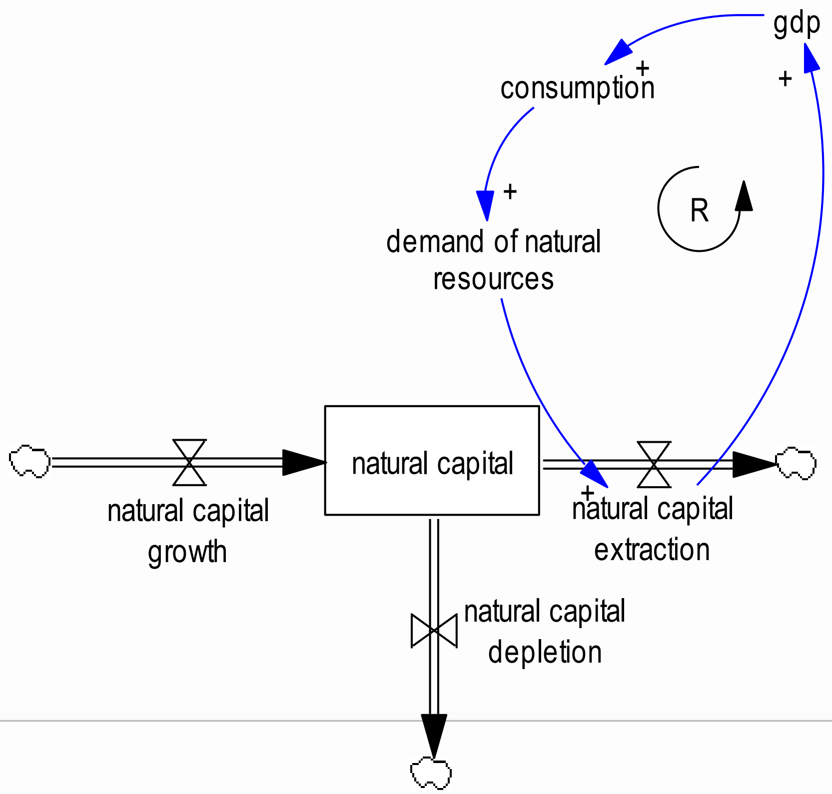
Sustainable development, an integrated approach

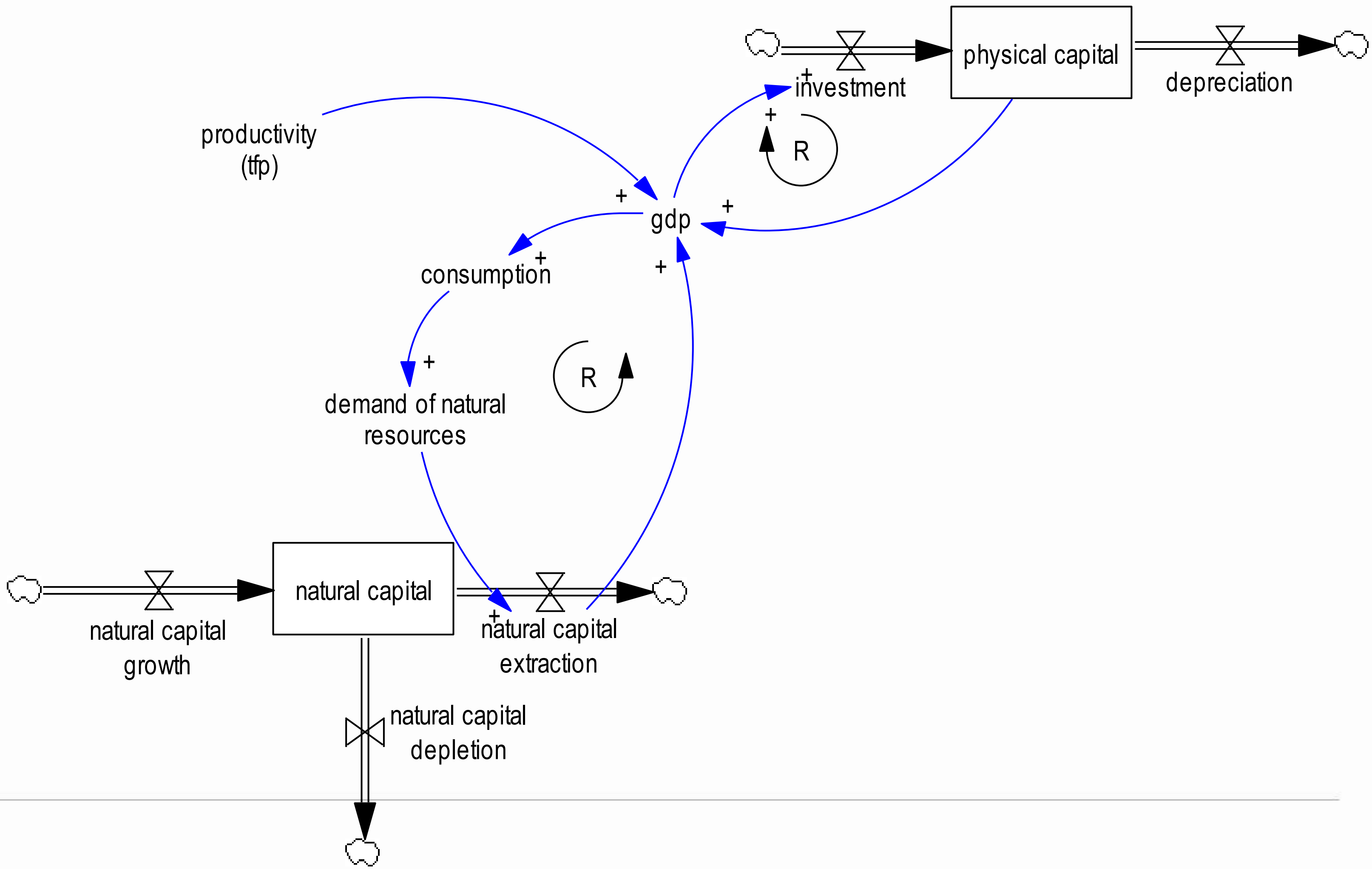
gdp

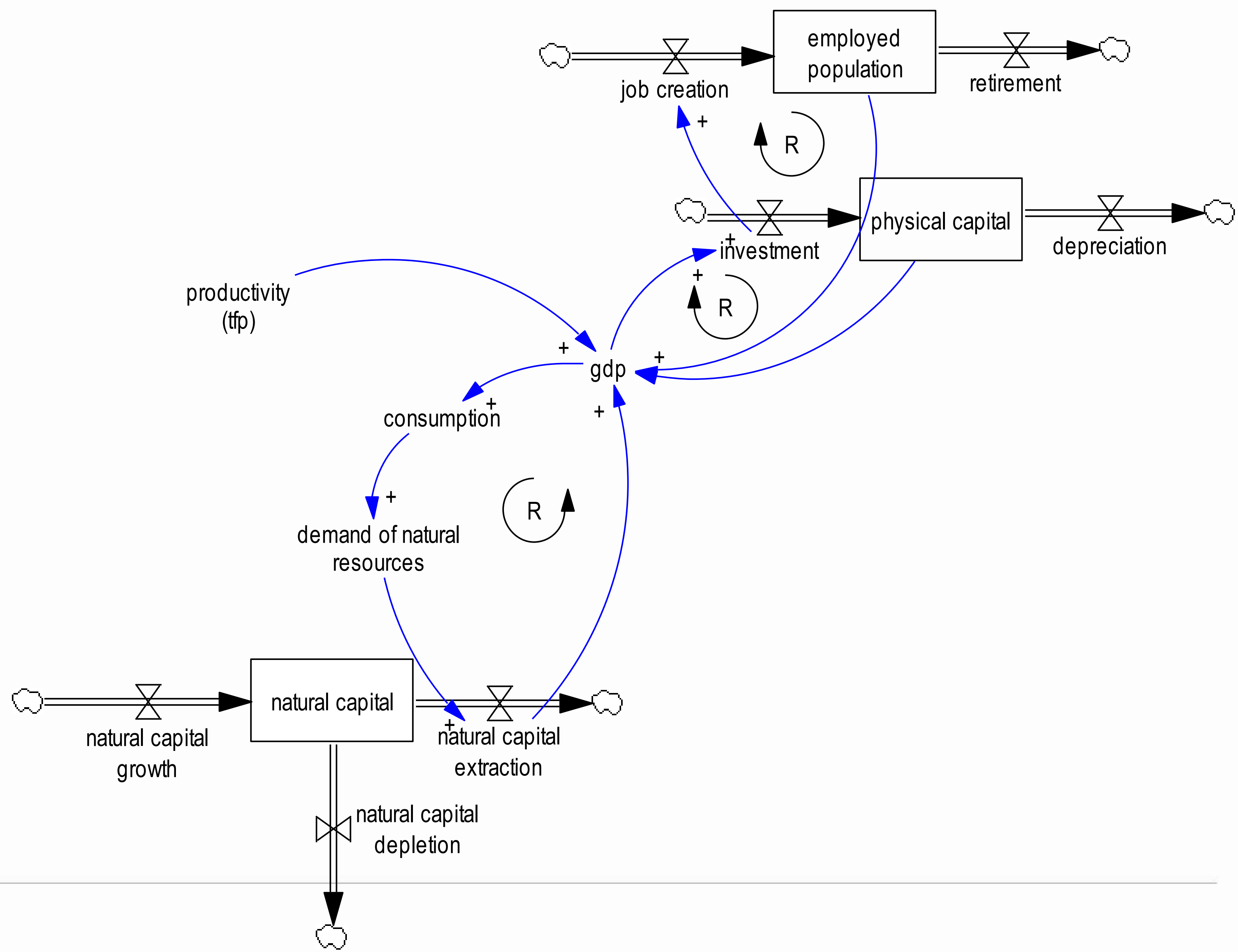


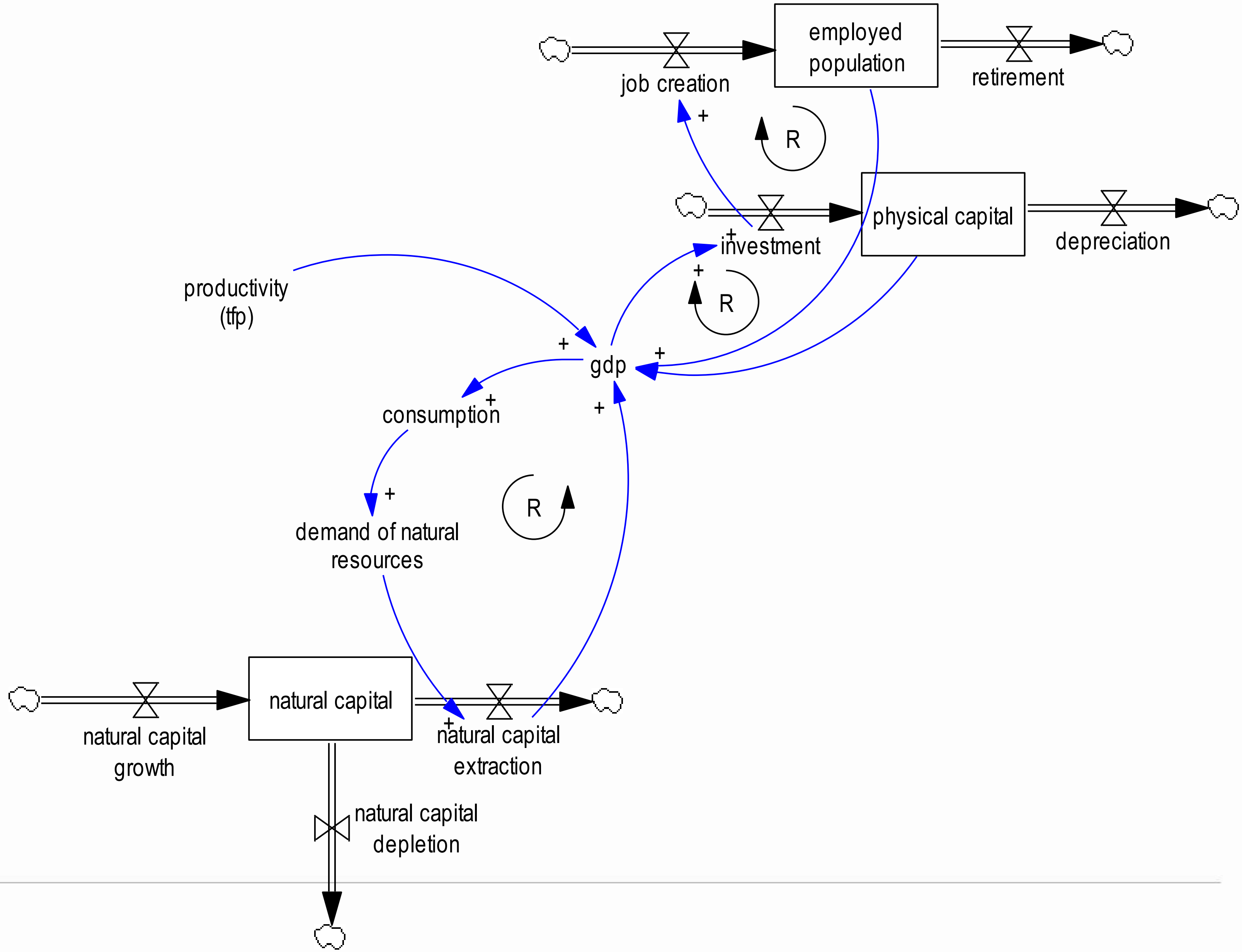
SEEA


gdp
consumption
+
+
demand of natural resources
natural capital
+
natural capital growth
natural capital extraction
natural capital depletion

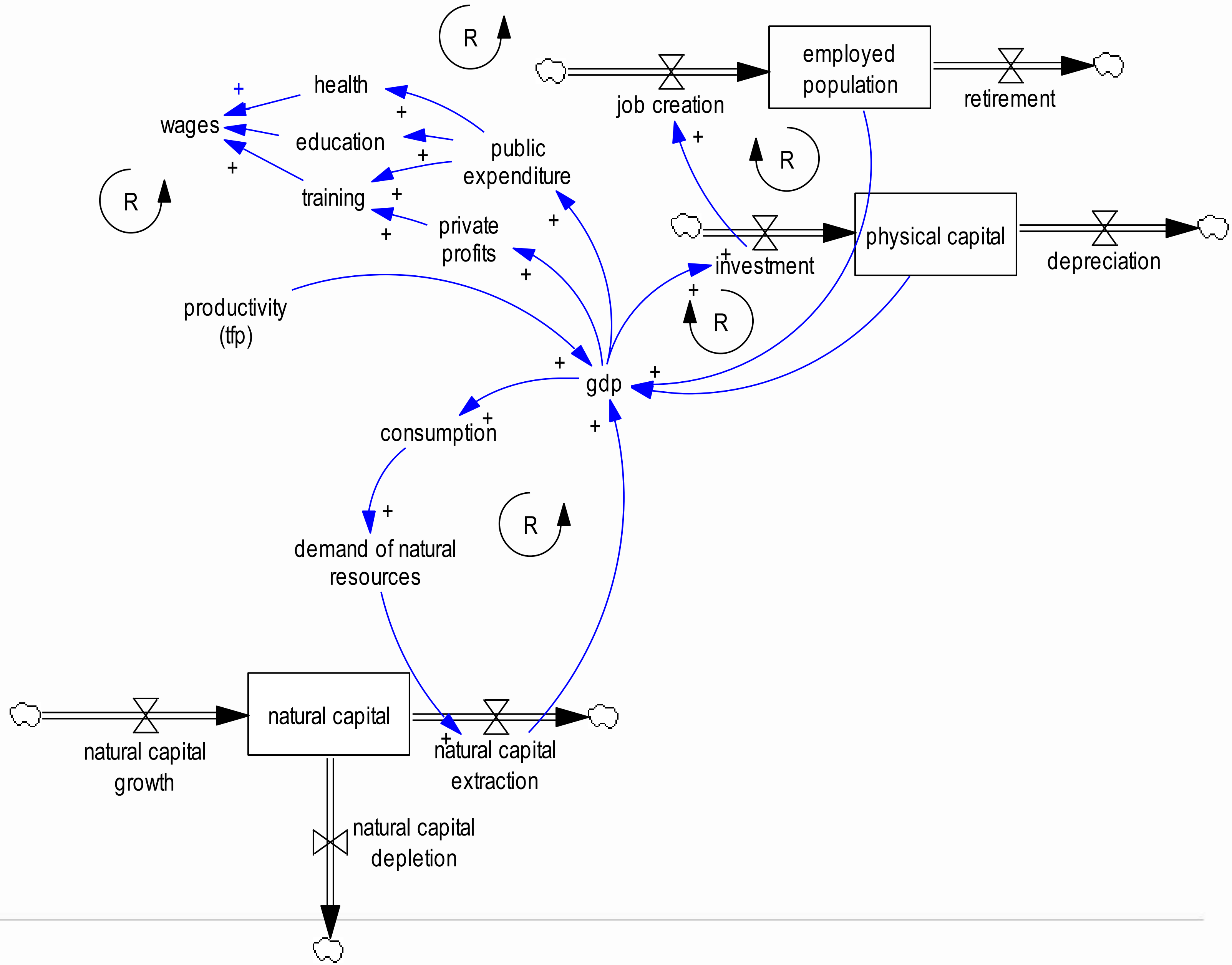

gdp
+
+
consumption
+
demand of natural resources
R
natural capital
natural capital growth
+
natural capital extraction
natural capital depletion


physical capital
investment
depreciation
productivity
(tfp)
gdp
R
consumption
demand of natural
resources
R
natural capital
natural capital
growth
natural capital
extraction
natural capital
depletion
+

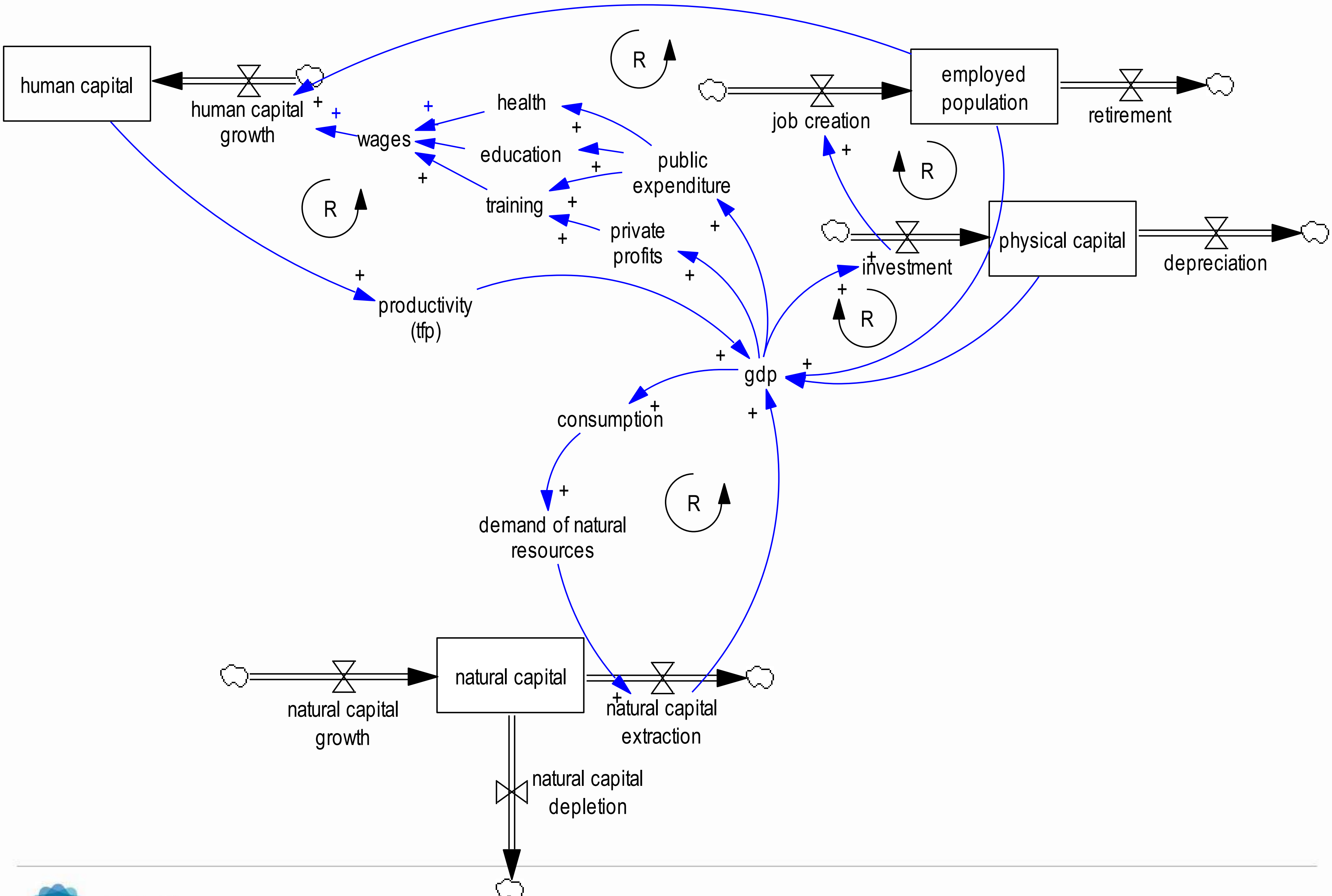

employed population
job creation
retirement
R
physical capital
investment
depreciation
R
productivity (tfp)
gdp
consumption
R
demand of natural resources
natural capital
natural capital growth
natural capital extraction
natural capital depletion
+


employed population
job creation
retirement
physical capital
investment
depreciation
productivity (tfp)
gdp
consumption
demand of natural resources
natural capital
natural capital growth
natural capital extraction
natural capital depletion
R
R
R
+

SEEA

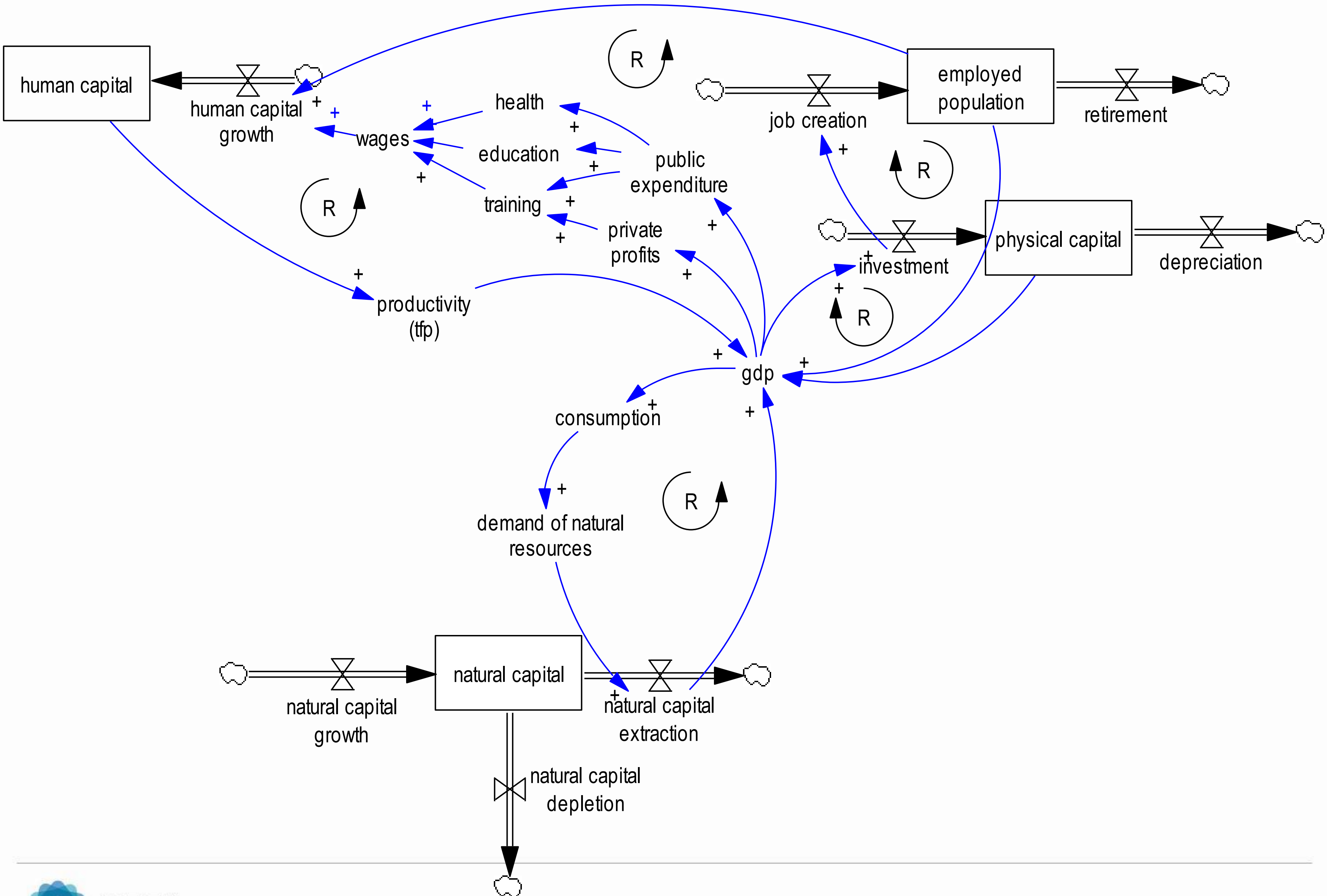

R
employed population
job creation
retirement
health
wages
education
public expenditure
training
R
private profits
R
physical capital
investment
depreciation
productivity (tfp)
R
gdp
consumption
demand of natural resources
R
natural capital
natural capital growth
natural capital extraction
natural capital depletion

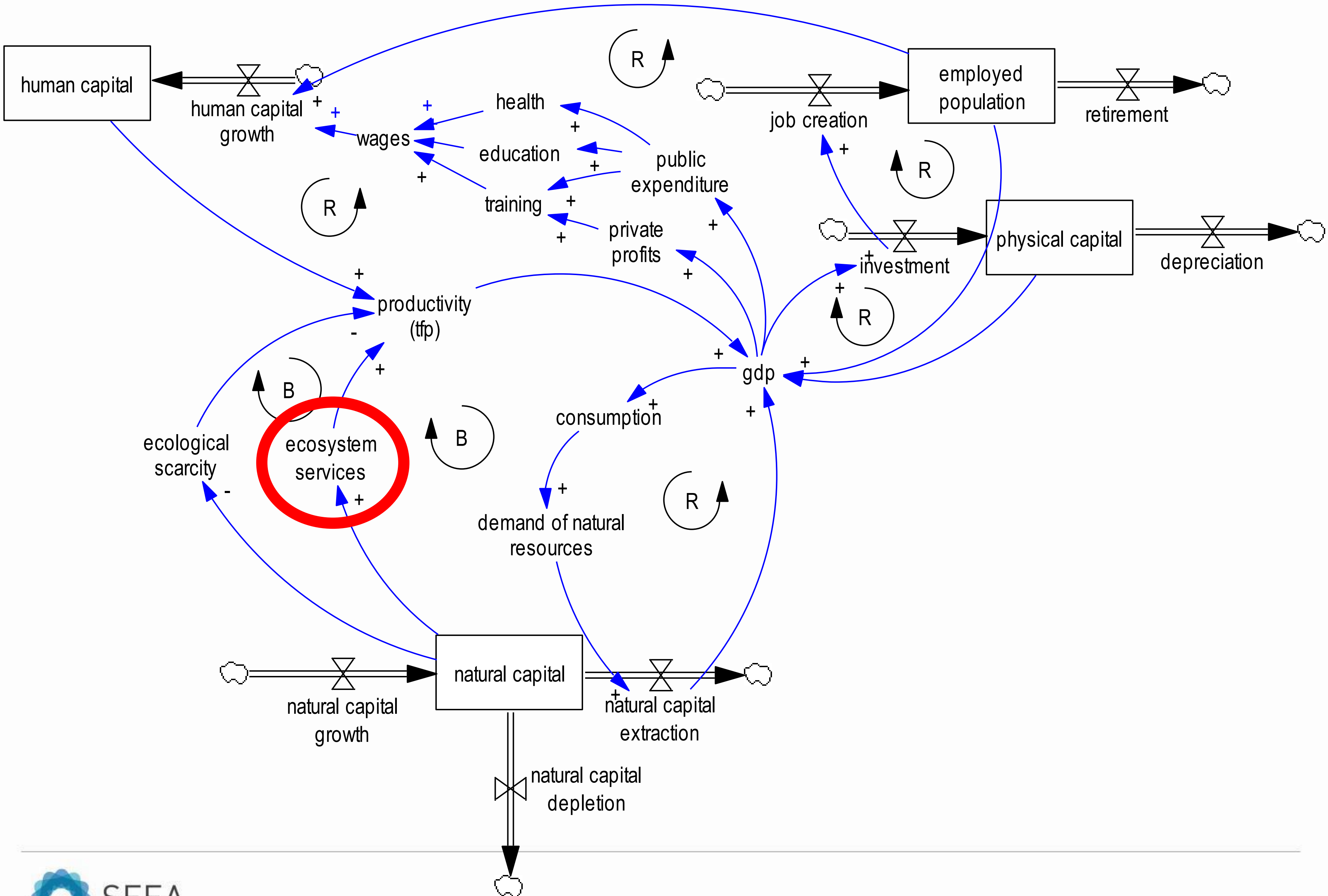
SEEA



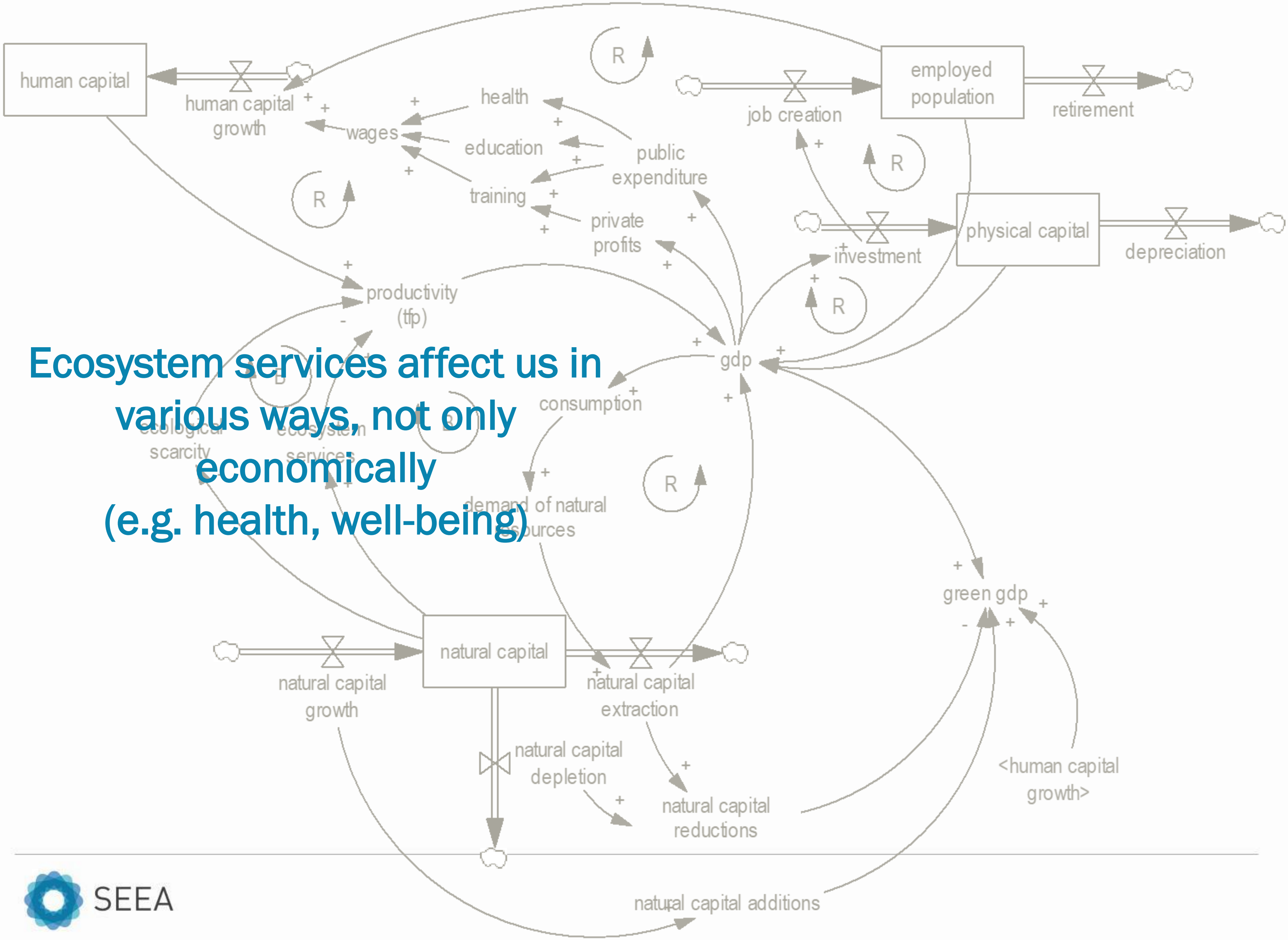
human capital
human capital growth
wages
health
education
training
public expenditure
private profits
productivity (tfp)
R
R
R
R
R
employed population
retirement
job creation
physical capital
depreciation
investment
gdp
consumption
demand of natural resources
natural capital
natural capital growth
natural capital extraction
natural capital depletion

SEEA

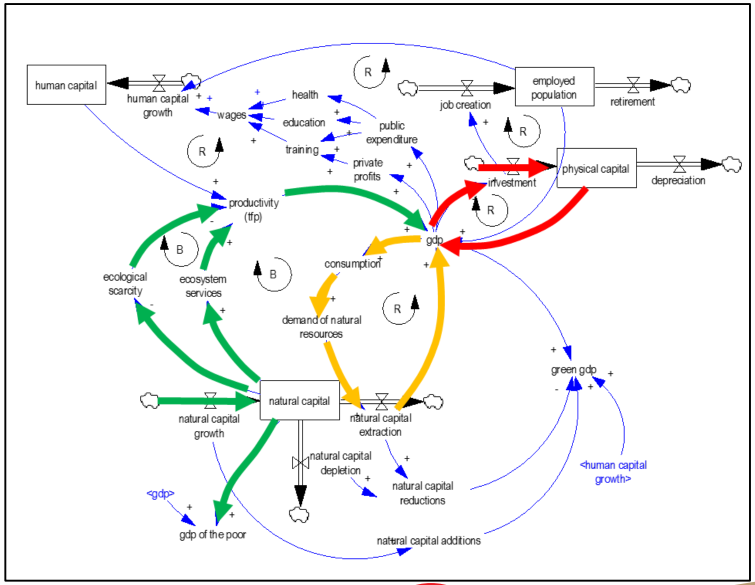

human capital
human capital growth
wages
health
education
training
public expenditure
private profits
productivity (tfp)
employed population
job creation
retirement
physical capital
investment
depreciation
gdp
consumption
demand of natural resources
natural capital
natural capital growth
natural capital extraction
natural capital depletion
R
R
R
R
R
+

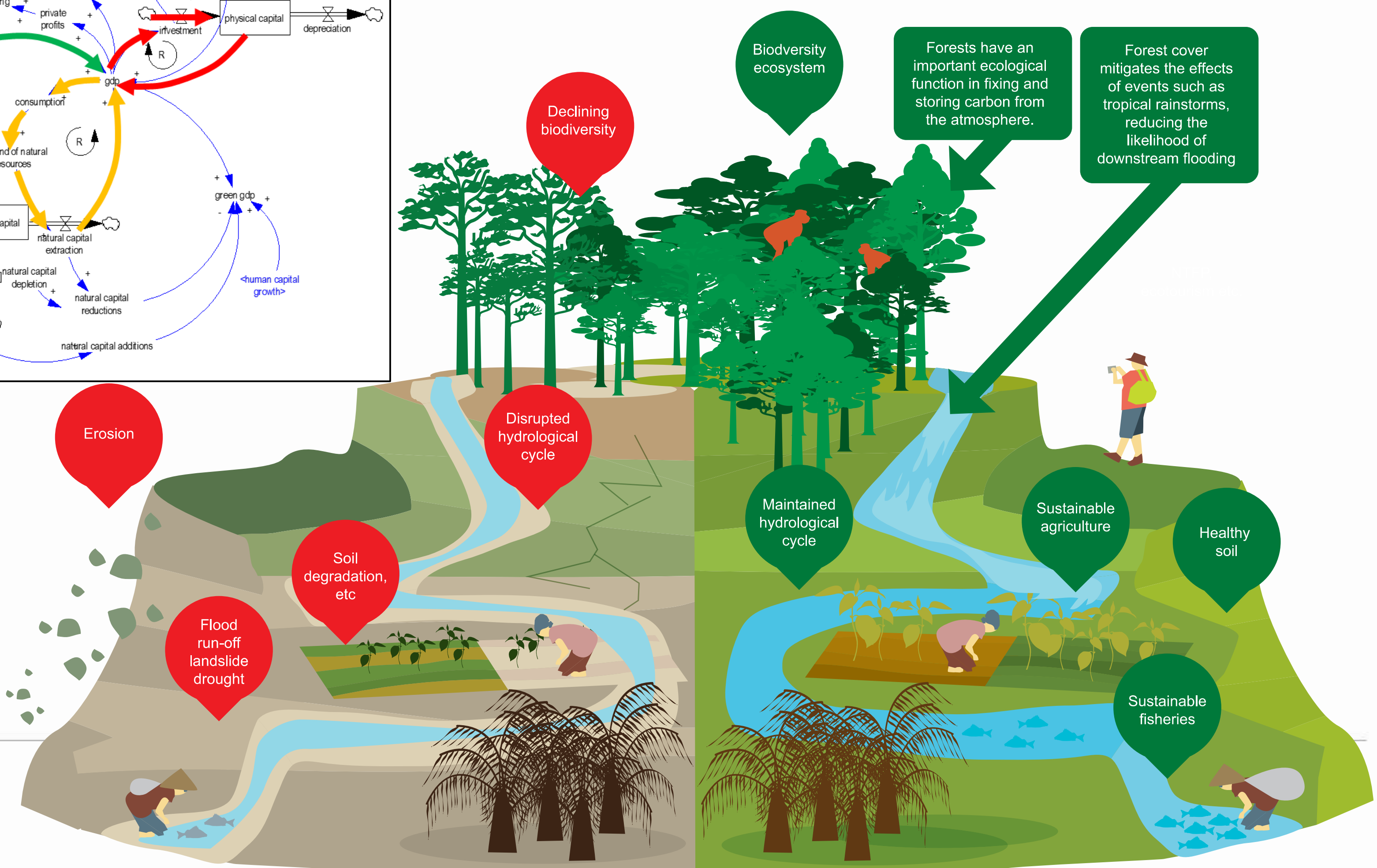

human capital
human capital growth
wages
health
education
training
public expenditure
private profits
employed population
job creation
retirement
physical capital
investment
depreciation
productivity (tfp)
gdp
consumption
demand of natural resources
ecological scarcity
ecosystem services
natural capital
natural capital growth
natural capital extraction
natural capital depletion
R
B
+
-

Ecosystem services affect us in various ways, not only economically
(e.g. health, well-being)



Sustainable development, an integrated approach





SEEA

What is an ecosystem?

"Dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit"
(UN Convention on Biological Diversity)

Note:

- Definition is independent of spatial scale
- Ecosystems are inevitably interconnected or overlapping
- The scale of analysis depends on the relationships we want to study

Ecosystem Assets

- Spatial area comprised of characteristics that are fundamental to analysis of ecosystems, such as:
  - Stocks and changes in stocks (extent and condition)
  - “Operational” characteristics of an ecosystem asset
    - Structure (e.g. food web)
    - Composition (biotic and abiotic components)
    - Processes (e.g. photosynthesis)
    - Functions (e.g. resilience)
- Contrast with “individual resources”

Ecosystem Condition

- Overall quality of an ecosystem asset, in terms of its characteristics
  - Land cover, biodiversity, spatial extent, soil type, freshwater, altitude and slope, climate
- Condition (along with ecosystem extent) reflects changes to expected future flows of ecosystem services (capacity)
- Need to prioritize most relevant characteristics first

Ecosystem Services

"… the contributions of ecosystems to benefits used in economic and other human activity" (TEEB, 2010)

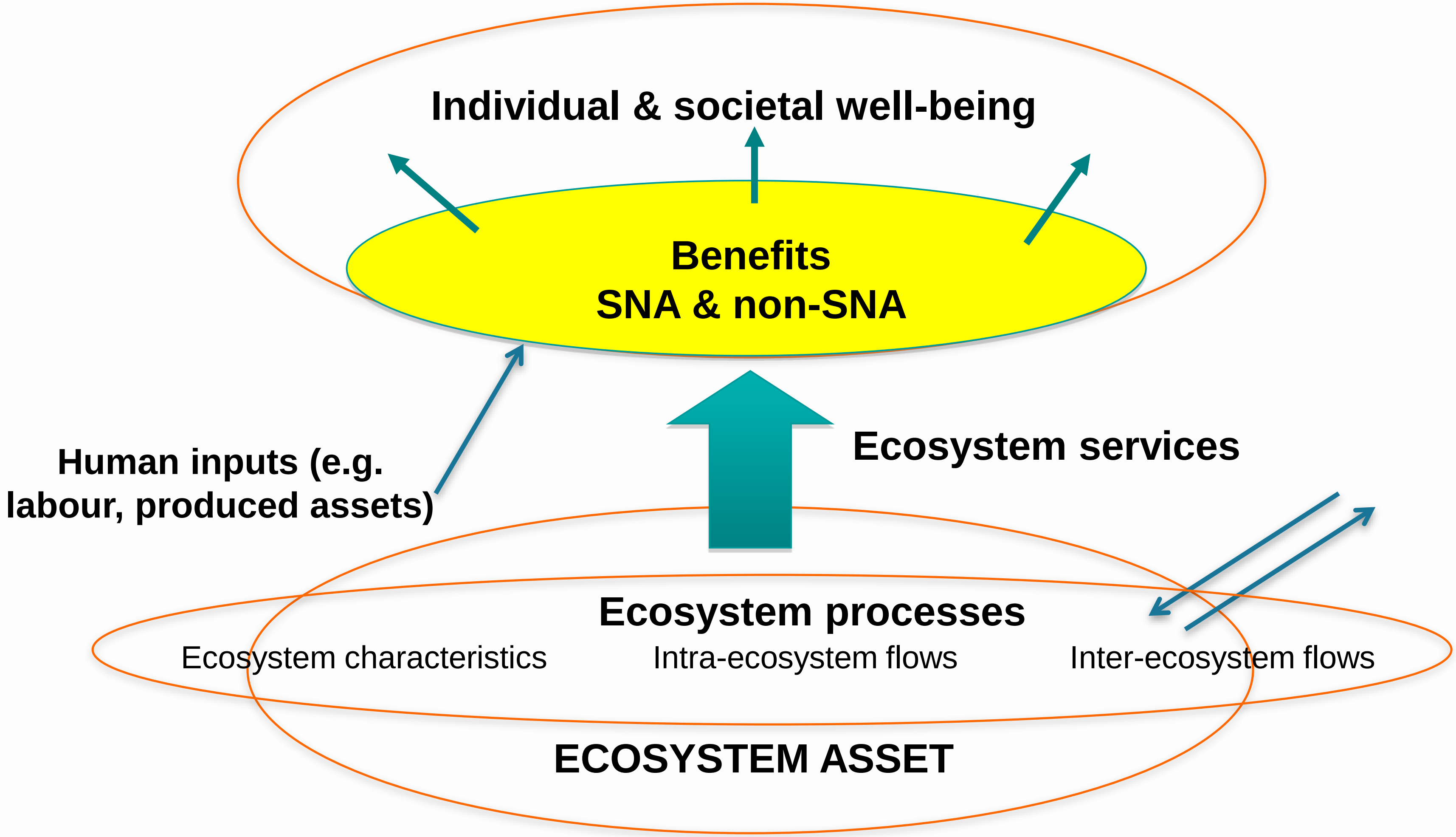
• "Contributions" because ecosystem services can be combined with other inputs (e.g. economic infrastructure) to provide benefits

• In some cases the contributions may be equivalent to the benefit (where there are negligible other inputs)

• Not all flows from the environment are ecosystem services

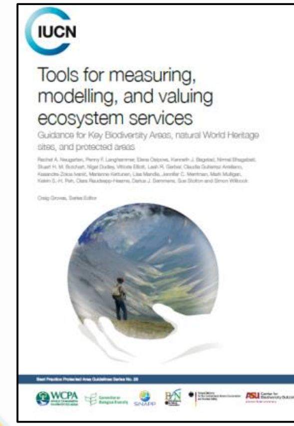
- Excludes extracted minerals
- Presence of human beneficiaries necessary

Ecosystem Services as Flows From Ecosystem Assets



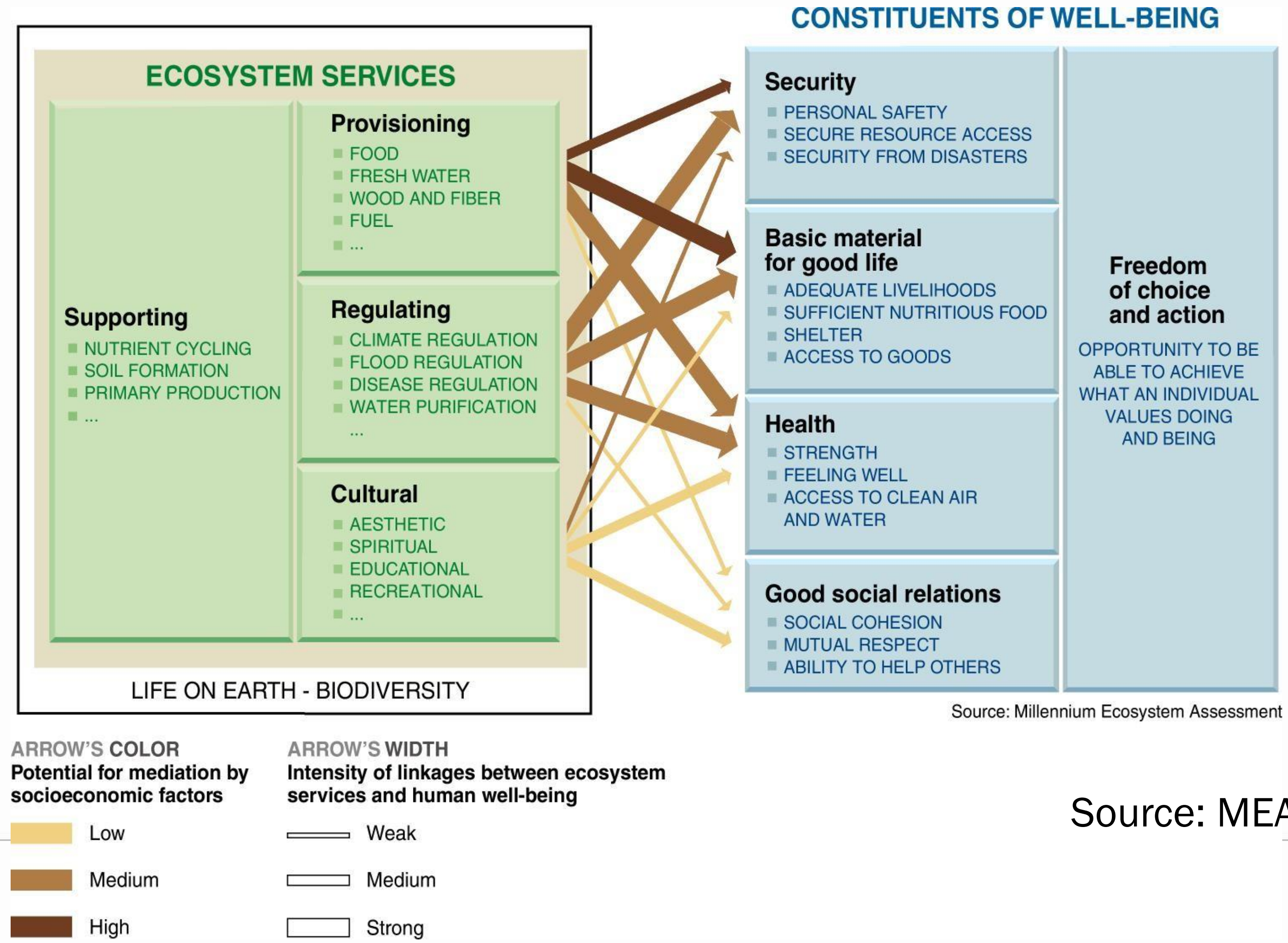
SEEA

Types of ecosystem services



Provisioning Services	= goods that can be harvested from, or extracted from ecosystems	Example: providing fish for fisheries, or providing wood for timber harvest
Regulating Services	= the regulation of climate, hydrological, ecological and soil processes	Example: pollination, carbon sequestration, flood control
Cultural Services	= the non-material benefits provided by ecosystems	Example: recreation, tourism, providing a setting for cultural or religious practices

Ecosystem Change and Human Well-being

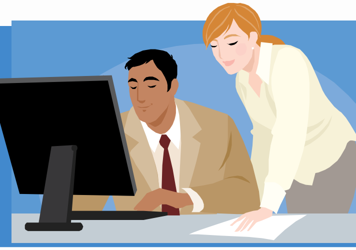


Source: MEA

SEEA

Modeling approaches

Policy level



Systems Model

Science & analytics

Environ-mental models

Human health models

Economic models

Implemen-tation

Detailed place-based model

Detailed place-based model

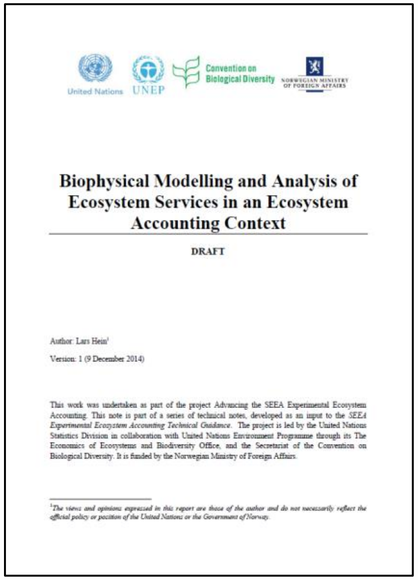
Detailed models

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

What are ecosystem service models?

- Models, and hence a simplified representations of reality
- Represent the processes in ecosystems that result in services
- These processes can be captured by sets of equations or proxy variables
- In most cases focused on creating spatial outputs

What are ecosystem service models?


United Nations UNEP Convention on Biological Diversity NORWEGIAN MINISTRY OF FOREIGN AFFAIRS

Biophysical Modelling and Analysis of Ecosystem Services in an Ecosystem Accounting Context

DRAFT

Author: Lars Hein[1]

Version: 1 (9 December 2014)

This work was undertaken as part of the project Advancing the SEEA Experimental Ecosystem Accounting. This note is part of a series of technical notes, developed as an input to the *SEEA Experimental Ecosystem Accounting Technical Guidance*. The project is led by the United Nations Statistics Division in collaboration with United Nations Environment Programme through its The Economics of Ecosystems and Biodiversity Office, and the Secretariat of the Convention on Biological Diversity. It is funded by the Norwegian Ministry of Foreign Affairs.

[1] *The views and opinions expressed in this report are those of the author and do not necessarily reflect the official policy or position of the United Nations or the Government of Norway.*

- Spatial modelling to produce maps of ecosystem services.
- In the case of data gaps, spatial interpolation and/or modelling techniques can be used.
- Various datasets can be used (e.g. remote sensing images, thematic maps, surveys for specific administrative or ecological units, and point data from specific studies).
- These datasets have to be spatially defined.

Model types

- There are a range of spatial modeling tools available for the modelling of ecosystem services.
- Two main approaches:
  - *Simple*: “Look-up Tables” approach or “proxy-based”, based on multipliers and statistical approaches.
  - *Complex* (static or dynamics): process-based models. Represent ecological processes to estimate ecosystem service provision based on a specific land cover / land use map and other data inputs (e.g. topography).

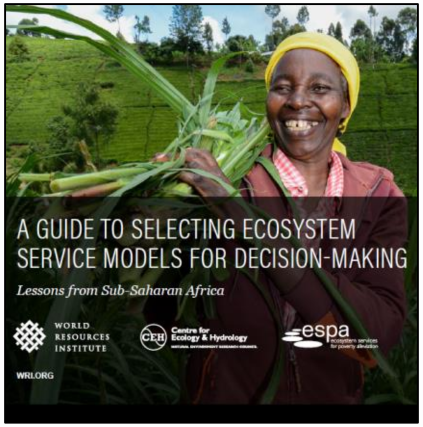
Look up table – proxy-based

- Specific values for an ecosystem service are attributed to every pixel in a certain class, usually a land cover or land use class.
- Makes use of various sources, and it is a form of knowledge integration.
- Ultimately quality of estimation based on the quality of land cover maps, similarity of conditions between study area and source of information.

Process-based

- Forecast values for a specified ecosystem service based on how one or more environmental variables affect the value of that service.
- This is done using equations (assumed relationships).
- “Value” can be a measure of a relevant environmental variable (e.g., tons of carbon or liters of water), the monetary or nonmonetary value to humans, or a measure of use of the service by people.

Examples



ARIES (aries.integratedmodelling.org)

- An open-source technology that can select and run models to quantify and map ecosystem services, including physical generation, flow, and extraction by beneficiaries.

Co$ting Nature (http://www.policysupport.org/costingnature)

- A web-based series of interactive maps that defines the contribution of ecosystems to the global reservoir of a particular ecosystem service and its realizable value (based on flows to beneficiaries of that service).

InVEST (www.naturalcapitalproject.org/invest/)

- A suite of free, open-source software models from the Natural Capital Project used to map and value the goods and services from nature. InVEST returns results in either biophysical or economic terms.

Many other models are available, e.g. Multiscale Integrated models for Ecosystem Services (**MIMES**), Social Value for Ecosystem Services (**SolVES**), Land Utilization and Capability Indicators (**LUCI**).

See: http://aboutvalues.net/method_database/

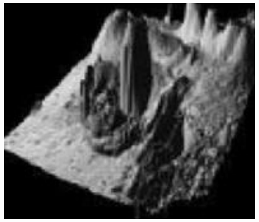
InVEST
integrated valuation of environmental services and tradeoffs

Sediment retention model

Biophysical inputs

Land use/Land cover

+ associated factors affecting soil loss and retention



Slope

Rainfall erosivity

Soil erodibility

Streams

Watersheds

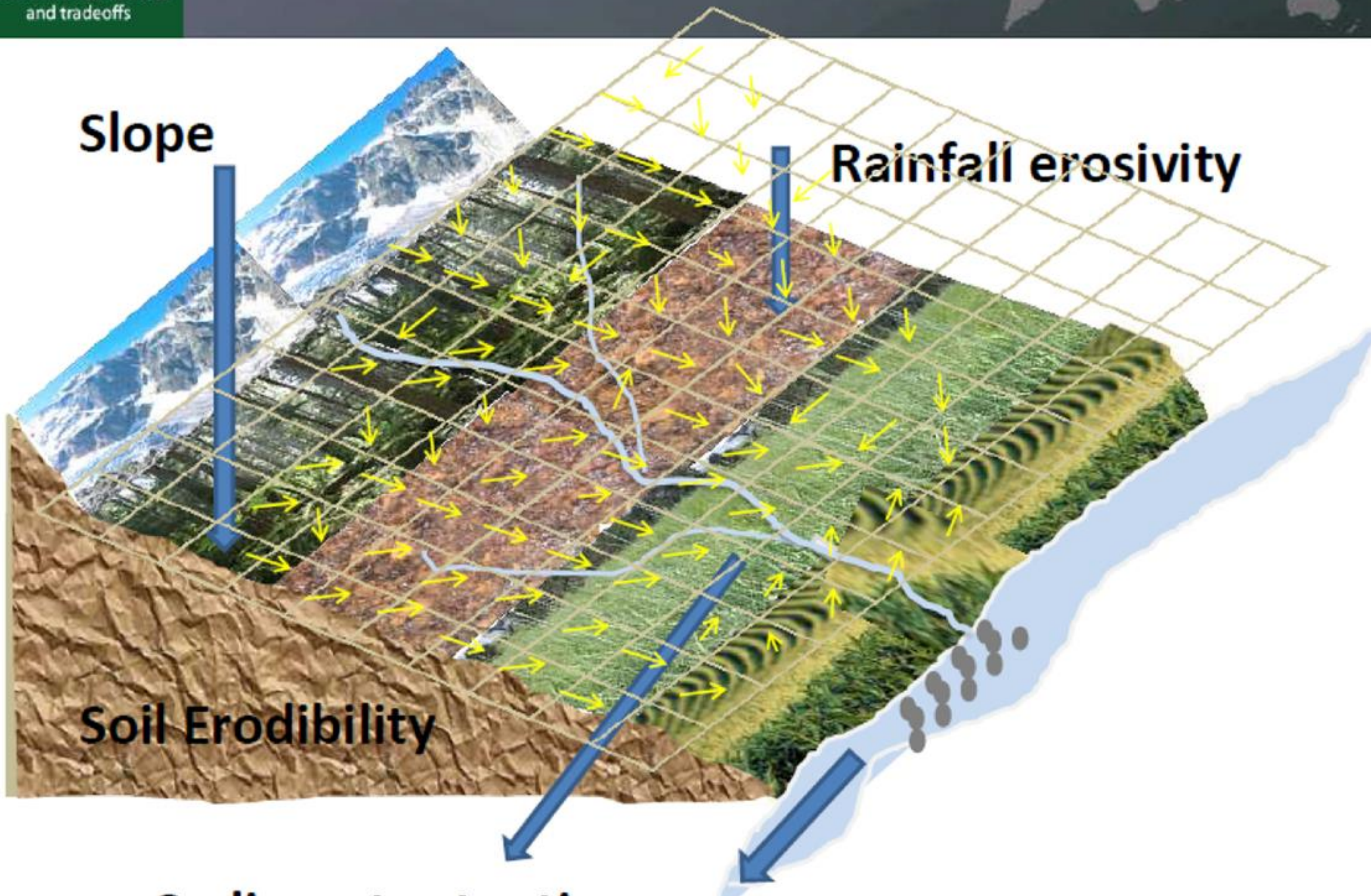
Sediment thresholds

(of reservoirs or water quality requirements)

InVEST

integrated valuation of environmental services and tradeoffs

Sediment retention model



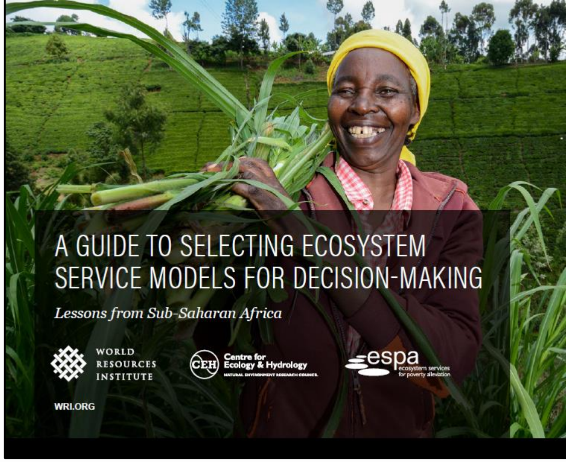
Sediment retention model

Routed Universal Soil Loss Equation

$$SED_{xD} = \overbrace{\left(R_x \cdot K_x \cdot LS_x \cdot \left(1 - C_x \cdot P_x\right)\right)}^{\text{Sediment held in place by vegetation}} + \left(\overbrace{SE_x \sum_{y=1}^{x-1} USLE_y \prod_{z=y+1}^{x-1} (1 - SE_z)}^{\text{Upslope sediment trapped by vegetation}} \right)$$

R_x rainfall erosivity
K_x soil erodibility
LS_x slope length factor
C_x crop or vegetation factor
P_x support practice factor
SE_x sediment retention
$USLE_y$ RKSLCP of upslope pixels
SE_z sediment retention efficiency of downslope pixels

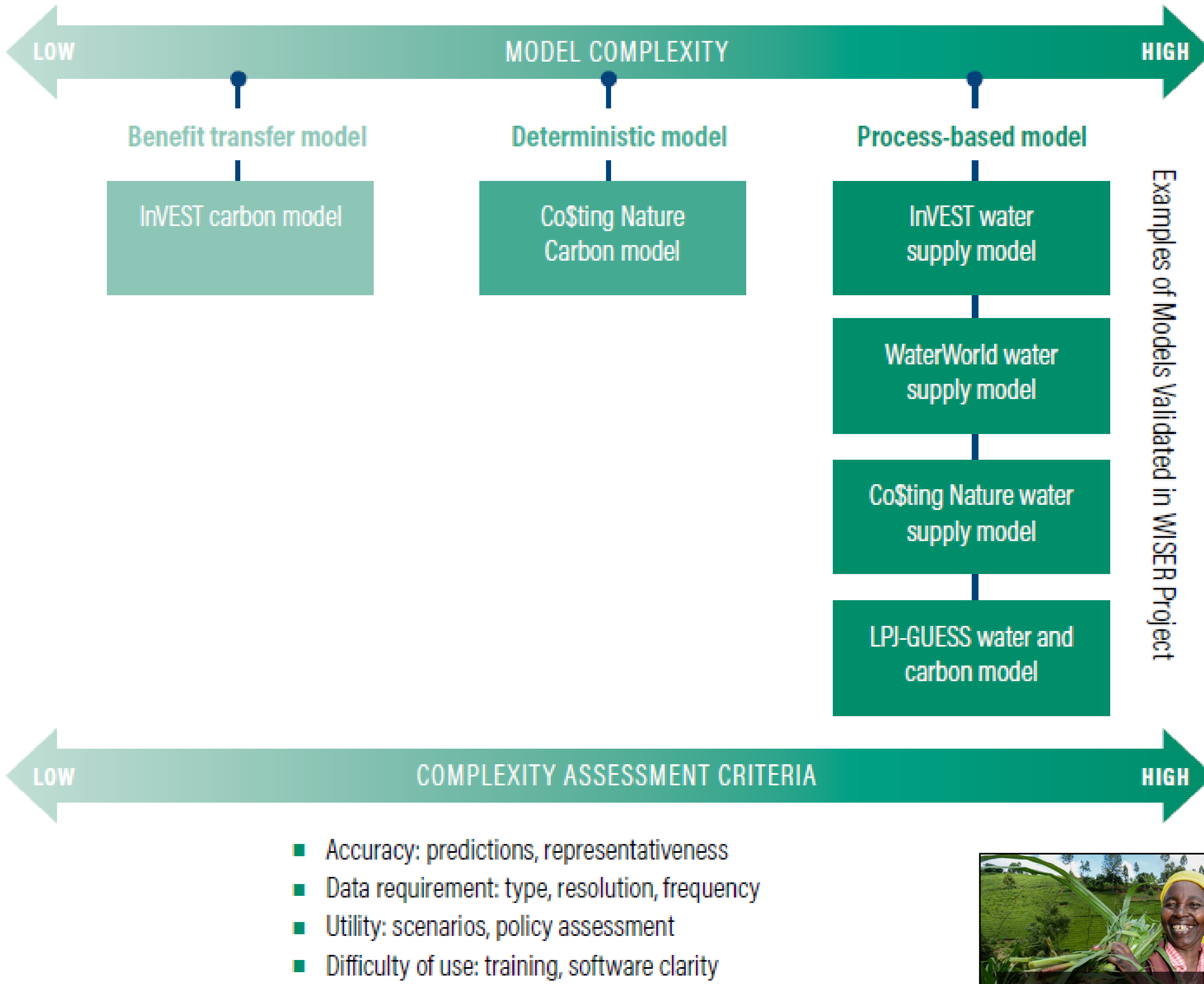
What model to use?



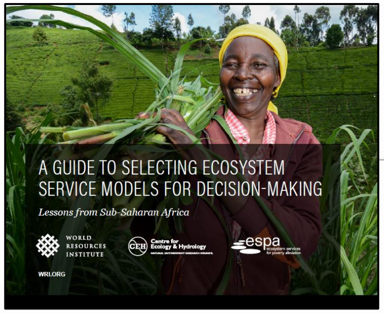
WRI, CEH and ESPA (2018) propose
5 steps to help decide which model to use:

- **Step 1.** Determine the policy questions and scope of the research.
- **Step 2.** Consider the decision-making context.
- **Step 3.** Evaluate ecosystem service models in the decision-making context.
- **Step 4.** Reassess your data resources and modeling capacity.
- **Step 5.** Choose the most appropriate model.

Figure C1 | Schematic of the Characteristics of Less- vs. More- Complex Models



Source: WRI authors, adapted from Willcock et al. 2016.



TECHNICAL SKILLS AND MODELING CAPACITY (HIGH)

- **Possible model choice:** LPJ-GUESS
- **Example of policy questions to address:**
  - ✓ Which are the most important locations for delivery of a specific service?
- **Example of policy applications:** Resource conservation and management

- **Possible model choice:** Construction of bespoke models, such as agent-based models or local process models
- **Example of policy questions to address:**
  - ✓ Which are the best actions to maintain specific services under climate change?
  - ✓ How will alternative strategies affect production of ecosystem services and their use by people?
- **Example of policy applications:** Cost-effective climate adaptation policies; UN Sustainable Development Goals

TECHNICAL SKILLS AND MODELING CAPACITY (LOW)

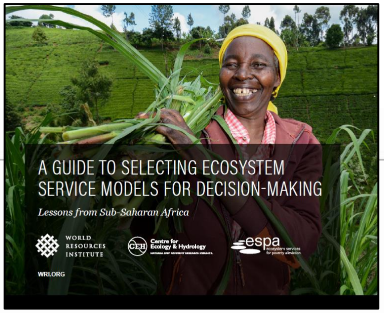
- **Possible model choice:** Benefit Transfer, WaterWorld, Co$ting Nature
- **Example of policy questions to address:**
  - ✓ What is the total economic contribution of each land use class in a region?
- **Example of policy applications:** Estimating value of environmental externality to correct market failure

- **Possible model choice:** InVEST
- **Example of policy questions to address:**
  - ✓ How will a focus on production—e.g. forestry or agriculture—impact other ecosystem services?
- **Example of policy applications:** Evaluating the benefits of landscape restoration interventions

LOW — DATA AND RESOURCE AVAILABILITY — HIGH

Note: See Appendix B for details on the models mentioned.

Source: WRI.



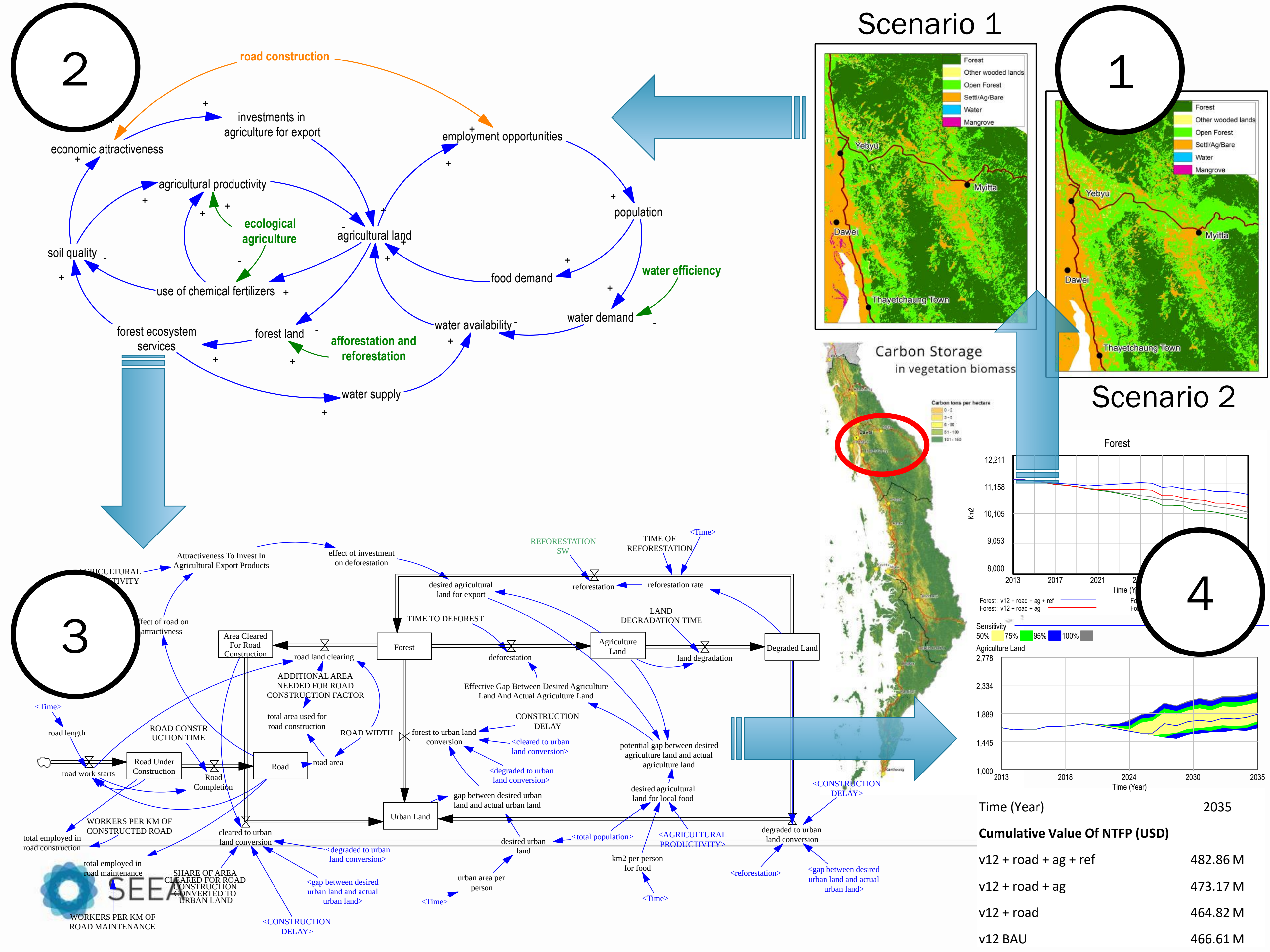
Example: WWF’s ‘Road to Dawei’ Study

The “Road to Dawei” project involves the construction of a road link from Bangkok (Thailand) to Dawei (Myanmar), across the highly biodiverse Dawna Tenasserim Landscape (DTL), and it was conceived under the framework of the “Dawei deep-sea port” project.

Relevant Example: WWF's 'Road to Dawei' Study

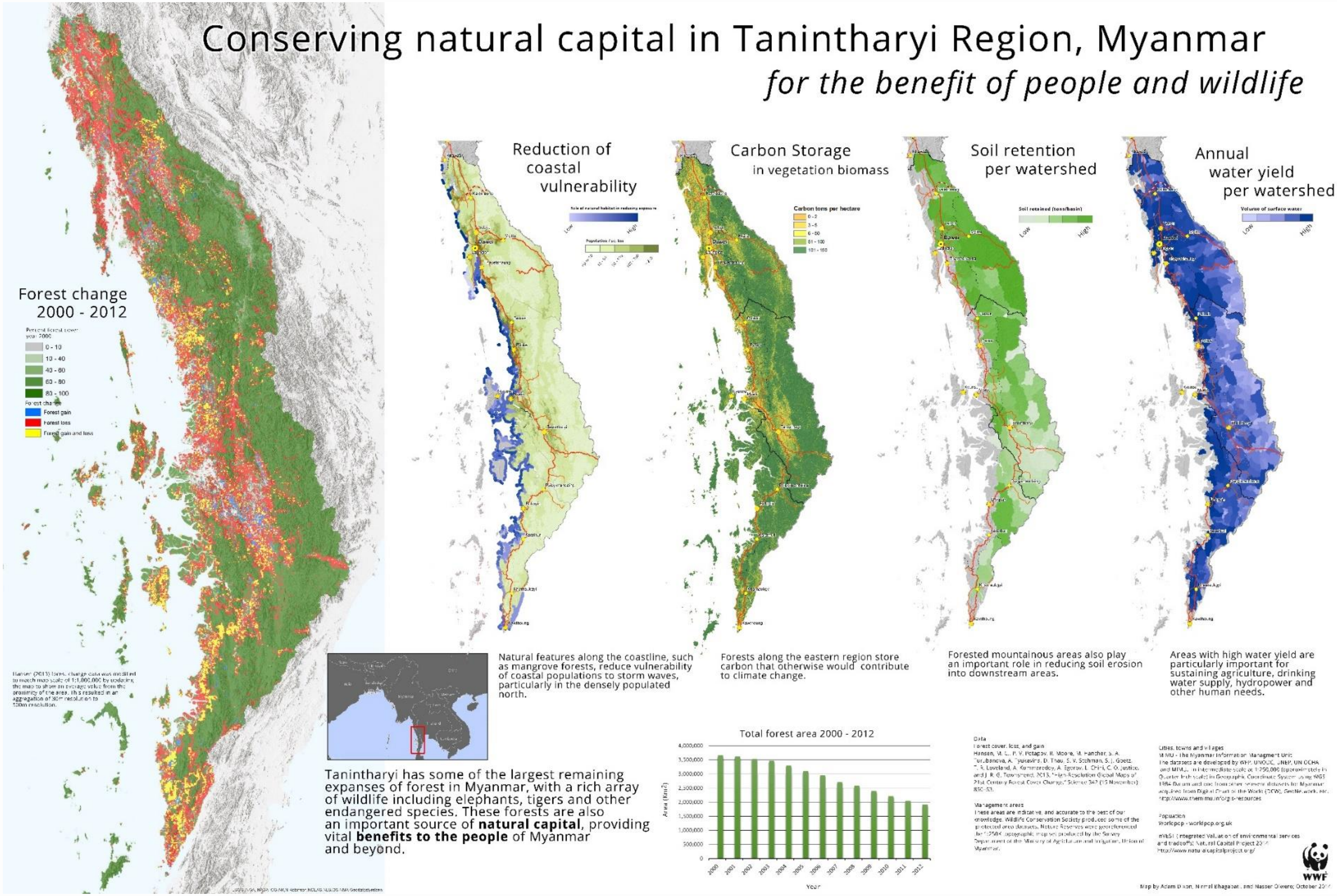
Three methodologies were used:

1. The **InVEST** tool to generate spatial information and estimate changes in natural capital stocks
2. **Causal Loop Diagram** to identify the main drivers and impacts of land use change in the DTL region.
3. The **Integrated Planning for Sustainability (IPS) model** was developed using the System Dynamics methodology, and incorporating the key drivers of land use change and impacts.



2
1
3
4
Scenario 1
Scenario 2
road construction
economic attractiveness
investments in agriculture for export
employment opportunities
agricultural productivity
ecological agriculture
agricultural land
population
soil quality
use of chemical fertilizers
food demand
water efficiency
water demand
forest ecosystem services
forest land
afforestation and reforestation
water availability
water supply
Forest
Other wooded lands
Open Forest
Settl/Ag/Bare
Water
Mangrove
Yebyu
Myitta
Dawei
Thayetchaung Town
Carbon Storage in vegetation biomass
Carbon tons per hectare
Forest
Km2
Time (Year)
Forest : v12 + road + ag + ref
Forest : v12 + road + ag
Sensitivity
50% 75% 95% 100%
Agriculture Land
Time (Year)
Attractiveness To Invest In Agricultural Export Products
effect of investment on deforestation
REFORESTATION SW
TIME OF REFORESTATION
<Time>
desired agricultural land for export
reforestation
reforestation rate
TIME TO DEFOREST
LAND DEGRADATION TIME
effect of road on attractiveness
Area Cleared For Road Construction
road land clearing
Forest
deforestation
Agriculture Land
land degradation
Degraded Land
ADDITIONAL AREA NEEDED FOR ROAD CONSTRUCTION FACTOR
Effective Gap Between Desired Agriculture Land And Actual Agriculture Land
total area used for road construction
CONSTRUCTION DELAY
road length
ROAD CONSTRUCTION TIME
ROAD WIDTH
forest to urban land conversion
<cleared to urban land conversion>
potential gap between desired agricultural land and actual agriculture land
road work starts
Road Under Construction
Road Completion
Road
road area
<degraded to urban land conversion>
gap between desired urban land and actual urban land
desired agricultural land for local food
<CONSTRUCTION DELAY>
WORKERS PER KM OF CONSTRUCTED ROAD
total employed in road construction
cleared to urban land conversion
Urban Land
desired urban land
<total population>
<AGRICULTURAL PRODUCTIVITY>
degraded to urban land conversion
total employed in road maintenance
SHARE OF AREA CLEARED FOR ROAD CONSTRUCTION CONVERTED TO URBAN LAND
<gap between desired urban land and actual urban land>
urban area per person
km2 per person for food
<reforestation>
WORKERS PER KM OF ROAD MAINTENANCE
SEEA
Time (Year) 2035
Cumulative Value Of NTFP (USD)
v12 + road + ag + ref 482.86 M
v12 + road + ag 473.17 M
v12 + road 464.82 M
v12 BAU 466.61 M

System mapping for the ‘Road to Dawei’

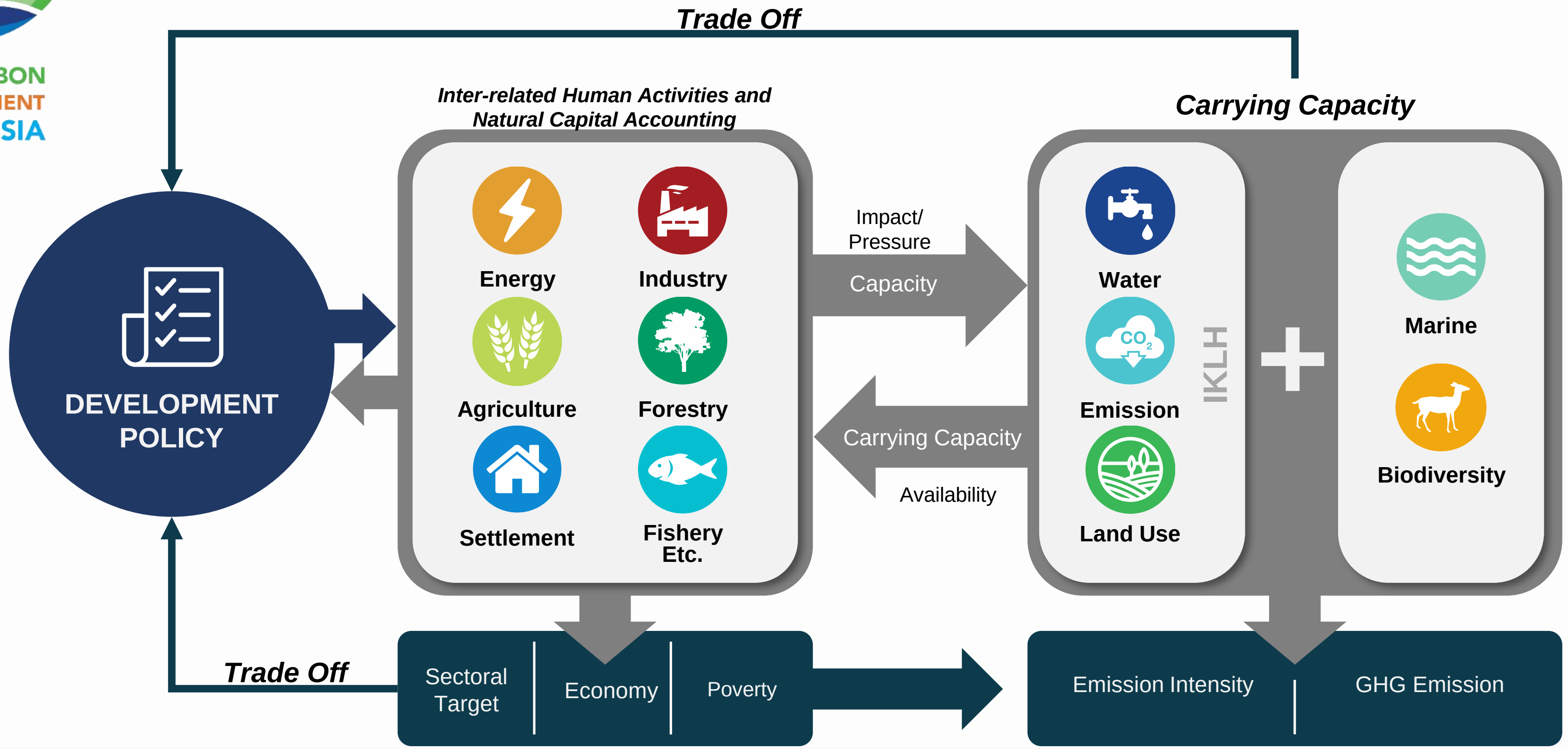


Indonesia case study

Low Carbon Development plan is a set of inclusive development planning policies and low-carbon investment strategies for the RPJMN 2020-2024 and the Roadmap of SDG 2030 that encourage Indonesia to reduce the intensity of emissions and GHG Emissions

Kementerian PPN/ Bappenas

LOW CARBON DEVELOPMENT INDONESIA



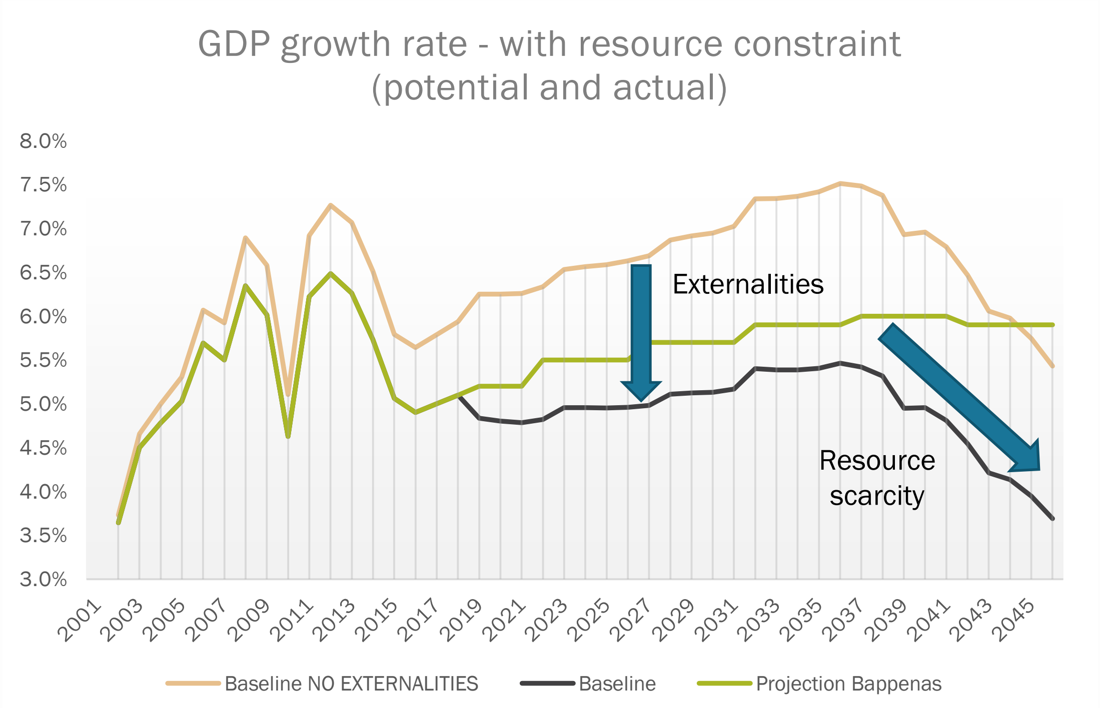
Indonesia case study

Carrying capacity is embedded in the model using two main dynamics:

- **Ecosystem services:** water and air quality have a negative impact on productivity and therefore on economic performance.
- **Ecological scarcity:** the use of natural resources is essential for production. The decline of the stock of available natural resources leads to price increases (e.g. imports are generally more expensive than domestic production, and fossil fuels become more and more expensive to extract as depletion increases).

Indonesia case study

Kementerian PPN/ Bappenas



Projection: Projection of Deputy of Economy Bappenas
Potential No Externality: Indonesian Simulation of IV2045 with unlimited resources
Baseline No Externality: Indonesian Simulation of IV2045 no externalities, with resource scarcity

The limitations of natural resources (depletion of Water, Energy and Forests) are projected to **hamper economic growth** if there is no intervention in development policies that **pro-carrying capacity**

Availability of Natural Resources → Real Level of GDP growth

Note: Temporary simulation results and validation will be carried out

SEEA

Thank you

For questions please contact me at:
andrea.bassi@ke-srl.com