Program

Morning:

- Clarifications
- Recap on ecosystem services
- Coffee: 10.30-11.00
- ES in ARIES for SEEA Explorer

Lunch: 12:30-13:30 lunch

Afternoon:

- Jamboard
- Next steps / support from BC3
- Coffee: 15.00 -15.30
- Closing 15.30-16.00

System of Environmental Economic Accounting

Ecosystem Services Accounts

Environmental-Economic Accounts Section

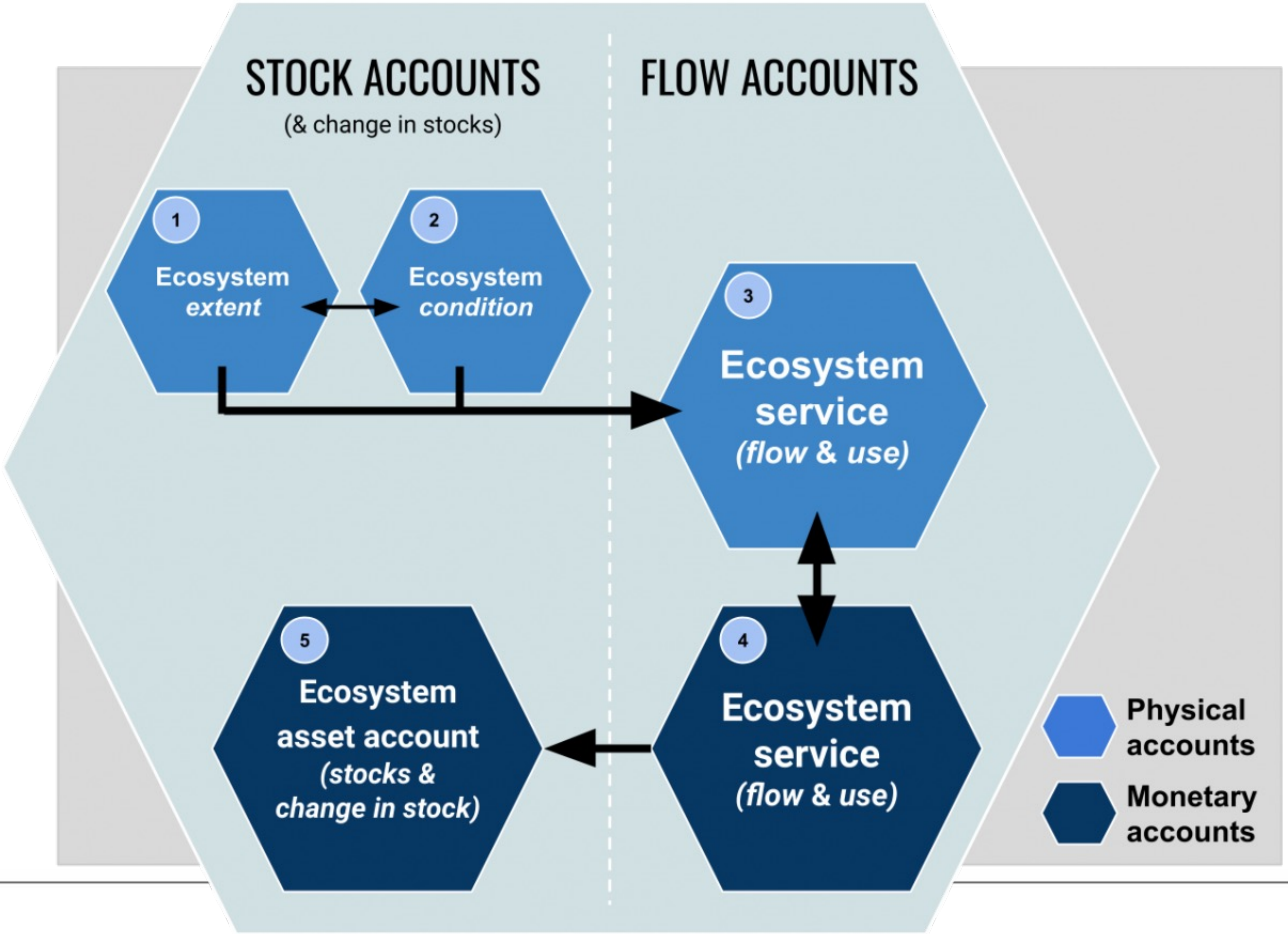
United Nations Statistics Division

United Nations

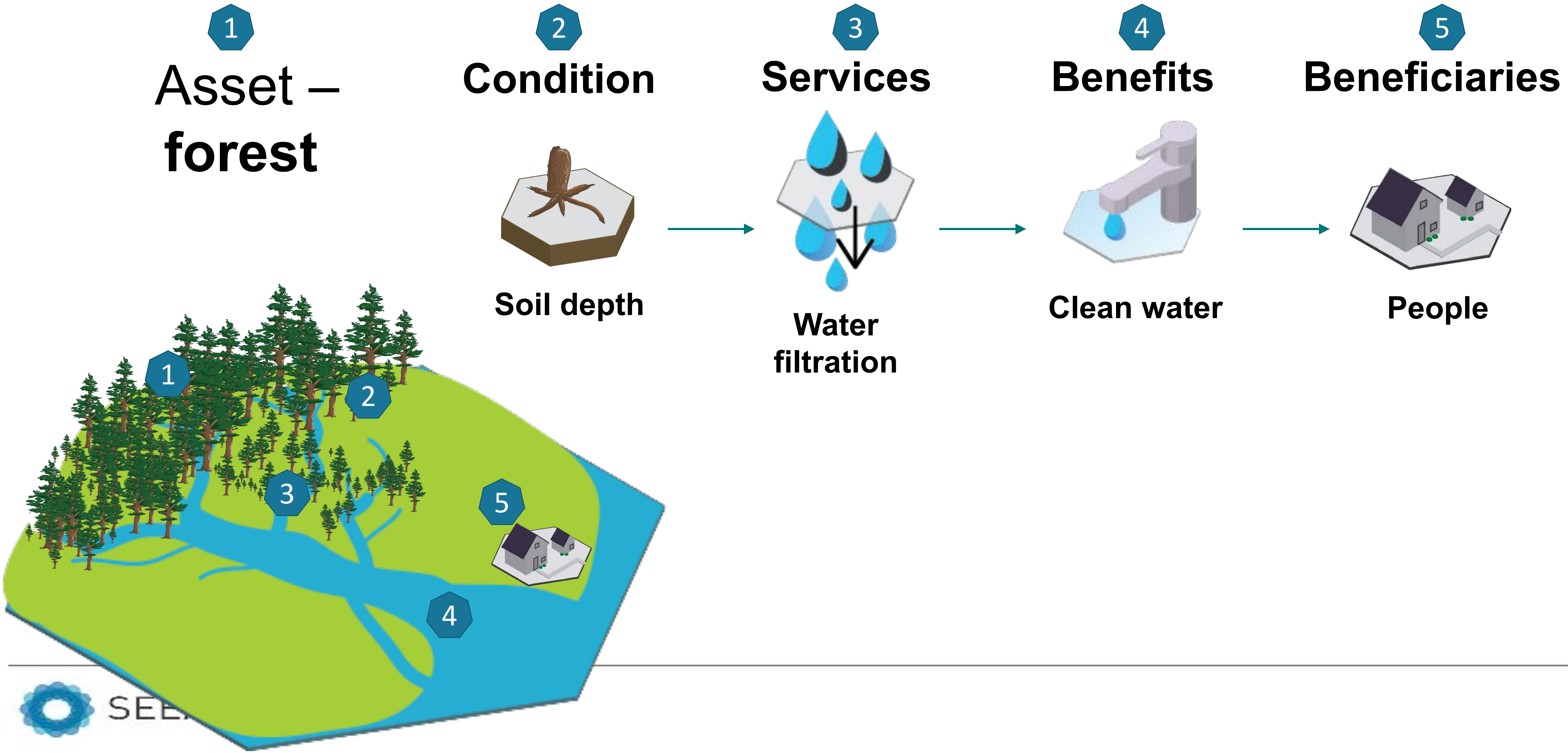
Outline

- Main ecosystem accounts
- Biophysical modelling
  - Guidelines on biophysical modeling for SEEA Ecosystem Accounting
    - Modelling techniques
    - Main modelling platforms
- Monetary valuation of ES
- Examples of measuring individual ES

SEEA EA Framework



SEEA EA Framework – Illustrative Example



Ecosystem services

- SEEA EA includes a reference list of 25 Ecosystem Services
- Final and intermediate ES

- Provisioning:
  - > Biomass
    - Grazed biomass
    - Livestock
    - Aquaculture
    - Wood
    - Wild fish + other
    - Wild animals, plants + other
  - > Genetic material
  - > Water supply
- Cultural:
  - > Recreation-related
  - > Visual amenity
  - > Education, scientific and research
  - > Spiritual, artistic and symbolic services
- Other ES
- Non-use

- Regulating and maintenance services
  - > Global climate regulation
  - > Rainfall pattern
  - > Local (micro and meso) climate regulation
  - > Air filtration
  - > Soil quality regulation
  - > Soil and sediment retention
  - > Solid waste remediation
  - > Water purification
  - > Water flow regulation
  - > Flood control
  - > Storm mitigation
  - > Noise attenuation
  - > Pollination
  - > Biological control
  - > Nursery population & habitat maintenance

Biophysical modelling

What is biophysical modelling?

- Biophysical modelling: the quantitative estimation of biophysical phenomena or processes that are difficult to fully observe directly.
- Distinguish between models and modelling platforms.
  - Models are highly diverse in purpose and approach, many are set-up to analyse a specific problem (e.g. a model to estimate carbon sequestration).
  - Modelling platforms: tools consisting of multiple models
- Biophysical models can be useful for compiling many of the extent, condition, as well as supply and use tables and maps produced in SEEA EA.
- Biophysical modelling may be instrumental, it can never replace data collection processes:
  - Earth observation data sets need ground-truthing
  - Models rely on in situ data (adjust model setup to local circumstances / calibration)

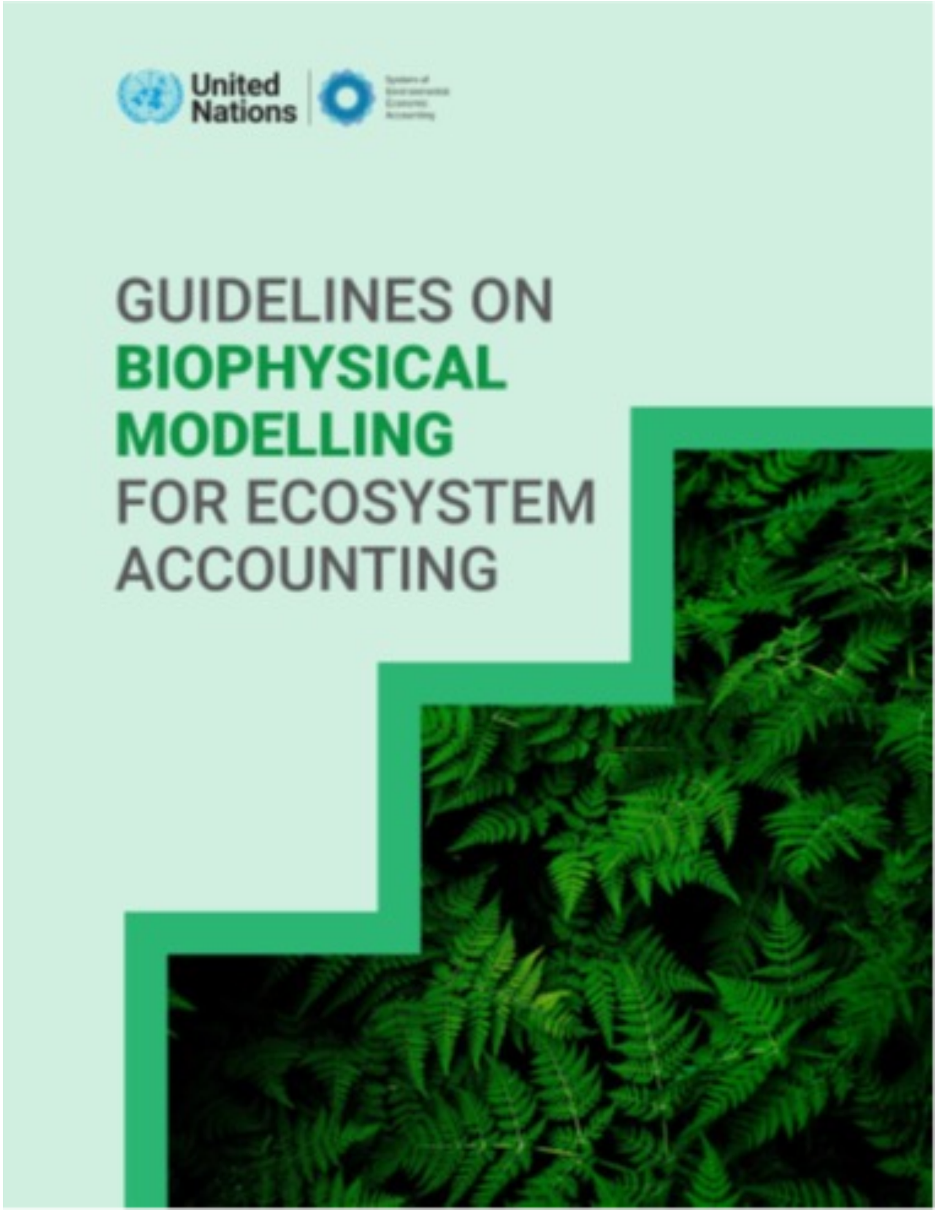
Why do we need modelling?

- Ecosystem accounting - as spatially explicit - requires maps with full spatial cover of ecosystem types, condition variables, and ecosystem services flows

- Data needed for ecosystem accounts not usually captured in regular data sources
  - Measuring ecosystem services directly is often difficult or costly to measure *in situ*.
- For some services or condition indicators, data are only available for specific locations
  - Spatialize tabular data (e.g. visitors, or water quality
- Usually, data from various sources and scales need to combined (e.g., point field data and satellite data)

Biophysical guidelines (1/3)

- Why developed?
  - > Diverse models and tools have proliferated over the past decade and are constantly evolving.
  - > Most models not developed specifically for accounting purposes, many models produce results can be used directly in SEEA EA or produce results that can be modified for use in SEEA EA.
- Audience:
  - > Ecosystem accounts compilers + managers
  - > Assumes familiarity with SEEA Ecosystem Accounting but does not assume knowledge of biophysical modelling
- Process:
  - > Under auspices of UNCEEA
  - > Global consultation in 2021
  - > Adopted by UN Statistical Commission



Biophysical guidelines (2/3)

1. Introduction
2. Process guidance for agencies
3. Modeling for ecosystem accounts
4. Modeling for extent accounts
5. Modeling for condition accounts
6. Modeling for ecosystem service accounts
7. Data quality
8. Future of biophysical modeling

Annexes

1. Global data sources + data portals
2. Modelling techniques
3. Cartography essentials
4. Literature list (16 pages)

NB: Living document: see for latest tables:

https://seea.un.org/ecosystem-accounting/biophysical-modelling

Biophysical guidelines (3/3)

- Tiered approach
  - > recognizes countries are in different circumstances (data availability + expertise)
  - > may differ per ES
  - > progress over time
- Decision trees to facilitate choices

TIER 1

Ecosystem services modelled from global datasets with no or little user input data

TIER 2

Ecosystem services modelled from national datasets customized for national contexts, some validation

TIER 3

Ecosystem services modelled with local data and direct surveys, better validation, and best available tools

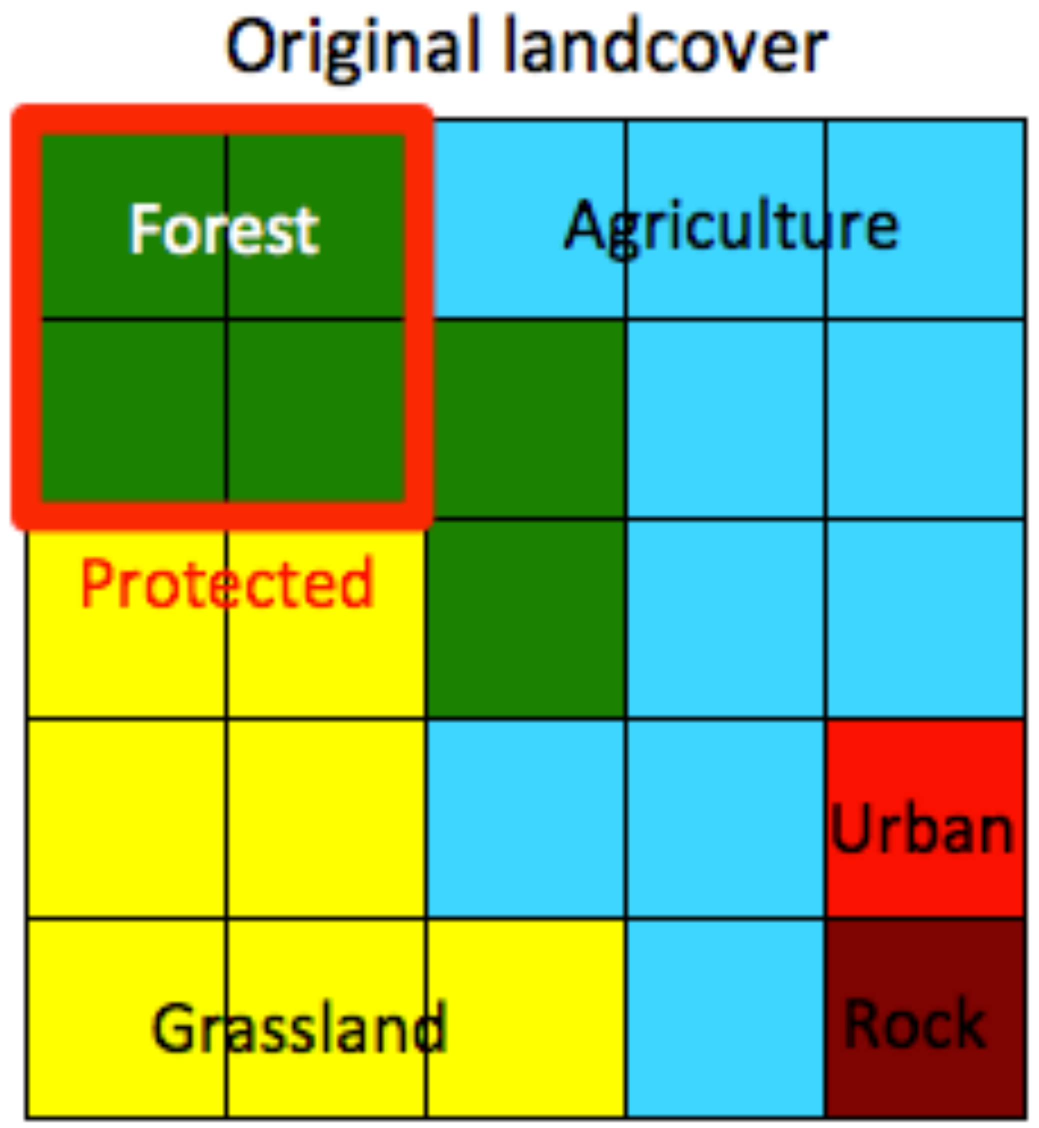
Figure 2: *Tiered approach*

Modelling techniques

Model technique	Definition	Data needs	Efforts
Look-up Table	Specific values for an ecosystem service or condition variable are attributed to every pixel in a certain class, usually a land cover, land use, or ecosystem type class.	Limited	Easy
Spatial interpolation	Creates surfaces from measured points	Moderate	Moderate
Geostatistical models	Statistical algorithms predict the value of un-sampled pixels based on nearby pixel values in combination with other characteristics of the pixel.	Moderate	Moderate
Statistical models	Values of pixels are assigned based on a set of underlying variables. The relation between the value and the independent variables is developed with a regression analysis.	Moderate	Moderate
Dynamic systems (such as process-based models)	Dynamic systems modelling uses sets of differential equations to describe responses of a dynamical system to all possible inputs and initial conditions. The equations include a set of state (level) and flow (rate) variables in order to capture the state of the ecosystem, including relevant inputs, throughputs and outputs, over time. Most process-based models are examples of dynamic systems models that predict ecosystem services supply or other variables based on a mathematical representation of one or several of the processes describing the functioning of the ecosystem.	High	High
Machine learning	A type of artificial intelligence. Machine learning uses training data to build algorithms to make predictions without explicit programming.	High	Moderate

Example modelling techniques (1/2)

- Look-up table:
  - > Attribute values for an ecosystem service (or other measure) to every Spatial Unit in the same class (e.g., a land cover class).
  - > Example: Carbon storage
    - one ha of forest = X tonnes
      ◎ attribute to each ha of forest



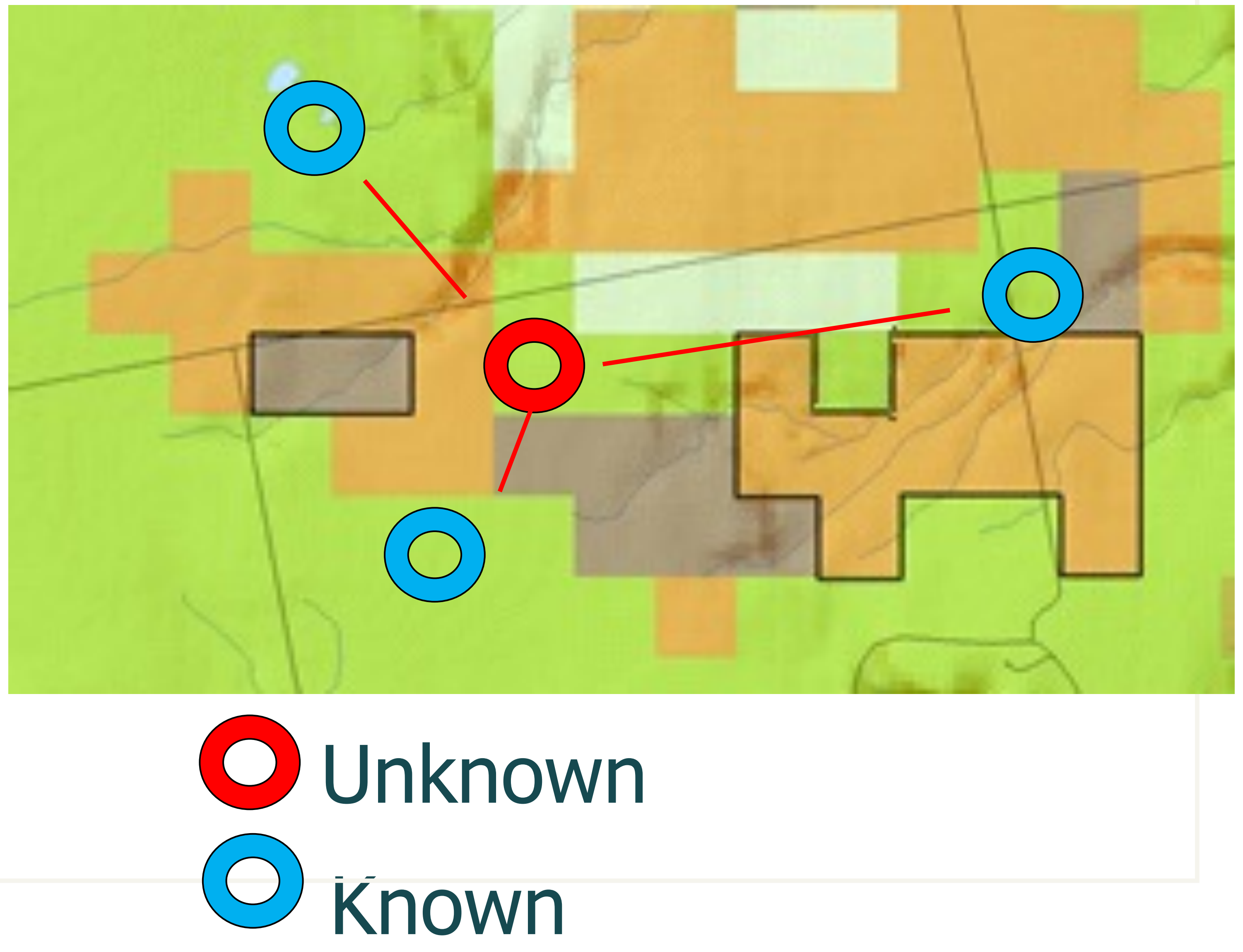
Source: Natural Capital Project

- Statistical model:
  - > Estimate ecosystem services, asset or condition based on known explanatory variables such as soils, land cover, climate, distance from a road, etc., using a statistical relation.
  - > Example: **Habitat quality**

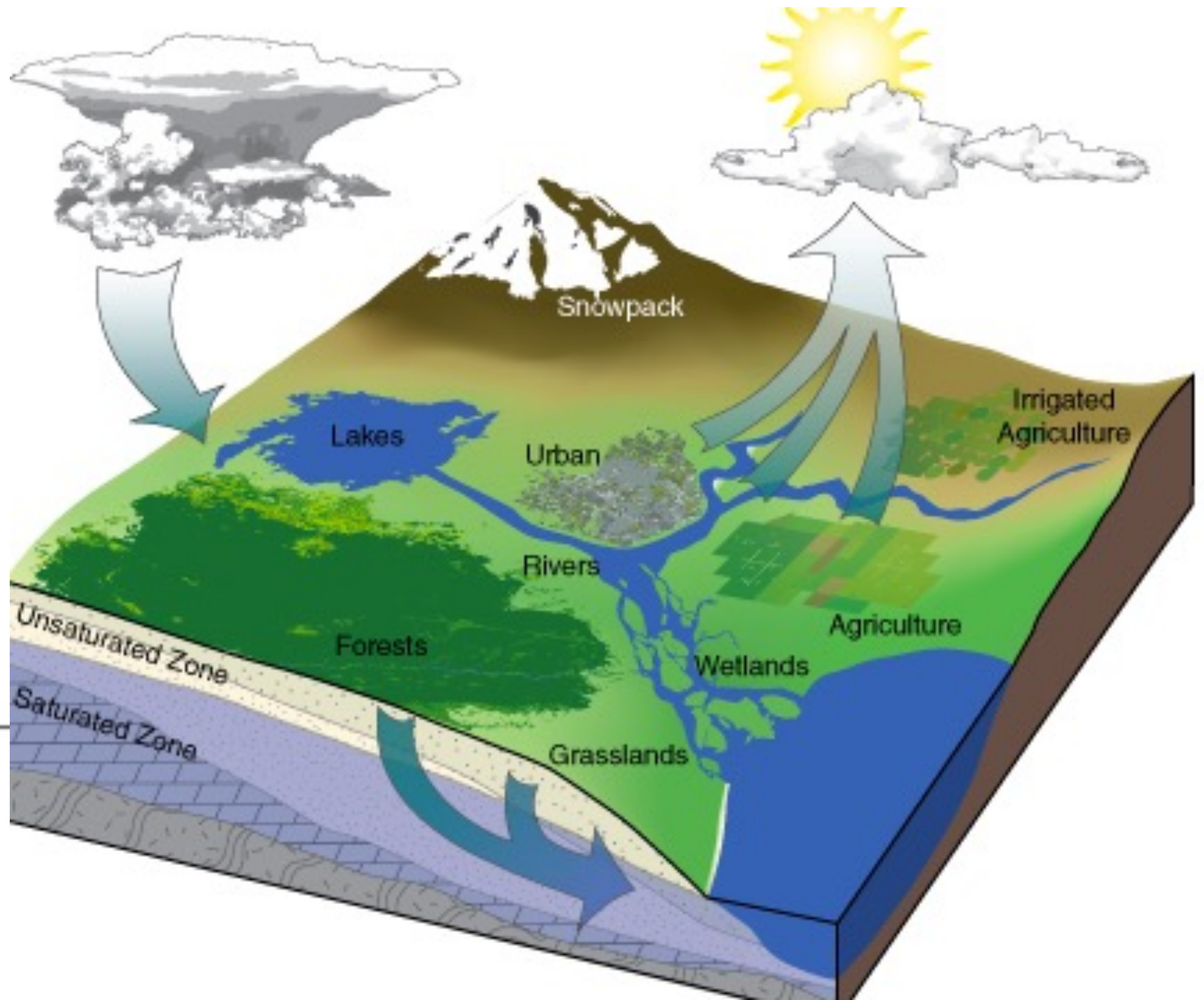
value = f(land cover, population, distance to roads, climate,..)

Example modelling techniques (2/2)

- Geostatistical model
  - > Use algorithms to predict the measure of unknown locations on the basis of measures of nearby known measures:
  - > Spatial interpolation



- Dynamic systems (such as process-based models)
  - > Predict ecosystem services based on modelling of processes involved in supplying the service:
  - > Example:
    - Hydrological model to model water flow regulation
    - SWAT



Software and tooling

- Depending on types of accounts prioritized, available data and expertise in the country, different ecosystem extent, condition and service models may require different software.
- GIS software for displaying spatial data will likely be needed regardless
- Two most widely used GIS systems are:
  - ArcGIS: commercial product
  - QuantumGIS (also called QGIS): freeware
- Which one to select - depends upon context:
  - Which systems are already used in the government agencies supplying / processing data?
  - Budget
- Also other web-based platforms to consider such as Google Earth Engine
- Programming languages like R or phyton have several packages for spatial analysis that can facilitate efficient workflows in the production of results and reports

Overview of platforms with potential use in SEEA EA

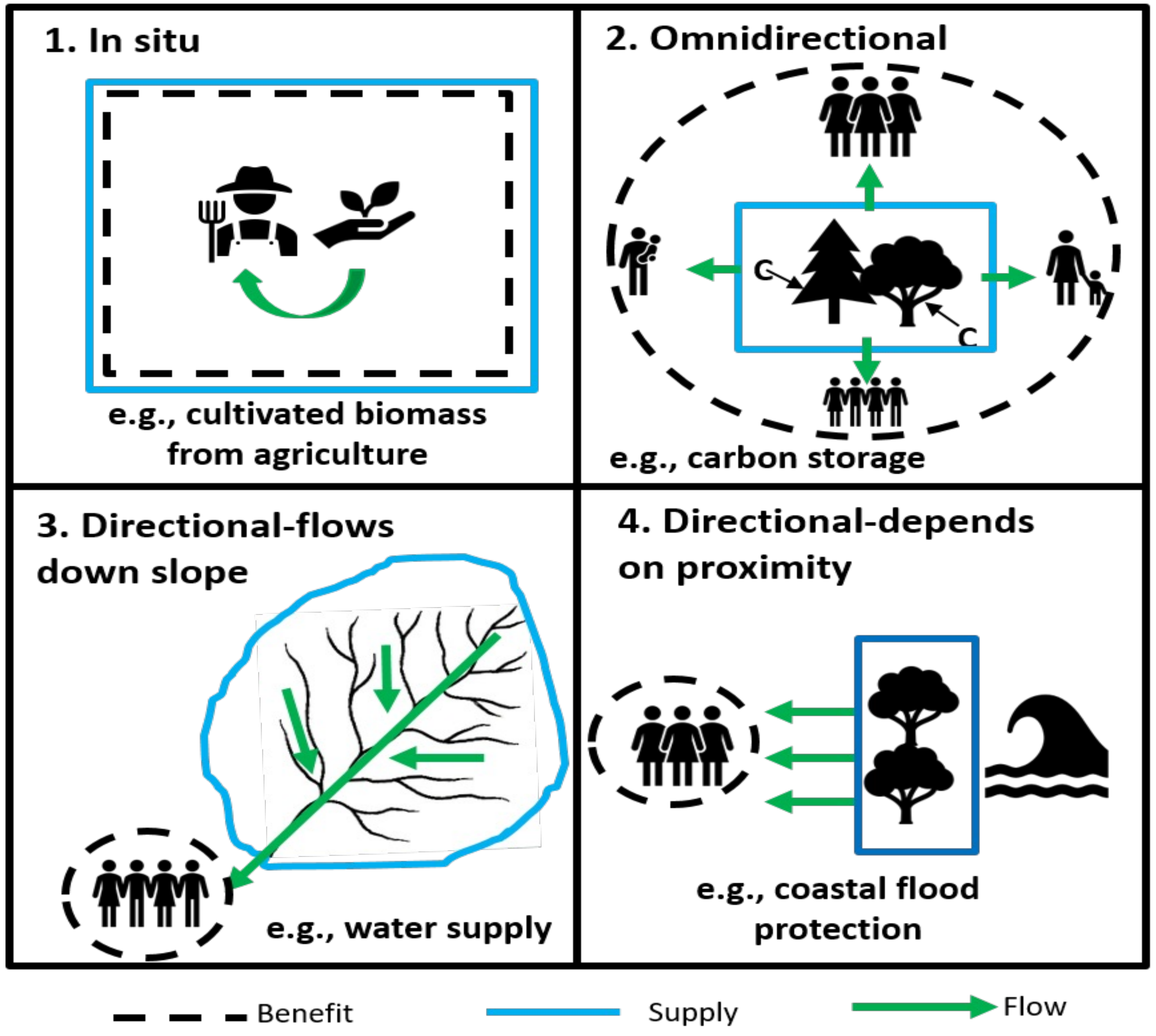
Modelling platform	Primary goal of platform	Coverage
ARIES (Villa et al., 2014)	ARIES (Artificial Intelligence for Ecosystem Services). Provides easy access to data and models through a web-based explorer and using Artificial Intelligence to simplify model selection, promoting transparent reuse of data and models in accordance with the FAIR principles.	Extent, Condition, Ecosystem Services
Data4Nature	Data4Nature (formerly known as EnSym - Environmental Systems Modelling Platform) is a decision support tool that is designed to answer questions about where organizations should invest in their natural resources. Data4Nature is specifically designed with SEEA EA in mind.	Extent, Ecosystem Services
ESTIMAP (Zulian et al., 2018)	ESTIMAP (Ecosystem Services Mapping tool) is a collection of models for mapping ecosystem services in a multi scale perspective (it can be applied at different scales) (Zulian et. al 2018).	Ecosystem Services
InVEST (Sharp et al., 2018)	A compilation of open-source models for mapping and valuing ecosystem services. InVEST is the flagship tool of the Natural Capital Project and has been the most widely used ecosystem service modelling tool globally.	Ecosystem Services, Condition
i-Tree	i-Tree is a tool developed by the USDA Forest Service with capabilities of modelling ecosystem services related to trees, particularly in urban settings (i.e. air filtration, carbon storage urban heat island mitigation, and rainfall interception and infiltration).	Ecosystem Services (forest related)
Nature Braid (Jackson et al., 2013)	The Nature Braid (formerly LUCI/Polyscape) provides a suite of high spatial resolution ecosystem services models designed to improve decision-making around restoration and land management. The Nature Braid is particularly well suited for mapping soil, water and chemical transport processes at high resolution.	Extent, Condition, Ecosystem Services (hydrological, soil)

Coverage by selected modeling platforms

			ARIES	InVEST	LUCI	ESTIMAP	Data4Nature	iTree
Provisioning services								
	Biomass pr	Crop provisioning	x	x	i		x	
		Grazed biomass provisioning					x	
		Timber provisioning	x				x	
		Non-timber forest products and other biomass provisioning	m					
		Fish and other aquatic products provisioning		x				
	Water supply		x		x		x	
	Genetic material							
Regulating and maintenance services								
	Global climate regulation services		x	x	x		x	x
	Rainfall pattern regulation services						x	
	Local (micro and meso) climate regulation services			i			x	x
	Air filtration services					x		x
	Soil erosion control services		x	x	x	x	x	
	Water purification services			x	x	x	x	
	Water flow regulation services			x	i	x	x	
	Flood mitigation services (coastal or riverine)		x	i		x	x	
	Storm mitigation services					x		x
	Noise attentuation services							
	Pollination services		x	x		x		
	Pest control services					x		
	Nursery population & habitat maintenance services					x	x	
	Soil waste remediation services							
	Other regulating and maintenance services						x	
Cultural services								
	Recreation-related services		x	x		x		

Modelling Ecosystem Services

- ES: both a supplier and user
  - > The supply may occur in different location (service providing areas) from benefits (service benefiting areas).
- Different ecosystem services may hold certain spatial characteristics and may also follow certain flow paths
  - > In situ
  - > Omnidirectional ecosystem
  - > Directional: downstream / downslope
  - > Directional: spatial proximity.



A framework highlighting the spatial characteristics of ecosystem services. Figure adapted from Fisher et al. (2009

SEEA

Monetary valuation

Context

- SEEA relation to SNA:
  - SEEA CF expands asset boundary
  - SEEA EA expands also the production boundary with ecosystem services
  - ES conceptualized as transactions between ecosystems assets (supply) and beneficiaries (users)
  - ES are contributions to benefits, not benefits per se
    - For example: crops -> already exchanged in markets
  - Distinguishing ES as “outputs” from “costs” as inputs, clear departure from restoration cost approach
- Main approach/intent is to be consistent with valuation principles of SNA
  - Exchange value (not welfare value)
  - Similar to for instance unpaid household work

Monetary valuation accounts in SEEA EA

- Foundation in physical measurement
- Place SEEA EA in context of broader welfare measurement (focus on “use”)
- Accounts, described in Chapters 8-11:
  - > Ecosystem services accounts in monetary units
  - > Monetary ecosystem asset accounts (including degradation / enhancement)
  - > Integrated presentations
  - > Complementary valuation approaches (e.g. welfare based; polluter pays principle etc.)
- SEEA Ecosystem Accounting adopted in March 2021
  - > *Chapters 1-7 with conceptual framework and physical accounts as statistical standard*
  - > *Chapters 8-11 recognized as describing internationally recognized statistical principles and recommendations for the valuation of ecosystem services and assets in a context that is coherent with the concepts of System of National Accounts*
  - > *Requested the Committee to promptly resolve the outstanding methodological aspects in chapters 8–11 as identified in the research agenda.*

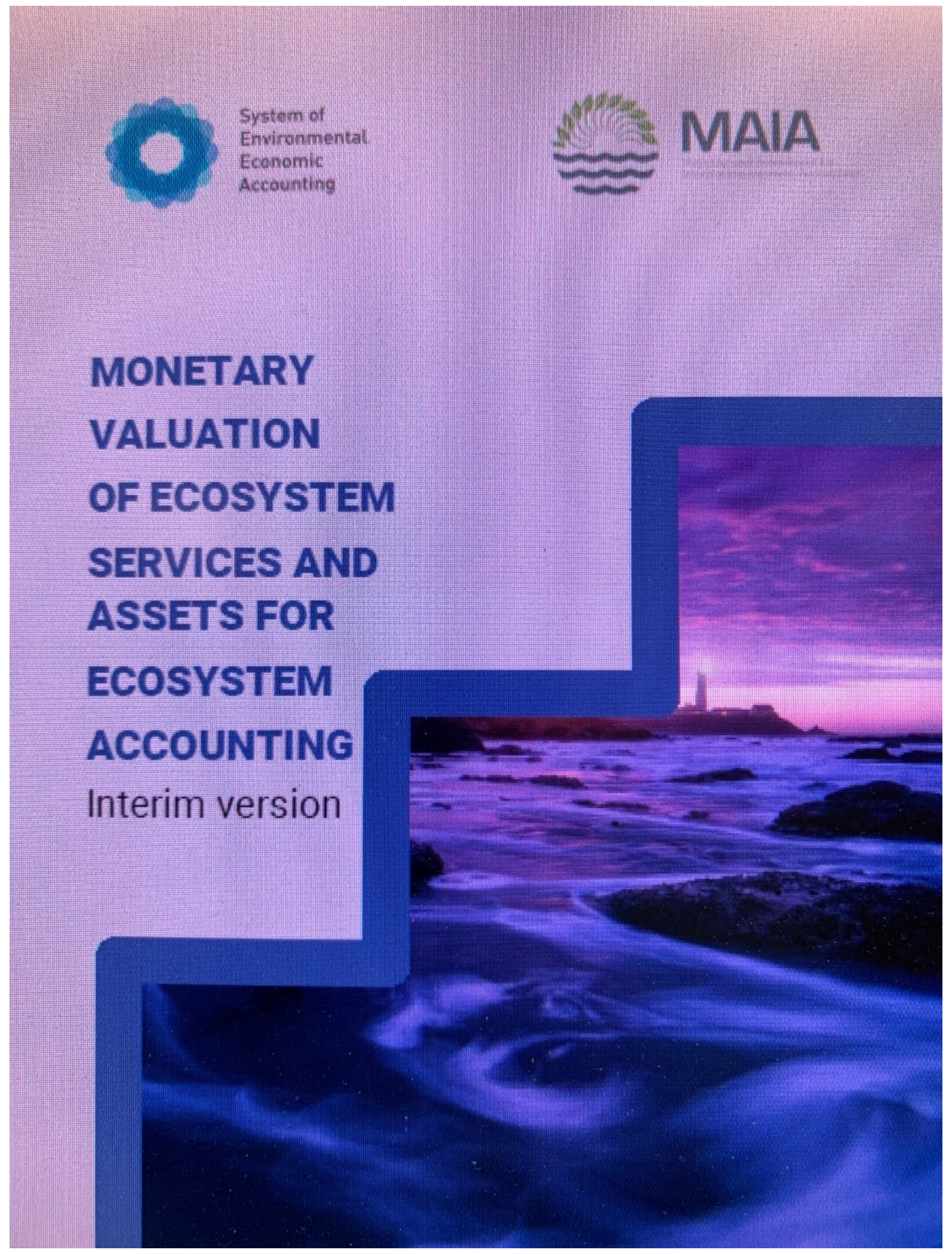
Valuation methods that generate exchange values

EA order	SEEA EA Category of method	
1	**Prices are directly observable**	Market prices
2	**Prices from similar markets**	Similar markets
3	**Prices embodied in market transactions**	Residual value; Reso
		Hedonic Pricing
		Productivity Change
4	**Prices from revealed expenditures on related goods and services**	Averting Behaviour
		Travel Cost
5	**Prices from expected expenditures or expected markets**	Replacement Cost
		Avoided Damage Co
		Simulated Exchange

SEEA

Valuation report – outline

1. Introduction
2. Foundations
3. Valuation methods
4. Valuing ecosystem services
    1. *Tiers per ES*
5. Valuing ecosystem assets
6. Other considerations
    1. *Value transfer*
    2. *Platforms and tools*
    3. *Aggregation*
    4. *Communicating values*

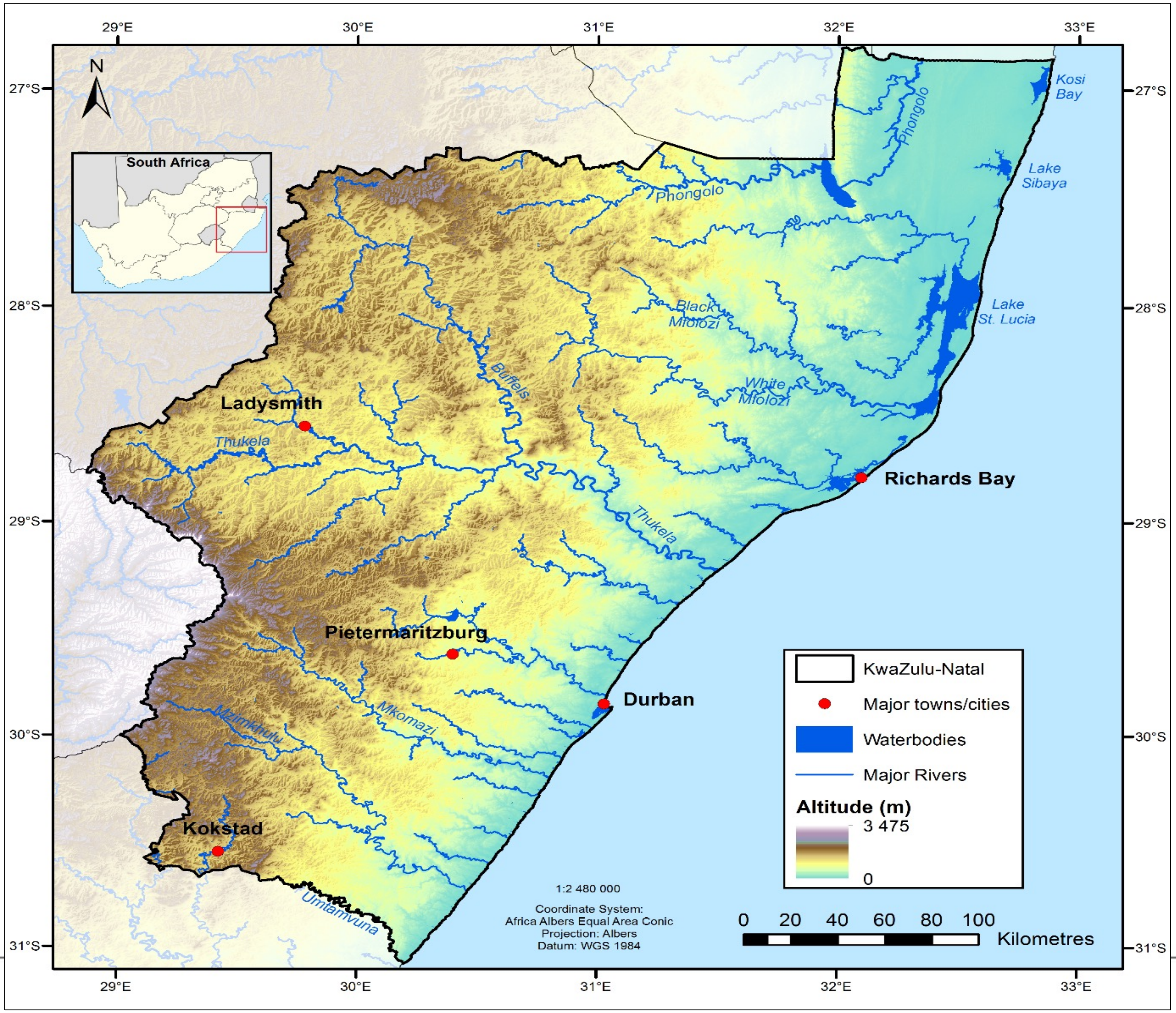


Examples

Example: South Africa (1/10)

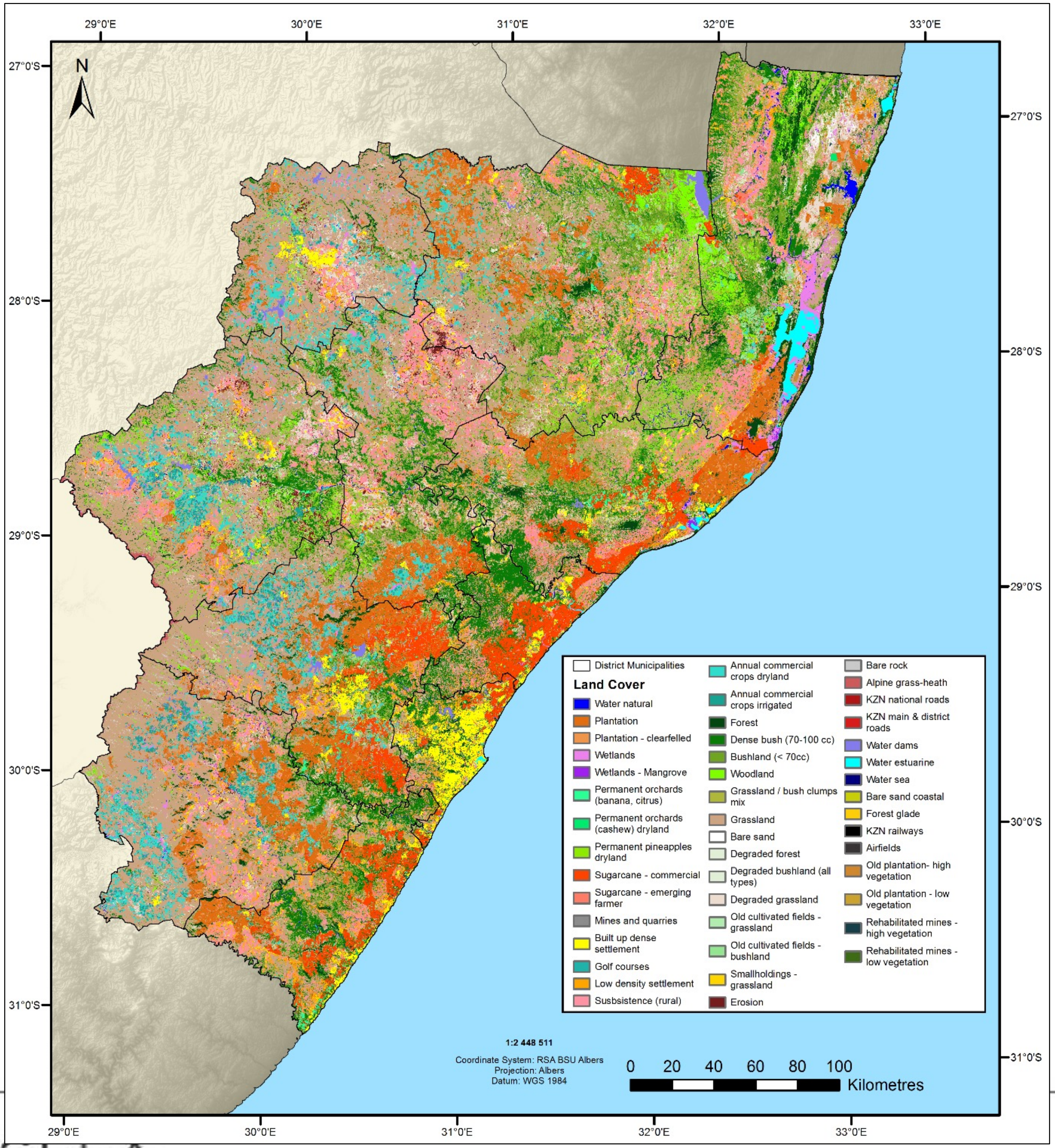
- Output of the NCAVES project
- Modelled 11 different ES for 2005 and 2011
- Kwazulu-Natal (KZN) province
- Physical + monetary

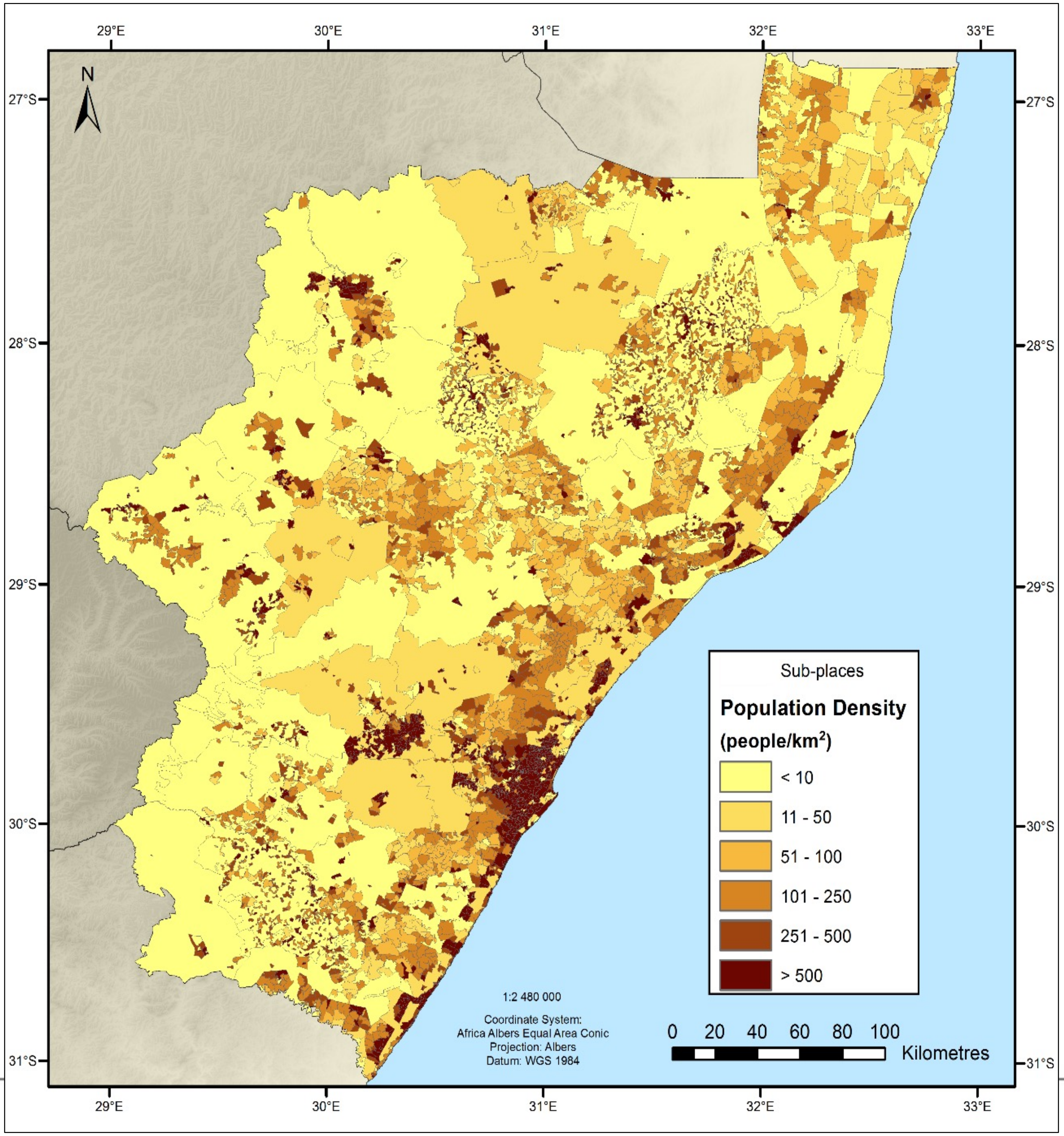

Towards a method for accounting for ecosystem services and asset value:
Pilot accounts for KwaZulu-Natal South Africa, 2005-2011
Updated Final Report January 2021
Turpie, J.K., Letley, G., Schmidt, K., Weiss, J., O'Farrell, P. and Jewitt, D.
United Nations



Source: Turpie et al. 2021

Example: South Africa (2/10)





SEEA

Source: Turpie et al. 2021

Example: South Africa (3/10)

ES1: Wild resources

- People in KZN use hundreds of species of plants and animals for food, medicine, energy and raw materials.
- For the purposes of this study and based on the nature of the data, the resources were grouped

	Purpose	Group
Wild plant resources	Nutrition and health	Wild plant foods and medicines
	Energy	Wood fuel
	Raw materials	Grass
		Reeds and sedges
		Palm leaves
		Poles and withies
		Timber
		Wood for carving/curios
Wild animal resources	Nutrition	Terrestrial birds and animals
		Fish and other aquatic organisms

Source: Turpie et al. 2021

- Step 1: Quantities demanded
  - Estimated at the census sub-place (~village) level based on household survey data and census data on numbers of households and types of dwelling.
  - Relevant census data: population, number of households, average household size, number of traditional dwellings, number of informal dwellings, households using wood, number of households collecting water from rivers and streams, and number of households using wood for heating and cooking.

Example South Africa (4/10)

- Step 2: Aggregate potential household demand estimated using additional information but also statistical models
  - To relate average use to household characteristics,
  - in this way, the total demand (e.g. kg/y, m3/y) for each resource was estimated for each sub-place

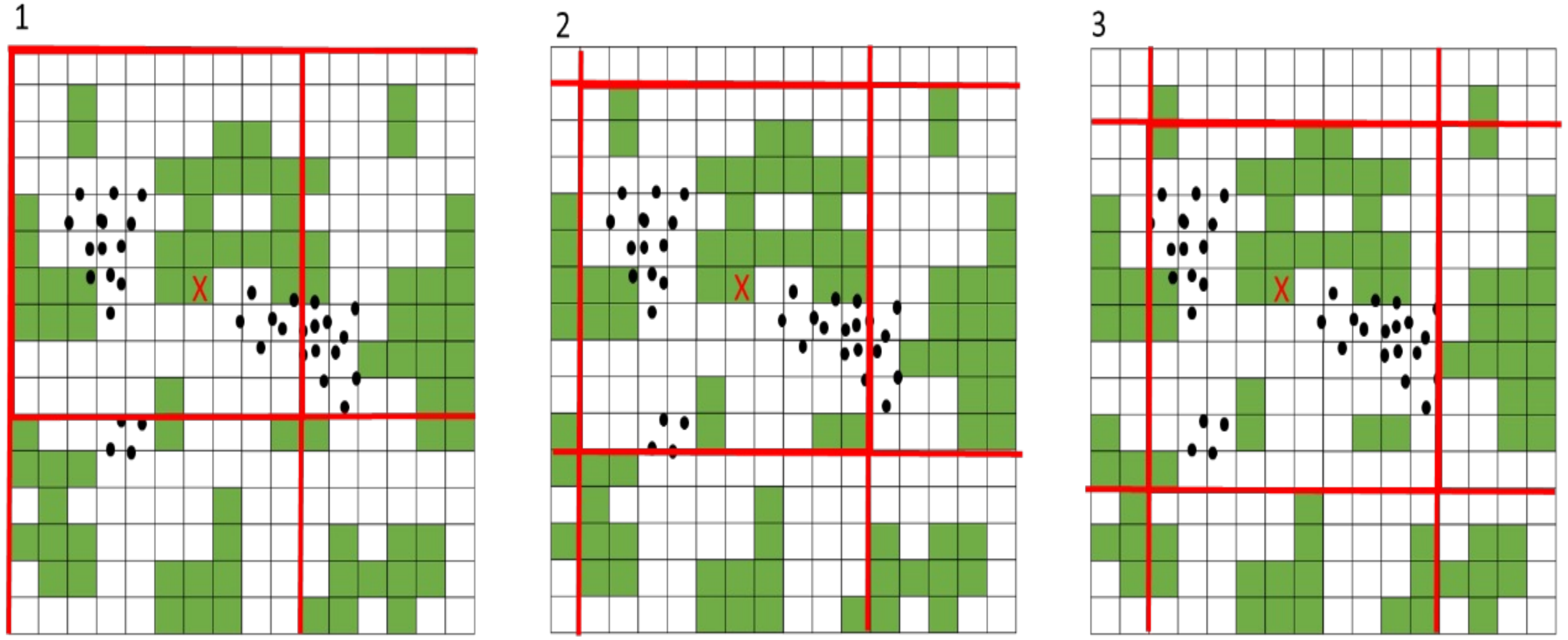
Resource group	Method/assumptions	Number of studies used	Other information
Fuelwood	hh using fuelwood; 3000 kg/hh/year	18	Converted kg/y into m^3/y using avg. wood density of 0.855 g/cm^3 (FAO)
Poles & withies	66% hh, 200 kg/hh/year	12	
Timber & wood	4% hh; 900 kg/hh/year	3	
Grass	33% hh; 76 bundles/hh/year	7	Grass bundle = 4.9 kg
Reeds & sedges	Turpie *et al.* (2010a) model	2	Reed bundle = 7 kg
Palm leaves	1.2% trad. hh; 660 leaves/hh/year	2	Each leaf provides 0.31 kg of weaving material
Wild fruits	Turpie *et al.* (2010a) model	1	
Wild vegetables	75% hh; 20 kg/hh/year	9	
Medicines	26% hh; 32 kg/hh/year	4	
Wild animals	Turpie *et al.* (2010a) model	1	
Wild birds	Turpie *et al.* (2010a) model	1	Avg. bird weight of 0.9kg
Fish	Turpie *et al.* (2010a) model	1	

Source: Turpie et al. 2021

- Step 3: Estimate the supply:
  - Estimated using vegetation maps
  - All harvestable resources were considered fully available and accessible within areas under communal land tenure.
  - Availability reduced to 10% of standing stocks in protected areas and for natural land under private ownership, such as commercial rangelands or wildlife ranches.

Example South Africa (5/10)

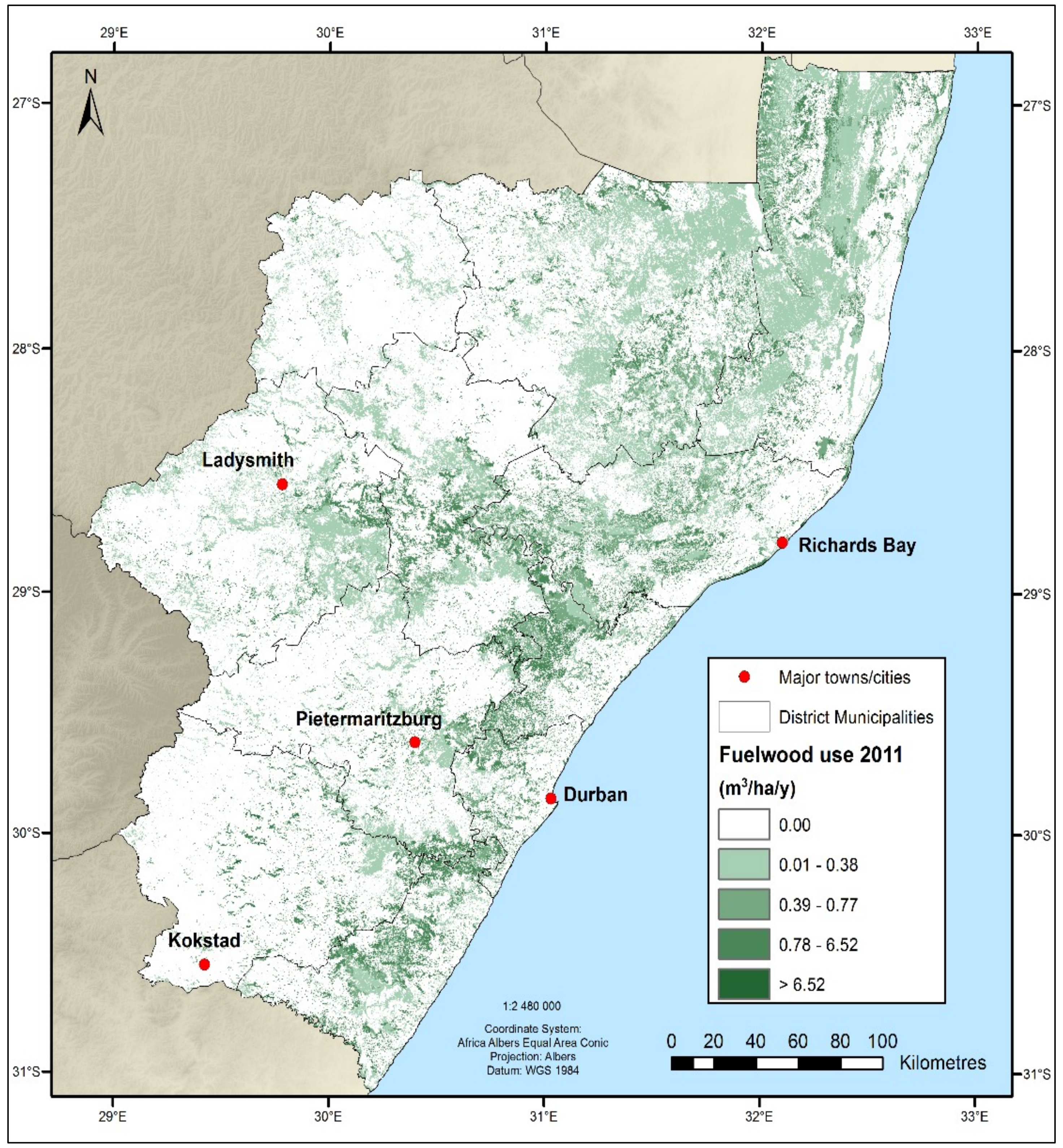
- Step 4: Model actual amount of wild resources harvested for subsistence using a geostatistical model:
  - estimated based on the minimum of the estimated demand and the estimated available stocks of resources within a specified distance of the demand source
  - an estimated average travelling distance to harvest natural resources of about 6 km
  - implemented with a "running mean" model

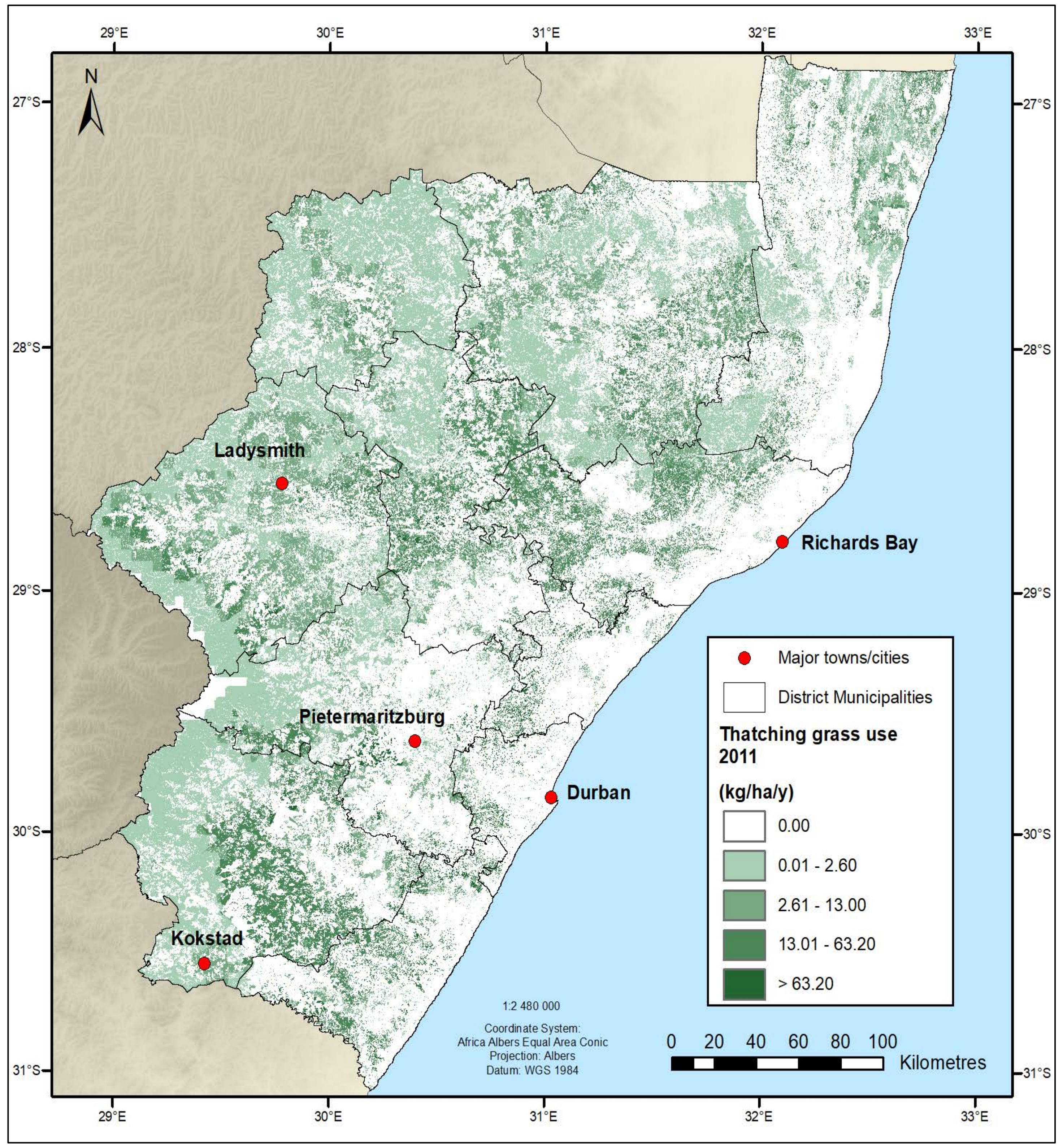


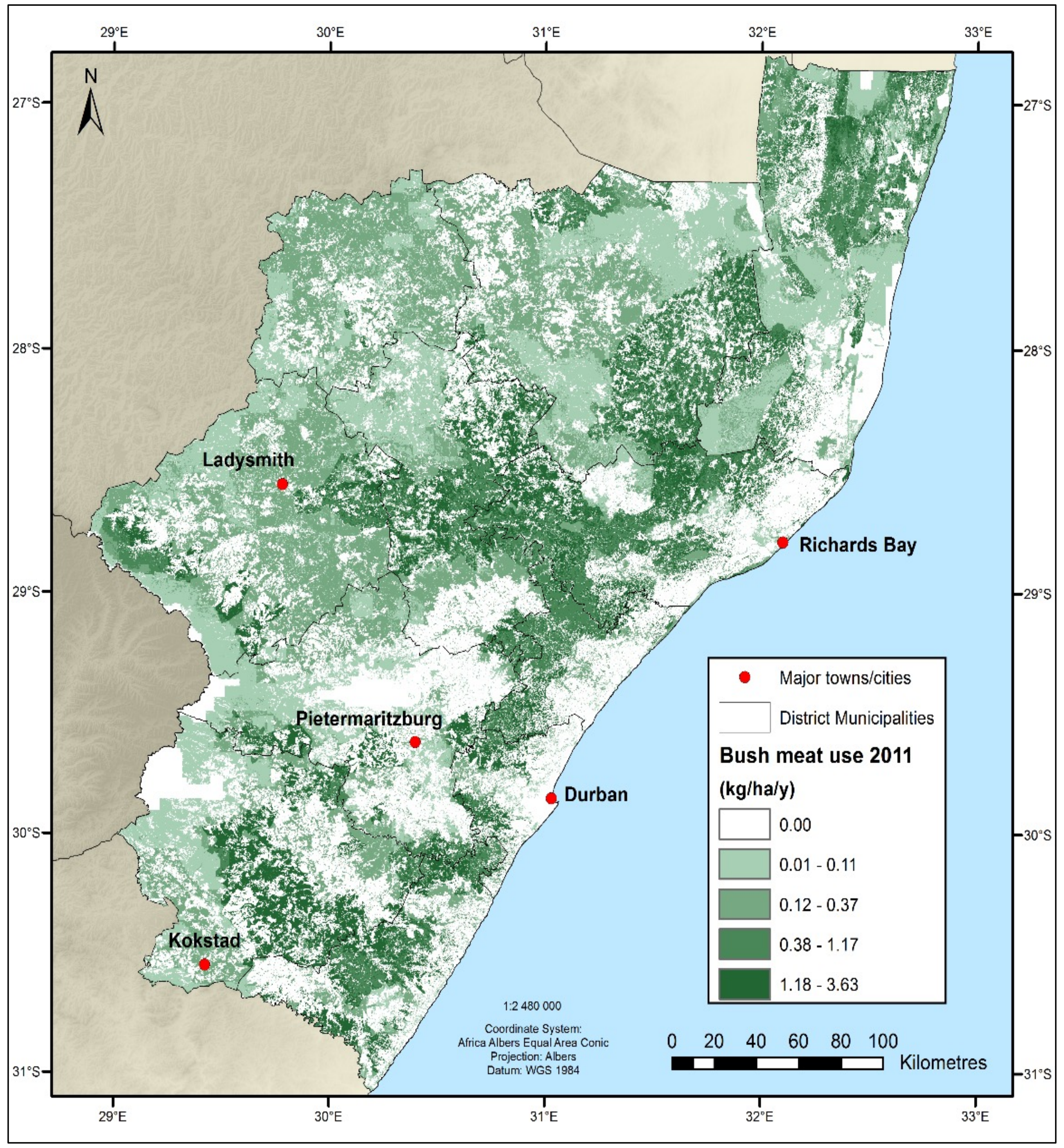
Source: Turpie et al. 2021

Running mean model used: Green areas are areas with stocks of a resource, and the dots are households demanding the resource at a certain rate.

Example South Africa (6/10)







- Results in form of maps

Source: Turpie et al. 2021

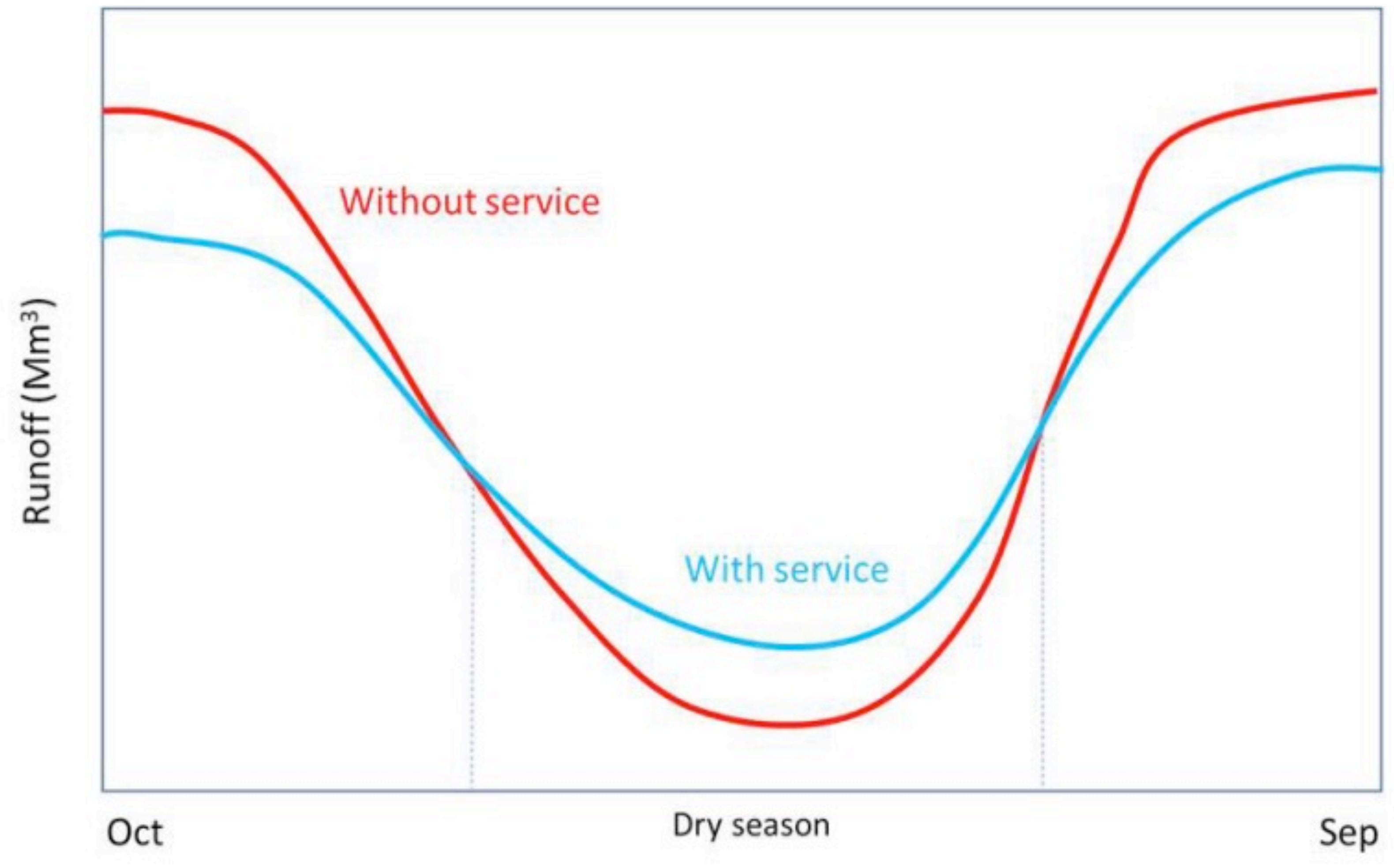
Example South Africa (7/10)

- After spatial overlay with ecosystem extent map
- Summarized as physical supply and use tables

Resource / Biome	Freshwater ecosystems	Grassland	Indian Ocean Coastal Belt	Savanna	Forests	Estuaries	TOTAL
Fuelwood (m^3)	3 341	663 349	223 178	755 244	247 315	158	**1 892 584**
Poles (m^3)	163	29 645	10 948	28 560	11 165	8	**80 489**
Timber (m^3)	20	2 643	999	3 491	8 567	3	**15 723**
Thatching grass (tonnes)	33	25 973	4 935	17 383	59	3	**48 384**
Reeds & sedges (tonnes)	752	3 801	1 508	2 371	324	22	**8 779**
Palm leaves (tonnes)	-	-	292	-	-	-	**292**
Wild foods/med (tonnes)	121	14 483	4 951	13 113	2 327	6	**35 001**
Bushmeat (tonnes)	6	1 542	338	1 934	179	0	**3 998**
Fish (tonnes)*	42	315	75	298	22	8	**759**

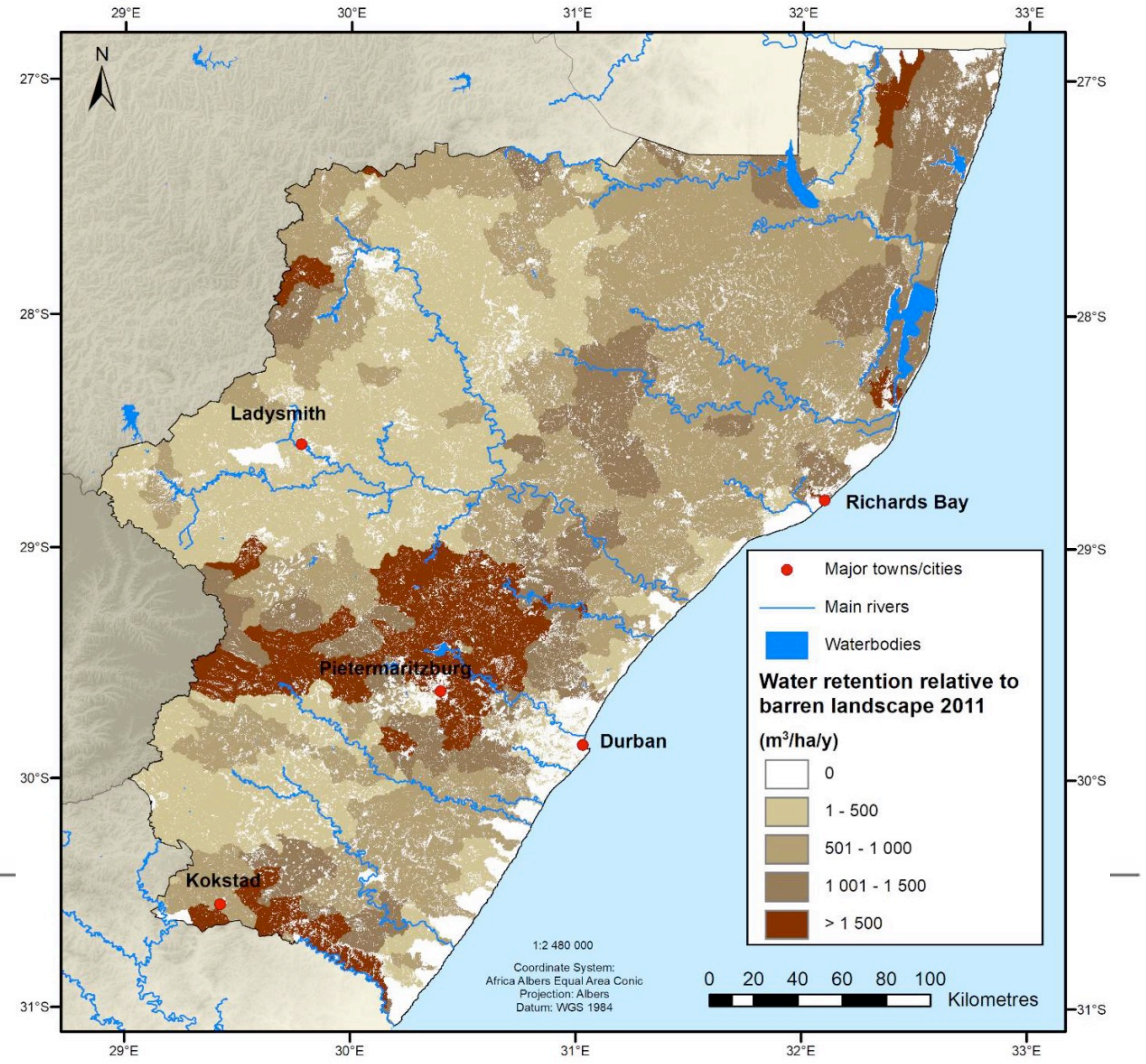
Source: Turpie et al. 2021

Example South Africa (8/10)



ES 2: Water flow regulation

- KZN – water flow regulation modelled with SWAT – process-based model
- ES measured as difference in infiltration relative to a barren scenario, in m3 per ha. This was obtained from the SWAT output "Percolation", given in mm.
- Main intuition: ecosystems function as 'sponges' mitigating peaks and ensuring higher base flows
- Modeled at sub river basin level
- Results:
  - > Maps
  - > Tables



Source: Turpie et al. 2021

Example: South Africa (9/10)

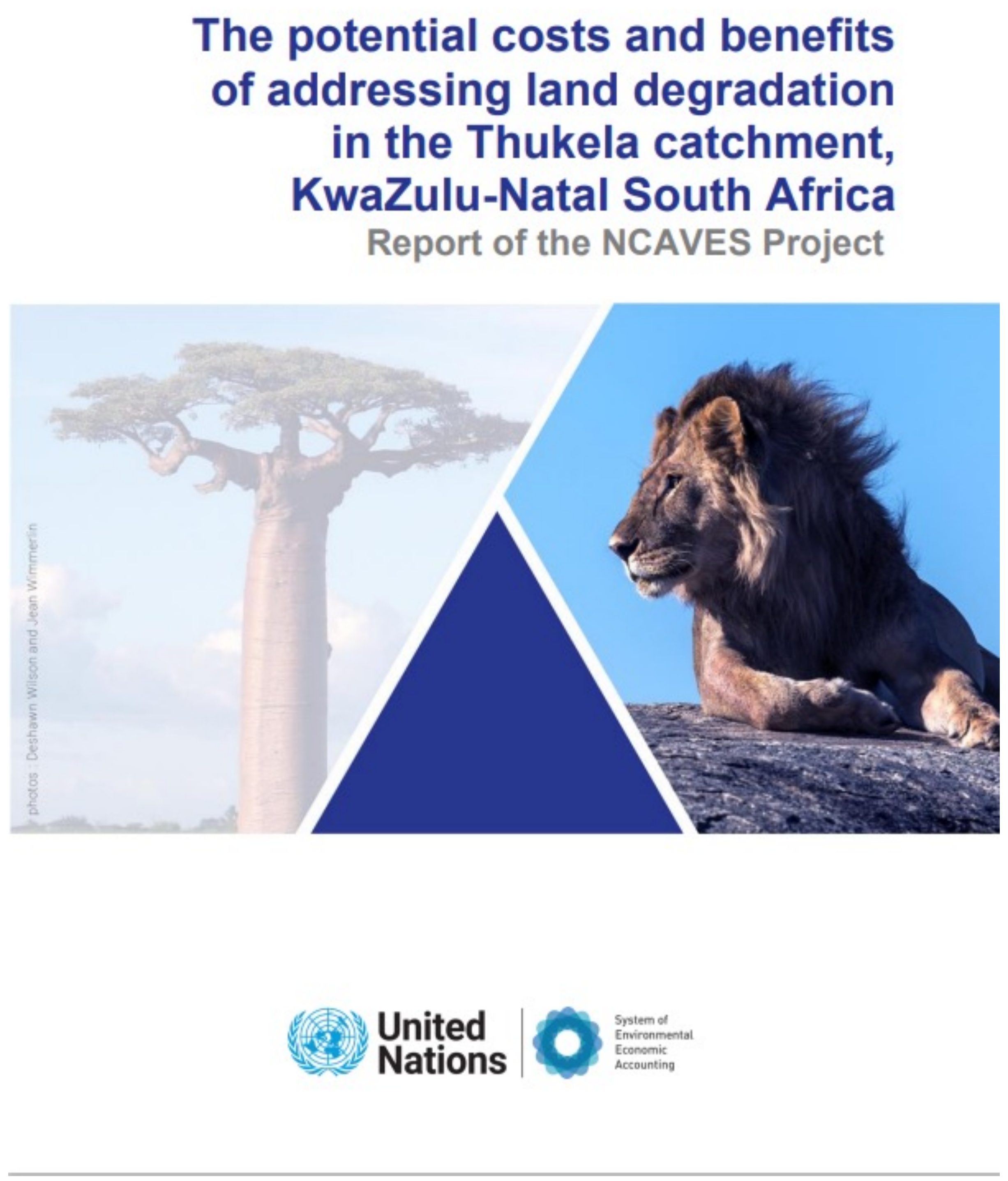
- All 11 ES modeled spatially
- After integration, physical supply and use tables (and monetary SUTs + monetary asset account

Table 5.1. Total biophysical supply per ecosystem type 2005

Resource / Biome	Freshwater ecosystems	Grassland	Indian Ocean Coastal Belt	Savanna	Forests	Estuaries	Cultivated	Urban green space	Total
Wood products (m³)	3 523	695 638	235 125	787 294	267 047	169			**1 988 796**
Non-wood products (tonnes)	834	46 494	11 489	34 952	2 911	38			**96 718**
Livestock production (LSU)	1 716	684 698	52 162	289 663	2 010	340			**1 030 589**
Crop production (tonnes)							43 305 781		**43 305 781**
Experiential value (R millions)	14	237	179	218	55	24	85	885	**1 698**
Carbon storage (Tg C)	5	512	61	348	33	0	279		**1 237**
Pollination (R millions)	0	12	6	31	2	0			**51**
Flow regulation (million m³)	78	3 315	421	2 198	634	36			**6 682**
Flood attenuation (R millions)								31	**31**
Sediment retention (million tonnes)	2	45	6	27	18	2			**99**
Water quality amelioration (tonnes P)	-	3 829	525	5 394	97	6			**9 850**

Source: Turpie et al. 2021

Example South Africa (10/10)



The potential costs and benefits of addressing land degradation in the Thukela catchment, KwaZulu-Natal South Africa

Report of the NCAVES Project

United Nations | System of Environmental Economic Accounting

- Policy use:
  - > Accounts applied in policy scenario analysis
  - > Cost-benefit analysis of addressing land degradation in the Thukela catchment
- Key outcomes:
  - > Halting and reversing ecosystem degradation has positive net economic benefits
  - > Preventing degradation now is more cost effective than fixing it later.
  - > In summary, the benefits of restoring the Thukela basin would outweigh the costs.

Mail&Guardian

AFRICA'S BEST READ

COVID-19 IN SA NEWS POLITICS OPINION ARTS & CULTURE EDUCATION HEALTH ENVIRONMENT PODCASTS WEBI

ENVIRONMENT

It pays to save the Thukela River catchment

Sheree Bega 17 Jul 2021

Benefits: The Wagendrift Dam on the Bushmans River, a tributary of the Thukela River. Rehabilitating the Thukela River catchment in KwaZulu-Natal would reduce soil erosion, improve the grasslands and water supply, all of which

SEEA

Source: Turpie et al. 2021 b

Global climate regulation service (carbon)

- Long debate during SEEA EA revision process how to frame carbon-related ecosystem services:
  - Net emissions cannot be considered transactions (negative production)
  - Need to provide right incentives, correct policy signals
- Global climate regulation service in SEEA EA considers two components:
  - carbon sequestration: the ability of ecosystems to remove carbon from the atmosphere
  - carbon retention: the ability of ecosystems to retain the stock of carbon – i.e., ecosystems supply a service through the avoided emission of carbon to the atmosphere
- In stable ecosystems, carbon retention will be the primary component while in those ecosystems where there is clear expansion in the stock of carbon, sequestration may be focus of measurement.
- Requires compilation of a basic carbon stock account.

Measurement boundaries: carbon retention

- The SEEA EA (paragraphs 6.112 - 6.113) specifies a number of measurement boundaries when it comes to carbon retention:
  - stocks are limited to carbon stored in above ground and below ground living and dead biomass in all ecosystems and soil organic carbon (including lake, river and seabeds);
  - in the case of peatlands and relevant organic carbon rich soils, only the carbon stored to a maximum of 2 meters below the surface should be included;
  - inorganic carbon stored in freshwater, marine and subterranean ecosystems is excluded from scope;
  - carbon stored in fossil fuel deposits should not be considered an ecosystem service;
  - storage of carbon in harvested wood products should not be considered an ecosystem service because these are products within the economy
  - -carbon stored in cultivated biological resources that have a short rotation cycle (e.g., crops) should not be included in the measurement of carbon retention.

Carbon sequestration

- Regarding carbon sequestration, the following 3 equations apply (based on IPCC 2006):
  1. *NPP (net primary production) = GPP (gross primary production) – plant respiration*
  2. *NEP (net ecosystem production) = NPP – soil respiration = GPP – ecosystem respiration*
  3. *NECB (net ecosystem carbon balance) = NEP – Carbon loss from Disturbance/Land-clearing/Harvest*
- The SEEA EA specifies (para 6.114) that regarding measuring carbon sequestration:
  - NECB is an appropriate metric;
  - In case NECB is zero or negative, the level of service supplied by an ecosystem will be zero.
- Guidelines recommend to measure NECB on a per ecosystem asset basis (for instance per grid cell). Carbon sequestration would hence be measured as the sum total of those ecosystem assets that provide a net uptake of carbon.
- Net primary productivity is considered a condition indicator for terrestrial ecosystems and is categorized in the functional class of the SEEA EA Ecosystem Condition Typology

Modelling options

- Follows Tiers specified by the IPCC Guidelines (IPCC 2006; Penman et al., 2003). Tiers increase with better stratification of land cover and nationally applicable coefficients thereby increasing in accuracy
- Tier 1: IPCC stock-difference method with default IPCC emission factors and parameters
  - InVEST's carbon storage and sequestration model: four carbon pools: aboveground biomass; belowground biomass; soil; and dead organic matter. Calculates both storage and sequestration, but requires user-specified carbon densities for each of these 4 pools for each of the land cover classes. This is an example of a single-layer look-up table.
  - ARIES for SEEA has implemented an IPCC Tier 1 approach following specifications of Ruesch and Gibbs (2008). Multi-dimensional look-up table.
- Tier 2: generally uses same methodology but country specific emission factors and parameters. More highly stratified data may be needed in Tier 2 (e.g. distinguishing between different forest classes)
- Tier 3: bespoke models using plot level data from National Forest Resource Assessments (FRAs). These models may include GIS-based information on forest age, class, production system, as well as soil parameters, thereby integrating data sources from various types of monitoring

Current ARIES for SEEA content: Global climate regulation

Methods

Tier 1 Intergovernmental Panel on Climate Change (IPCC) approach: Aboveground & belowground vegetation carbon storage quantified using a multilayer lookup table[1].

Data

Land cover, ecofloristic region, continent, presence of frontier forests (proxy for forest degradation), recent occurrence of fires, soil carbon storage.

Outputs

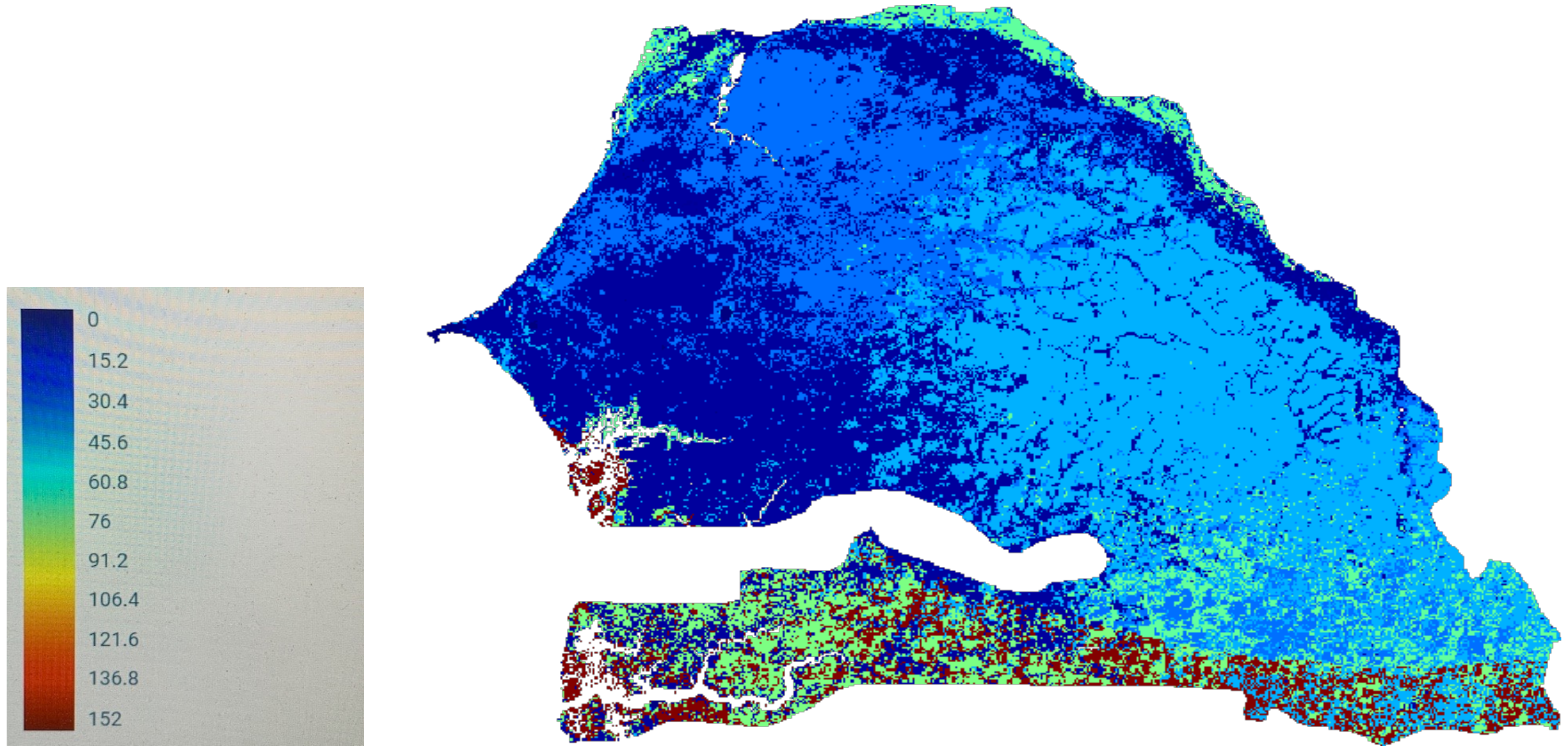
Estimated carbon stored in aboveground & belowground vegetation, plus the upper 2 m of soil. Results priced using Social Cost of Carbon.

Next Steps

Incorporate newer & more regional carbon storage estimates, as well as models more sophisticated than lookup tables.

1: Ruesch, A., & H.K. Gibbs. 2008. New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000. Available online from the Carbon Dioxide Information Analysis Center [http://cdiac.ornl.gov], Oak Ridge National Laboratory, Oak Ridge, Tennessee

Example: Senegal (Tier 1)



- ARIES for SEEA: carbon storage
  - Disaggregation by Ecosystem Type
  - Time series: 1995-2015
- Retention modelling :

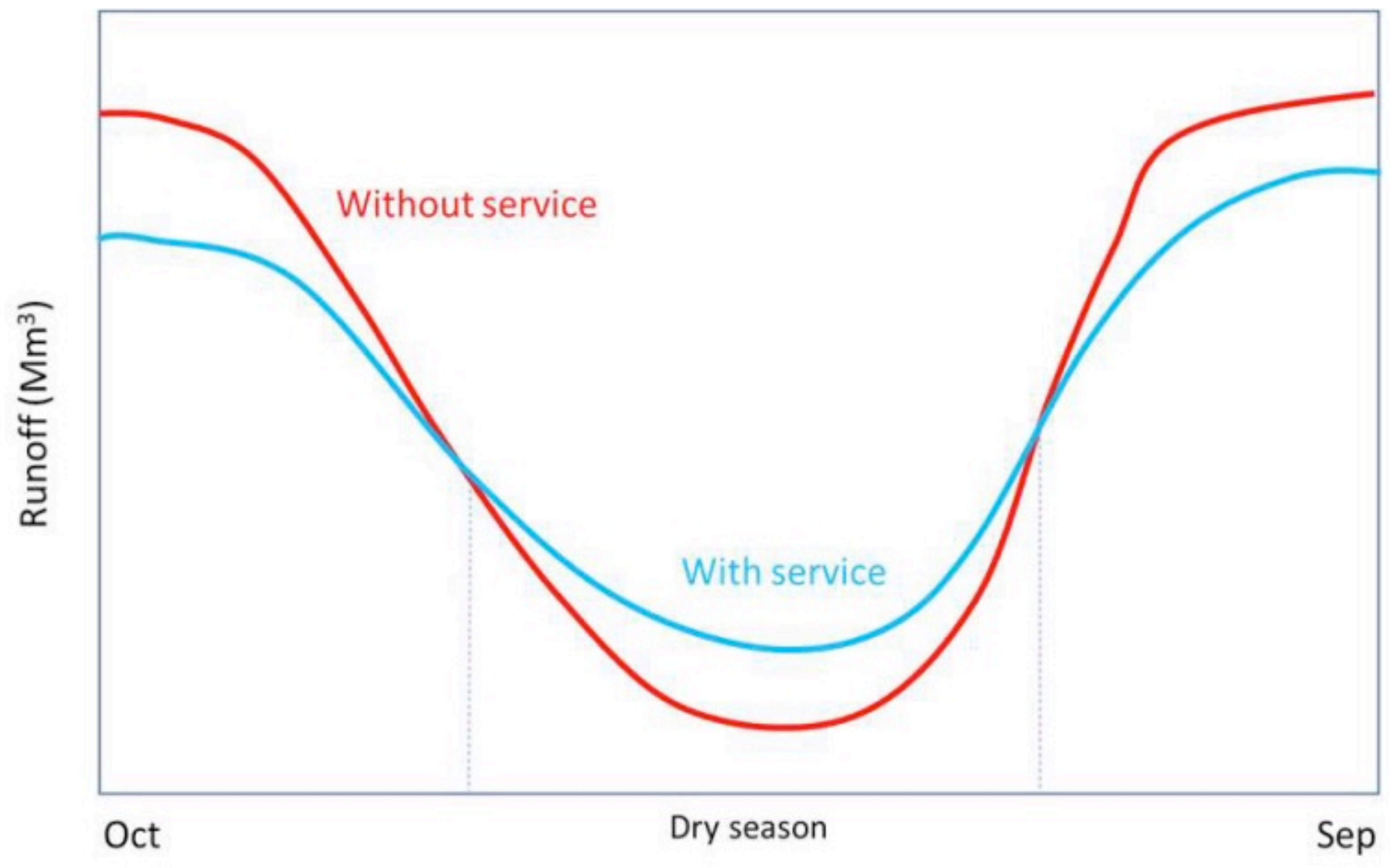
ES = Stock*price*rate of return

  - Social cost of carbon (Nordhaus (2017).
  - Costs assumed to increase 3% per year
  - Results: 11,1 billion USD, > 60% of GDP.
- Sequestration modelling:
  - Result: about 2 % of GDP

Million tons carbon	Intertidal forest shrubland	Coastal saltmarsh reedbed	Cropland	Urban industrial ecosystem	Tropical subtropical savanna	Seasonally dry tropical shrubland	Rocky pavement lavaflow scree	Tropical subtropical lowland rainforest	Tropical subtropical dry forest thicket	Other desert semidesert	Episodic arid floodplain	Tropical flooded forest peat forest	**Total**
Quantity at start of 1995 (tons C storage)	106	32	703	4	11	759	1	2	598	383	37	4	2,640
Quantity at start of 2015 (tons C storage)	106	33	714	7	11	710	0	1	651	377	37	4	2,652
Net change	**0**	**1**	**11**	**3**	**0**	**-49**	**0**	**-1**	**53**	**-6**	**0**	**0**	**12**

Water flow regulation

- Water regulation services consist of **baseline flow maintenance** services and **peak flow mitigation** services.
- Ecosystem contributions to regulation of river flows and groundwater and lake water tables.
- Derived from the ability of ecosystems to absorb and store water, and gradually release water during dry seasons or periods through evapotranspiration and hence secure a regular flow of water
- Likewise, this ability mitigates the effects of flood and other extreme water-related events.



- Different metrics that can be used to quantify the service depending also on the model that is used.
  - A good option is baseflow or local recharge
  - Change in volatility of stream flows.
  - The curve number component of InVEST's Sustainable Water Yield model is sometimes used as a proxy of runoff in relation to water flow regulation

Modelling options

- In order to model water flow regulation, it is essential to use a model with at least a monthly time scale
- Tier 1/2: A model such as the InVEST seasonal water yield model ESTIMAP's flood control model.
  > InVEST Seasonal Water Yield model: comparing current water yield patterns with existing land cover with the water yield that would arise in a counterfactual situation of bare soil

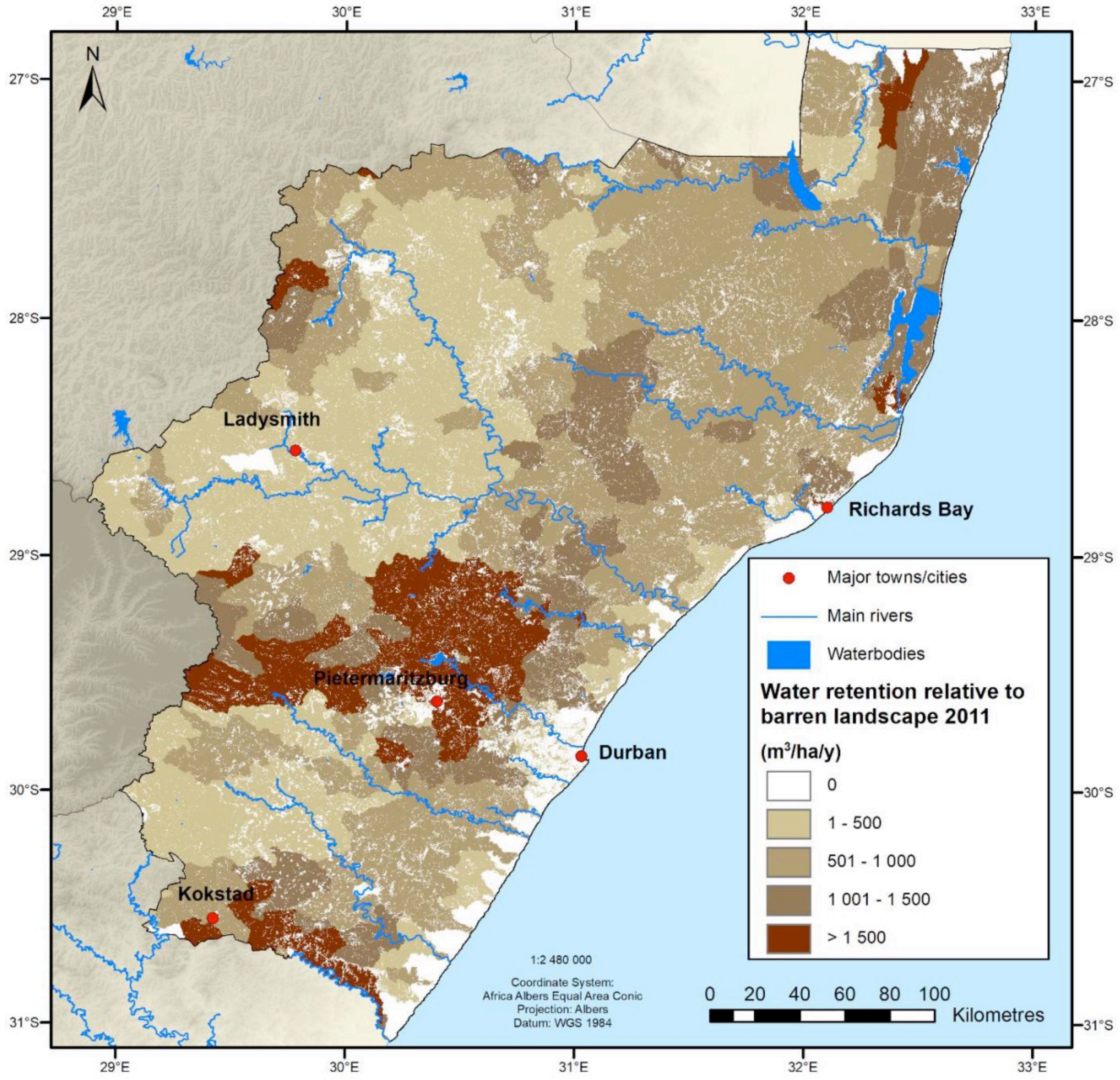
  > ESTIMAP model of flood control (Vallecillo et al., 2019): defines flood control as regulation of water flow by ecosystems mitigates / prevents potential damages to economic assets:

    - Potential runoff retention is modelled based on the curve number for land cover classes, corrected for imperviousness, slope and semi-natural land covers in riparian zones.
    - Based on certain thresholds, the model delineates flood control providing service areas.
    - Demand for flood control based on location of economic assets
    - Actual service flow: calculate for each spatial unit within the service demanding areas, the share of the upstream area to that unit that provides flood control services.
- Tier 3: Apply a model with a daily time step such as SWAT (soil and water assessment tool).
  > Example KZN study

  > Already set-up for Ghana

Water flow regulation/ flood control - SWAT

- KZN – water flow regulation modelled with SWAT – process-based model
- ES measured as difference in infiltration relative to a barren scenario, in m3 per ha. This was obtained from the SWAT output "Percolation", given in mm.
- Main intuition: ecosystems function as 'sponges' mitigating peaks and ensuring higher base flows
- Modeled at sub river basin level
- Results:
  - > Maps
  - > Tables



Source: Turpie et al. 2021

Sediment retention

- Soil erosion control services are the ecosystem contributions, particularly the stabilizing effects of vegetation, that reduce the loss of soil (and sediment) and support use of the environment (e.g., agricultural activity, water supply) (UN et al 2021).
- Sometimes described as **soil erosion prevention** or **sediment control**.
- Soil retention is also linked to natural-hazard reduction by stabilizing slopes and preventing landslides, which is seen in SEEA EA as a separate (sub) ecosystem service.
- The target unit for sediment retention for SEEA EA ecosystem service supply accounts is the volume of sediment per year retained due to the presence of ecosystems.
- Foundational to many sediment retention models is RUSLE (Revised Universal Soil Loss Equation)
- RUSLE output: sediment loss per year and SEEA EA aims to measure sediment retained per year
  - > further conversion of this RUSLE output is needed
  - > Assess difference in outputs assuming current land cover versus assuming bare land (i.e. by running the model twice

Modelling options

- Tier 1: Sediment retention modelling that relies on globally available data sets and pre-constructed ecosystem service models (i.e. InVEST, ARIES, ESTIMAP, LUCI/Nature Braid),
  - uses freely available tools and requires very little user input.
  - Inputs to the model include raster data sets of climate, soil, elevation, land use and land cover, as well as look-up tables for crop management and support practice factors (Hamel et al., 2015).
  - A key benefit of the InVEST and LUCI/Nature Braid models is that they quantify the connectivity of each pixel to streams. In other words, these models can calculate the sediment that is likely to leave a given pixel, as opposed to just potential erosion.
- Tier 2: Sediment retention modelling that relies on national data sets, requiring some customization and instream sediment measurements for validation.
- Tier 3: sediment retention models are implemented using best available local data using customized models that have been parametrized and calibrated for local contexts.
  - An example model is the Unit Stream Power Erosion and Deposition (USPED)
  - SWAT / can run at a daily temporal scale; very data intensive requiring a wide range of inputs. SWAT is typically applied at the local/watershed scale and not at the national level

Erosion control ARIES output

Methods

Estimates **soil held in place by vegetation** that would otherwise be lost, by calculating the difference in soil erosion modelled under existing land cover vs. bare soil (**Revised Universal Soil Loss Equation, RUSLE**[1])

Data

5 inputs:

1) slope steepness and length (DEM)
2) rainfall erosivity
3) soil erodibility
4) support practice
5) cover management

Outputs

Soil retained by vegetation (T) that would be lost to erosion with bare soil

Next steps

1. Incorporate **sediment delivery** through upstream-downstream connectivity.
2. Valuation (multiple beneficiaries, extremely challenging to generalize).

	Coastal saltm	Cropland	Alpine grasslanc	Temperate woodla	Temperate subhu	Rocky pavement la	Cool temperate he	Temperate forest	Episodic arid	Boreal cool te	Aquatic	**Total**
Soil retained 2012 (tons)	20	529086	1868	154088	40335	366234	435579	1244001	22	86	0	2773088
Soil retained 2018 (tons)	20	528441	1868	154595	39815	365267	436059	1243262	22	86	0	2771203
Net change	0	-645	0	507	-519	-967	480	-739	0	0	0	-1886

THANK YOU

seea@un.org // https://seea.un.org/