Biophysical Modelling & GIS

Regional Training Workshop on the SEEA Experimental Ecosystem Accounting for Countries of Latin America and the Caribbean

21-23 November 2018, Rio de Janeiro, Brazil

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  - Why do it?
  - What does it entail?
- Methods, applications and examples
  - SEEA context:
    - Spatial modelling
    - Temporal modelling
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  - General modelling

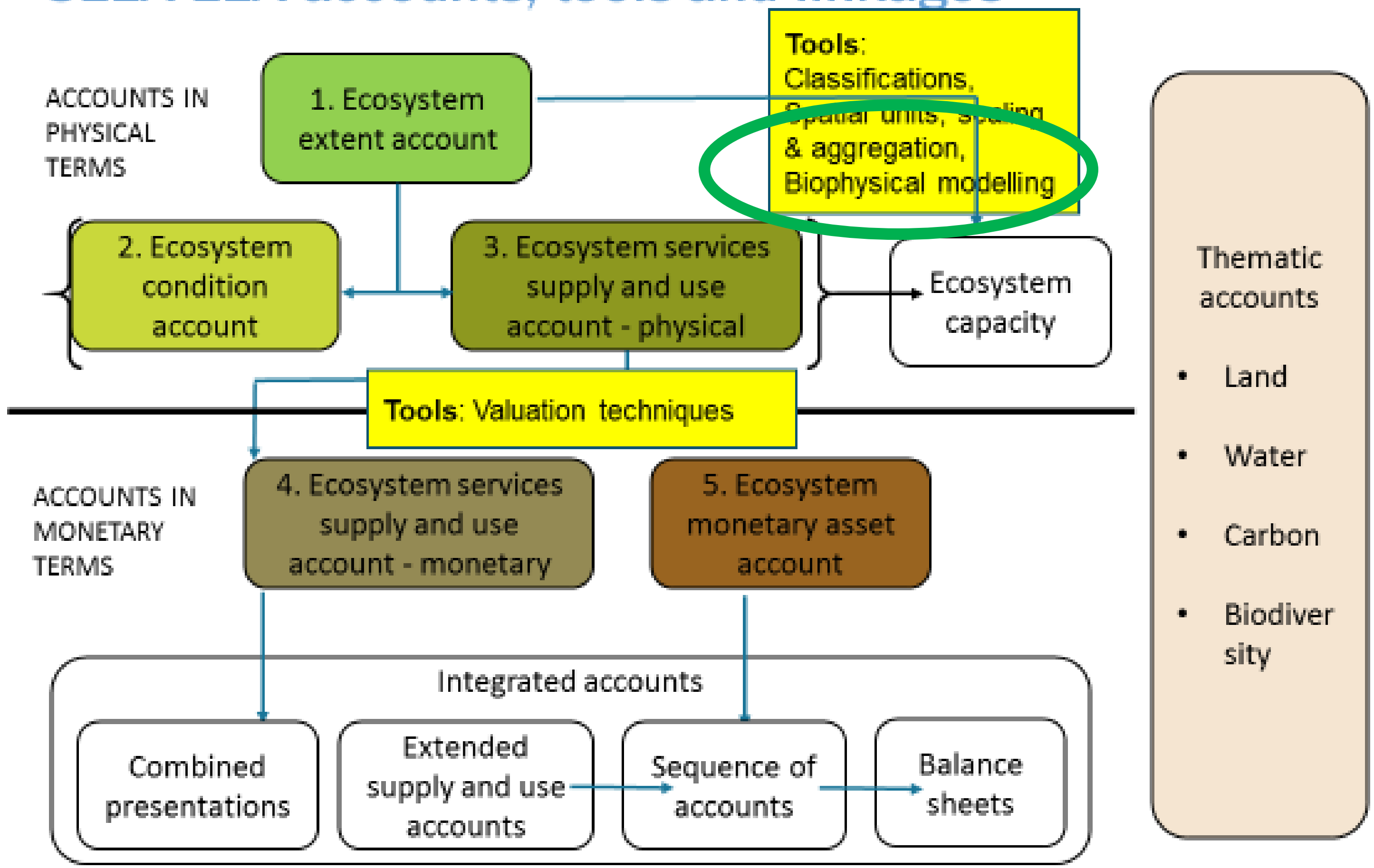
- Summary/ key points

Biophysical modelling

= modelling biological and/or physical processes in order to analyze the biophysical elements of an ecosystem account.

- In the condition account: modelling of ecosystem state indicators
- In the ecosystem services account: modelling the supply of ecosystem services by ecosystem, in an accounting period
- In the asset account: modelling the supply of ecosystem services, by ecosystem, during the ecosystem asset life (spatial and temporal dimension)

SEEA-EEA accounts, tools and linkages



Introduction: Biophysical modelling

- **Why?**
  - Accounts require a full spatial cover of ecosystem condition, services flows or asset values. Hence – condition indicators, services, and asset need to be defined for the total area of the accounting area.
  - Often – for some services or condition indicators - data are only available for specific locations. Usually, data from various sources and scales need to combined (e.g., point field data and satellite data)
  - **Spatial models** can be used to integrate point and spatial data and obtain full spatial cover of information, and to model ecosystem services flows.
  - **Temporal models** are required for the asset account, where the flow of services during asset life needs to be considered. This may involve linking changes in condition to changes in ecosystem services flows

Spatial modelling: how (1)

Spatial models have been developed over decades, and are available for a wide range of services. They are usually integrated in a GIS:

- GIS = Geographical Information System: integrated system combining hardware (processing capacity + data storage), software and spatially georeferenced data.
- The two most widely used GIS systems are:
  - ArcGIS: commercial product, high processing capacity, many add on models available
  - QuantumGIS (also called QGIS): freeware, add on models are also available.
  - Information can be exchanged easily between the two systems.
- Which one to select?: depends upon context:
  - Which systems are already used in the government agencies supplying / processing data?
  - Is there budget for ArcGIS?

Spatial modelling, how (2)

Spatial modelling is always done in a GIS and involves:

- A coordinate system to link the various datasets in the GIS (can be a global or national coordinate system)
- Storing data (from remote sensing images, existing topographic and/or thematic maps, georeferenced spot data, processed data)
- Models/algorithms to:
  - Inter and extrapolate data in order to obtain full spatial cover
  - Models for specific condition indicators & ecosystem services
  - Temporal models for ecosystem assets
- Tools for viewing and sharing data (standard tools are in ArcGIS and QGIS, but specific tools are needed to make information available on-line)

Stand alone GIS model or Modelling Platform? (1)

- Instead of stand alone GIS packages, the use of modelling platforms has been proposed. Modelling platforms include predefined models for analysing ecosystem services.
- Modelling platforms include Aries, EnSYM, INVEST, LUCI, GLOBIO, etc.
- There are large differences between these modelling platforms, in terms of scope/level of detail/accuracy/data needs and flexibility of the modelling approaches

Stand alone model or Modelling Platform? (2)

Advantages of Modelling platforms:

- Easier start with SEEA EEA by using predefined models
- Some platforms (e.g. Aries) offer sophisticated ecosystem services models

Disadvantages of modelling platforms

- Need to learn to use modelling platform (which usually also involves applying ArcGIS or QGIS). Some platforms are complex (e.g. Aries)
- Dependency upon platform developers for technical support, updates, etc.
- Lack of flexibility of platforms to accommodate differences in ecosystem characteristics, data availability and technical capacities between countries Some of the models quite simplistic (e.g.InVEST), can only be used as an entrée to EEA
- Relatively small user communities (compared to total GIS community)
- There are many different relevant models (e.g. on hydrology) available for ArcGIS and QGIS without the need for an integrated modelling platform

Modeling platform	Advantages	Disadvantages	Synthesis
ArcGIS or QGIS	Flexibility, potentially therefore most accurate, allows full control over data (does not require data sharing with outside servers), not dependent upon external expertise	Requires advance GIS skills, requires time to prepare models and set up data infrastructure	Preferred approach where GIS skills are available or can be built up
Aries	Flexibility, connection to available datasets, information on uncertainty, well documented, freeware	Requires training in Aries, may involve sending data to Aries servers, up to a degree ‘black-box’ outputs, dependency on Aries community for maintenance of models	Very suitable to advanced ecosystem services modeling and trade-off analyses, potentially, in current format, less suitable for accounting
Co$ting Nature	Quantitative approach, open access, based on global datasets, partially documented, relatively easy to apply	Difficult to integrate custom defined input datasets, tool not well aligned with SEEA concepts, focus on aspects relevant for conservation, applied at landscape scale	Not very suitable for accounting, given the disadvantages.
Ensym	Quantitative approach, open access, modular including module based on Modflow	Application of modules still requires expert knowledge, partially documented, tested in limited number of cases, limited	Potentially suitable to support accounting, for those services for which modules are available

Modeling platform	Advantages	Disadvantages	Synthesis
Globio,	Easy to apply, requires very little expert knowledge	Focused on biodiversity, high uncertainty in numbers (related to its initial development for application at the global scale), one aspect of biodiversity	Useful as indicator for trends in biodiversity at continental scale, not very suitable at local scale, further testing of accuracy and representativeness required before it could be used for accounting
InVEST	Has been widely applied, well documented, open access, relatively simple to use (needs ArcGIS or QGIS environment)	Some of the modules somewhat simplistic/ coarse (e.g. hydrological models), limited analysis of accuracy and uncertainty	Can be used for initial testing of SEEA accounting approaches in low data environment, insufficient detail for advanced accounting
MIMES	Quantitative, flexible, detailed modeling possible (but requires high inputs of time), open access	Only applied in relatively few case studies, not at national scale, requires SIMILE ecological modeling software, time consuming to develop,	Potentially very suitable to analyze specific environmental policy questions with a spatial and temporal dimension, but not very suitable for SEEA ecosystem accounting
LUCI	Open access, quantitative, spatially detailed models.	Only tested in temperate environments, to date applied up to landscape and national scale. Requires ArcGIS to operate.	May be applicable to support SEEA in temperate or humid countries but further testing is required.

Fig 1 from Bagtad et al. (2013):


Ecosystem Services
Volume 5, September 2013, Pages 27–39

A comparative assessment of decision-support tools for ecosystem services quantification and valuation

Kenneth J. Bagstad[a], Darius J. Sem

[a] U.S. Geological Survey, Geosciences & Environme
[b] BSR, San Francisco, CA, USA
[c] Socioeconomics Program, USDI—Bureau of Land

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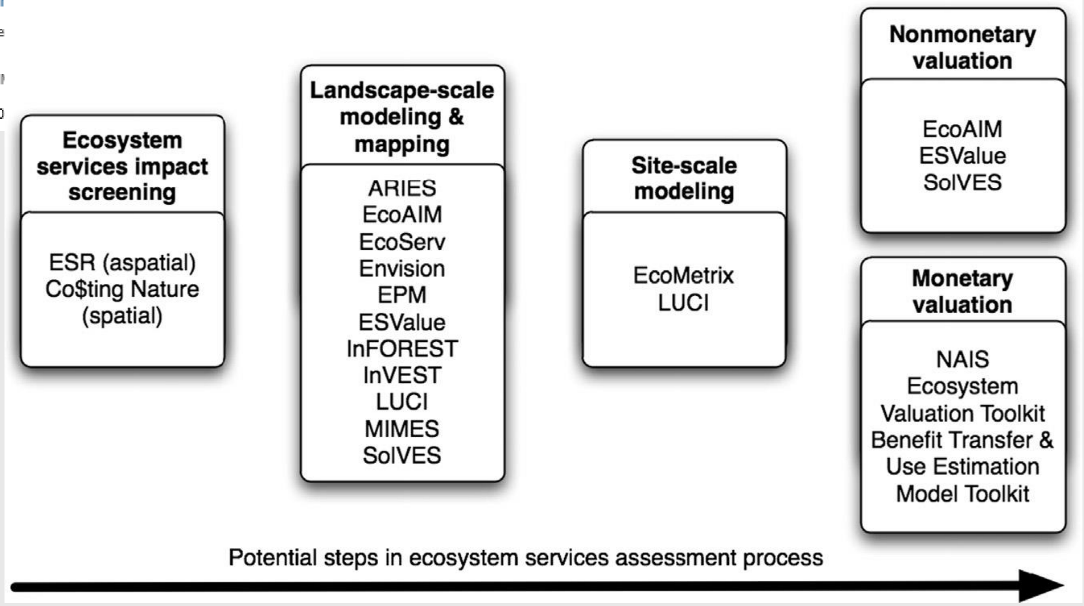
<u>Ecosystem services</u> are the benefits mankind derives from a range of ecosystem processes

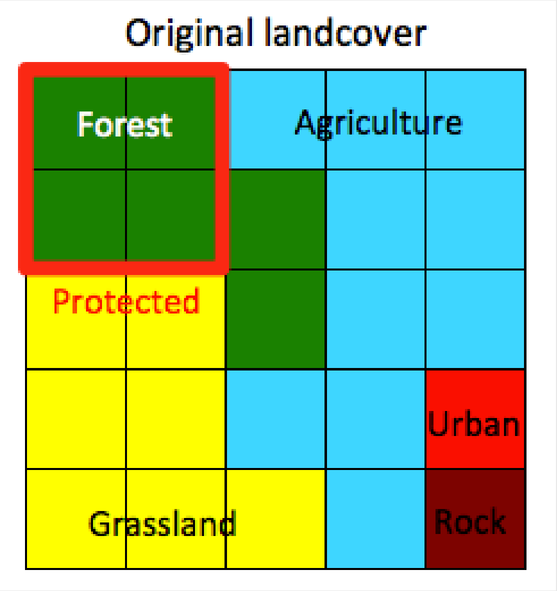


Modelling ecosystem services

- A wide range of models is available to model specific elements of the ecosystem condition or services accounts. These models may require somewhat different data or may have different functionalities that make them more or less appropriate in specific contexts.
- For instance there are many models for modelling hydrology and water related ecosystem services
- Often, there are national experts experienced in the use of some of these models. It is recommendable to consider the available expertise and data when selecting models for SEEA EEA.

Biophysical modelling types

- **Model types**:
  1. **Look-up tables**
  2. Statistical approaches
  3. Geostatistical interpolation
  4. Process-based modeling

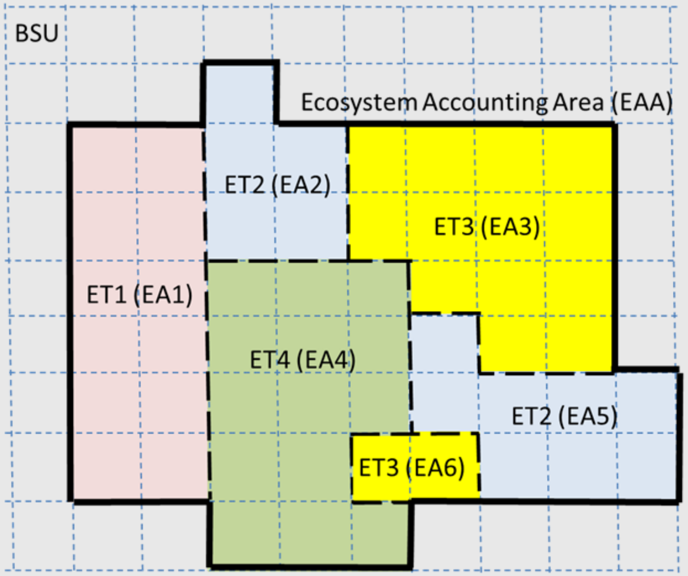


Source: Natural Capital Project

Attribute values for an ecosystem service (or other measure) to every **Spatial Unit** in the same class (e.g., a land cover class).

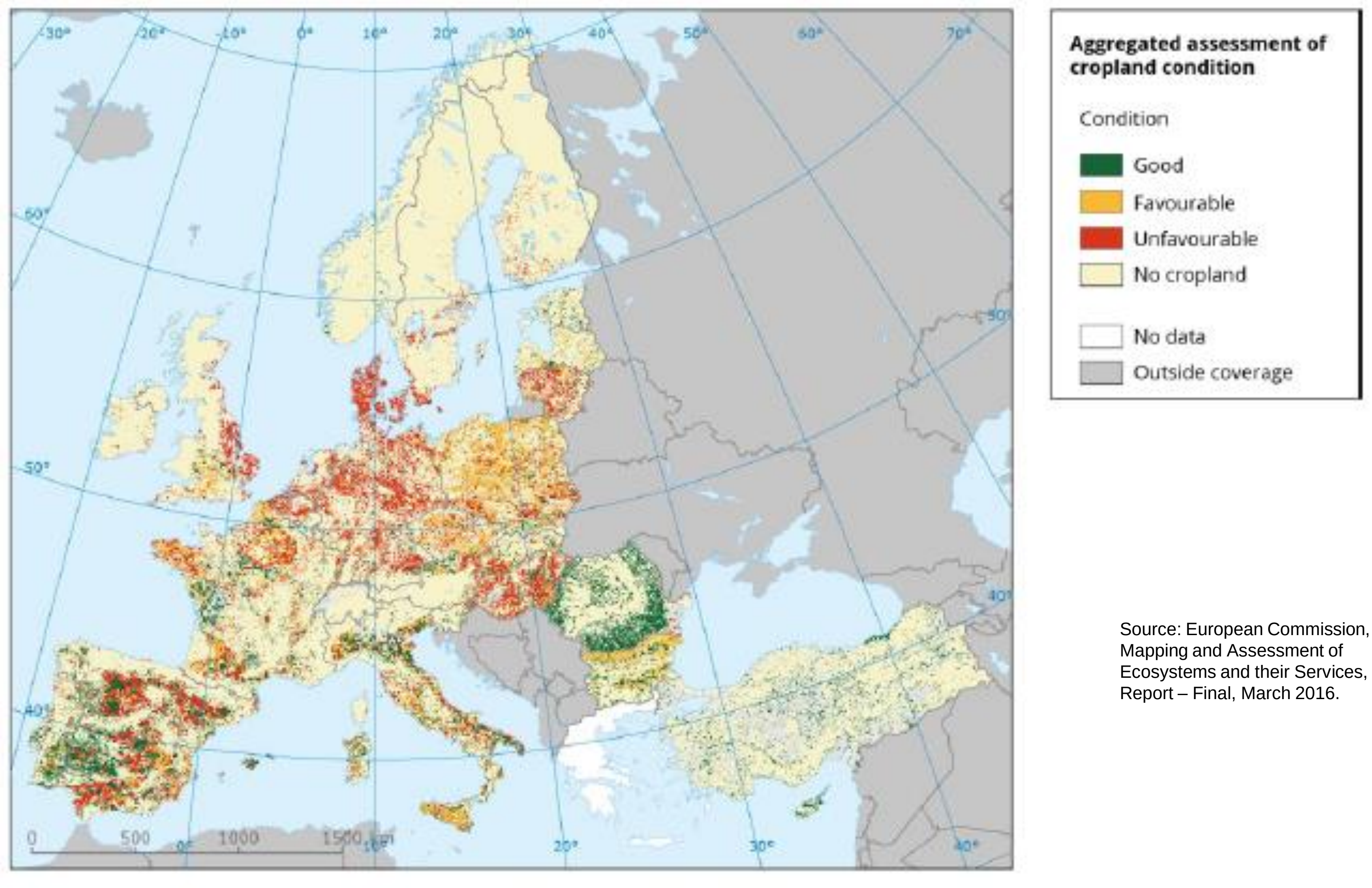
- Example: **Carbon storage**
- *one ha of forest = X tonnes → attribute to each ha of forest*

Accounts aggregate spatial units and aggregate /map information to tables



4 types of units
-Basic spatial units (BSU)
-Ecosystem asset (EA)
-Ecosystem type (ET)
-Ecosystem Accounting Area (EAA)

Purpose is important for display and to dictate detail of underlying data/ability to map back



Source: European Commission, Mapping and Assessment of Ecosystems and their Services, 3rd Report – Final, March 2016.

Biophysical modelling approaches

- **Approaches**:
  1. Look-up tables
  2. **Statistical approaches**
  3. Geostatistical interpolation
  4. Process-based modeling

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.

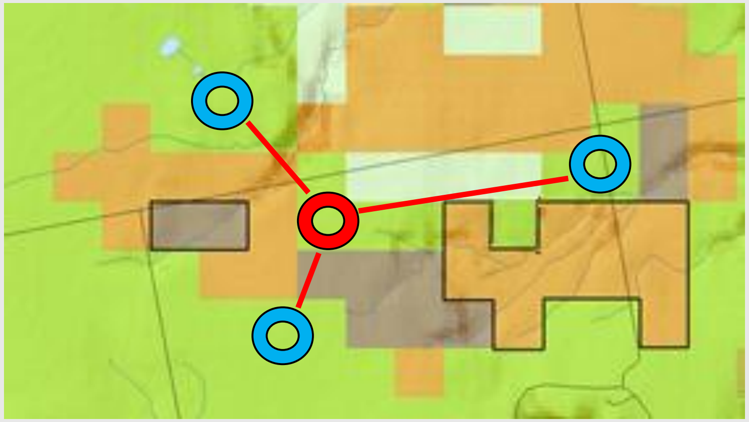
- Example: **Habitat quality**
- *value = f(land cover, population, distance to roads, climate,..)*

Biophysical modelling approaches

- **Approaches**:
  1. Look-up tables
  2. Statistical approaches
  3. **Geostatistical interpolation**
  4. Process-based modeling

Use algorithms to predict the measure of unknown locations on the basis of measures of nearby known measures:

- **Timber**

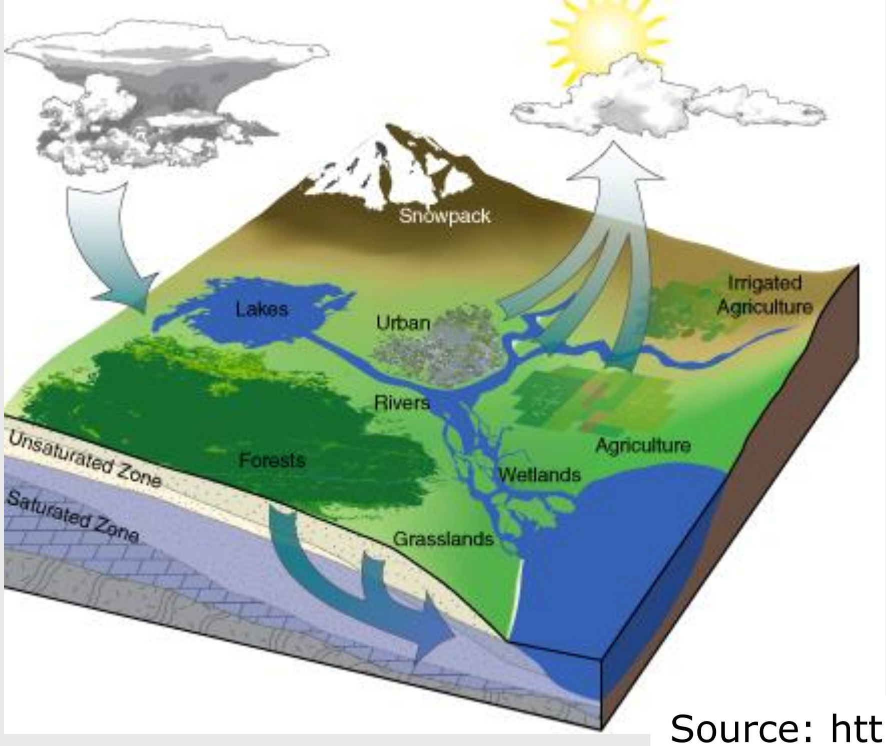


Unknown
Known

Source:https://img.wikinut.com/img/3tpc523nbou--ksz/jpeg/0/Timber-and-Wood.jpeg

Biophysical modelling approaches

- **Approaches**:
  1. Look-up tables
  2. Statistical approaches
  3. Geostatistical interpolation
  4. **Process-based modeling**



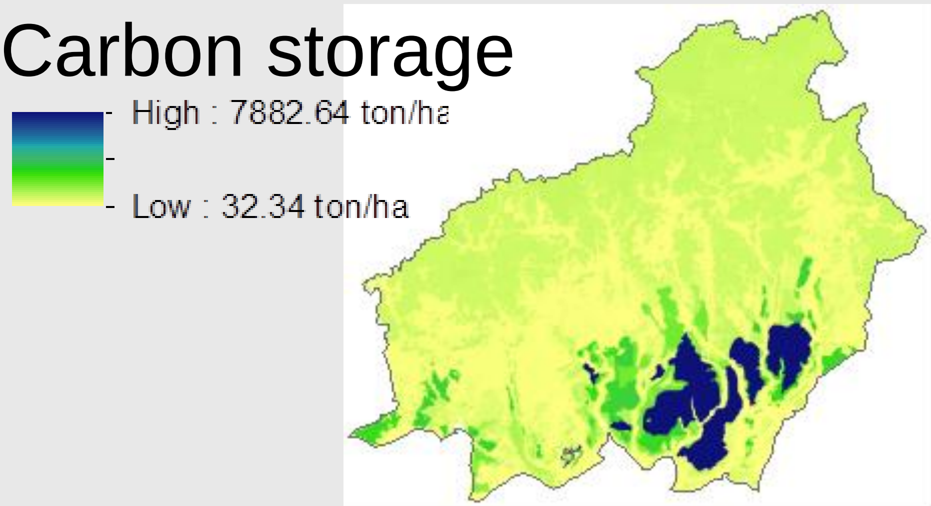
Predict ecosystem services based on modelling of processes involved in supplying the service:

- Example: carbon sequestration.
- Carbon sequestration can be modelled as the Net Primary Production of the vegetation minus the autotrophic respiration ("rotting leaves") minus the loss of carbon due to wood harvest and fire.

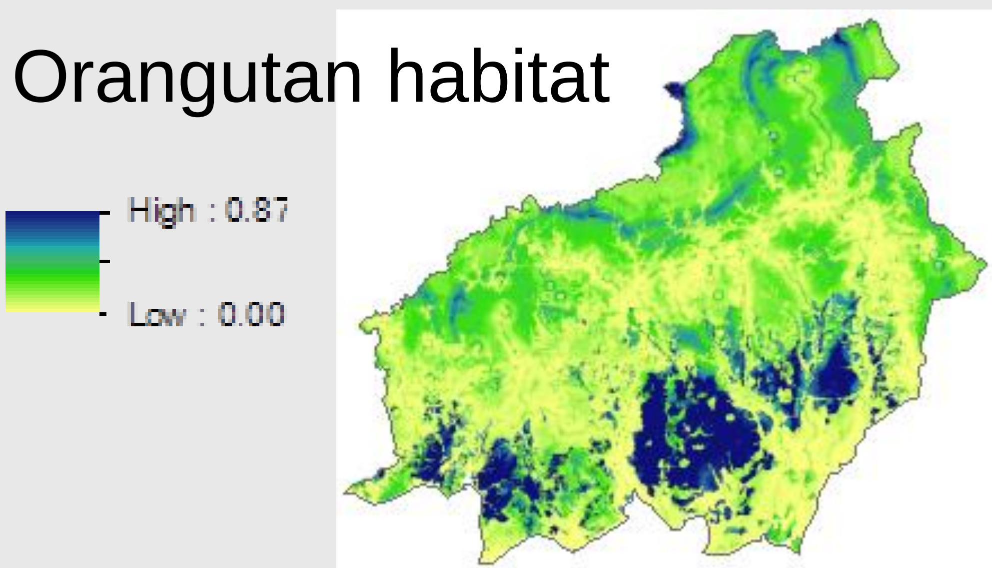
Source: http://hydrogeology.glg.msu.edu/research/active/ilhm

Ecosystem services Central Kalimantan

Carbon storage



Orangutan habitat



Model used

Look Up Tables (every land cover class is attributed a specific carbon storage value)

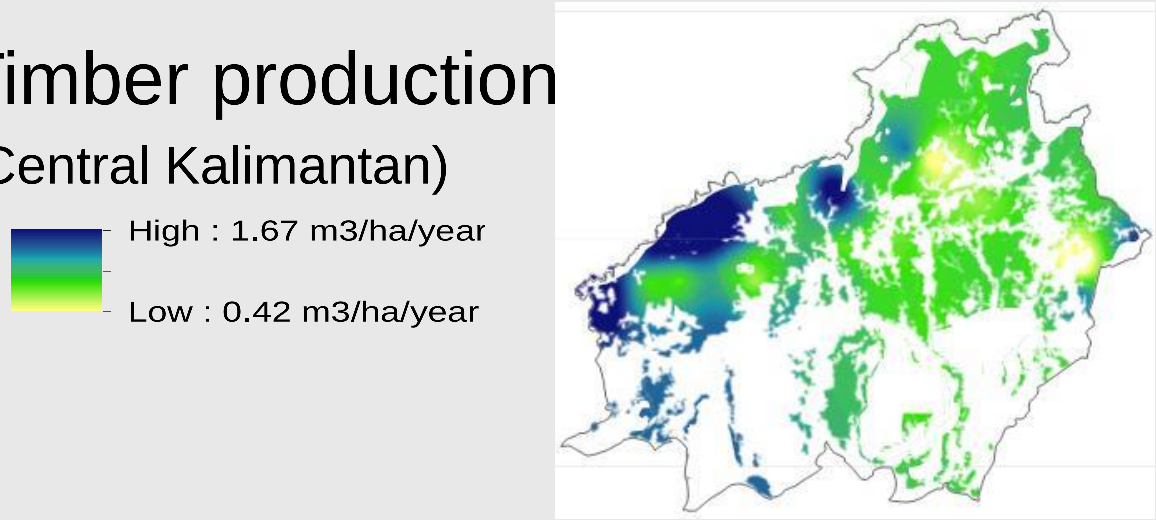
Statistical model (Maxent) (habitat suitability predicted on the basis of forest cover, distance from road, etc.)

Source: Sumarga and Hein, 2014

Ecosystem services

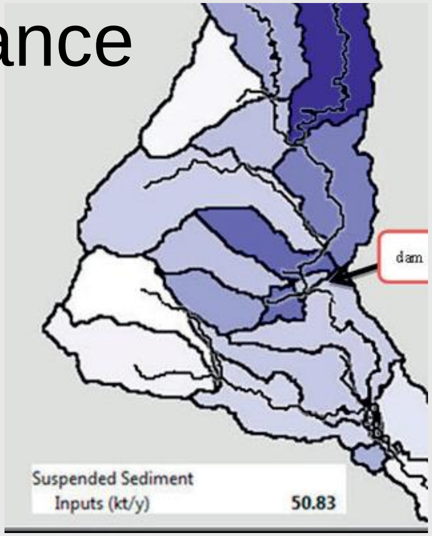
Timber production

(Central Kalimantan)



Erosion control / avoidance of sedimentation

(Palawan, Philippines)



Model used:

Kriging (values are interpolated from samples)

Source: Sumarga and Hein, 2014

Process-based Model (Sediment retention modelled with hydrological model, in this case SedNet)

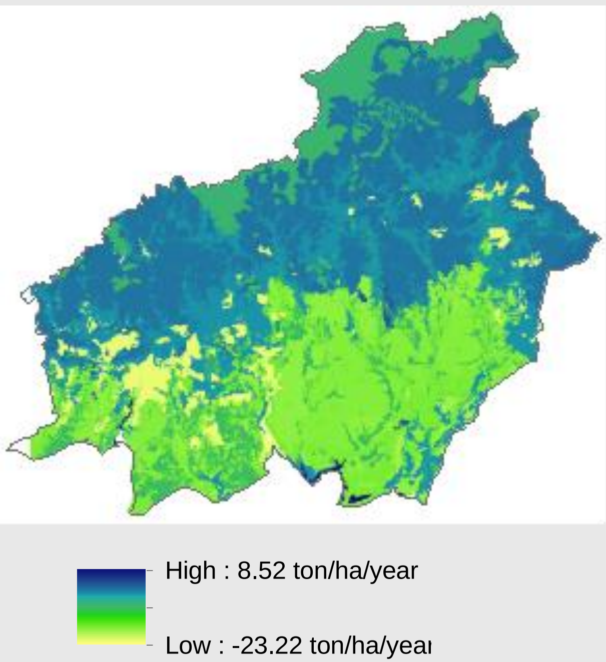
Source: Philippines WAVES program, 2015

Sometimes, multiple methods can be used to map the physical supply of an ecosystem service – comparing the outcomes of the methods indicates accuracies achieved.

- Carbon sequestration, for instance, can be mapped with a process based model or a Lookup Table approach.
- In the process based model,
- CS = NPP – AR – C_fires – C_harvest, with:
  - CS = carbon sequestration
  - NPP = Net Primary Production of the vegetation (which can be estimated with satellite images)
  - AR = Autotrophic Respiration (CO_2 released from e.g. rotting leaves)
  - C-fires = Carbon loss due to fires
  - C-harvest = Carbon loss due to wood harvest.

Carbon sequestration can also be estimated with a Lookup Table approach

Carbon sequestration



Land cover	Carbon flux; + indicates sequestration, - is emission (ton C/ha/year)	Sources
Mangrove	8.5	Komiyama (2006)
Primary dipterocarps forest (protected forest)	0.8	Hirata et al. (2008)
Primary dipterocarp forest	0.6	Hirata et al. (2008)
Secondary dipterocarp forest	4.0	Luyssaert et al. (2007); Hirata et al. (2008); Saigusa et al. (2008)

Source: Sumarga and Hein, 2014

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Example of a process based model to assess an ecosystem services (source: WAVES Philippines, Palawan island)

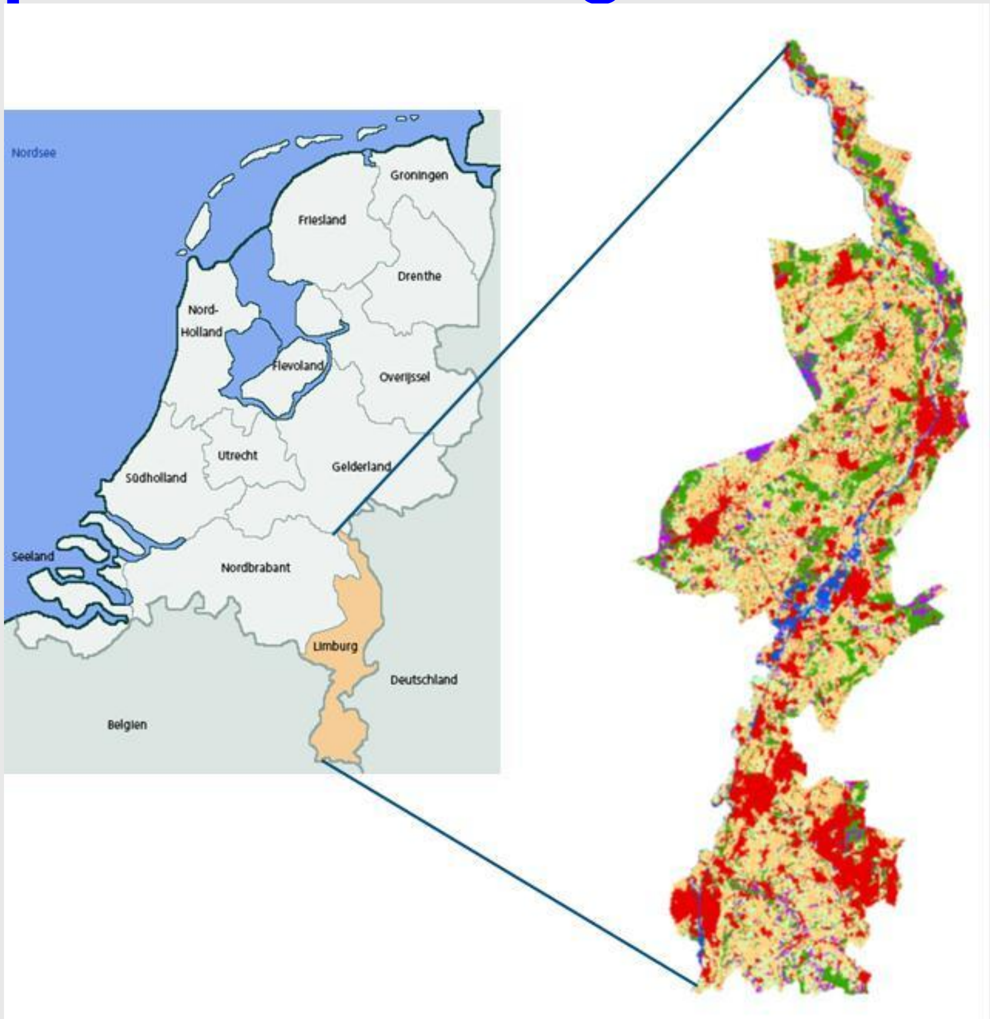
- Siltation of a reservoir for a local irrigation scheme reduces the amount of water available for irrigation
- Forest prevent erosion and thereby siltation in this reservoir and hence provide an ecosystem service
- Modelling this service can be done with various hydrological models

Year	Sediment generated (kton/year)	Avoided sedimentation due to remaining forest cover	Avoided loss of rice production
2010	37	745	23% of 2010 production
2014	53	703	20% of 2014 production

Model type	Applicability across ecosystem types indicators	Data needs (+++ = limited, + = a lot)	Efforts involved in applying the model	Freeware software available	Allows analyzing reliability/ accuracy	Verified/ tested/ documented
Lookup Table	++	+++	+++	+++	+	+++
Spatial interpola-tion	+++	++	++	+++	+++	+++
Statistical models	+	++	++	+	+++	++
Process-based models	++	+	+	+	++	+
Machine learning	+++	+++	++	+++	+++	++

Compiling an ecosystem services supply and use table, example for Limburg

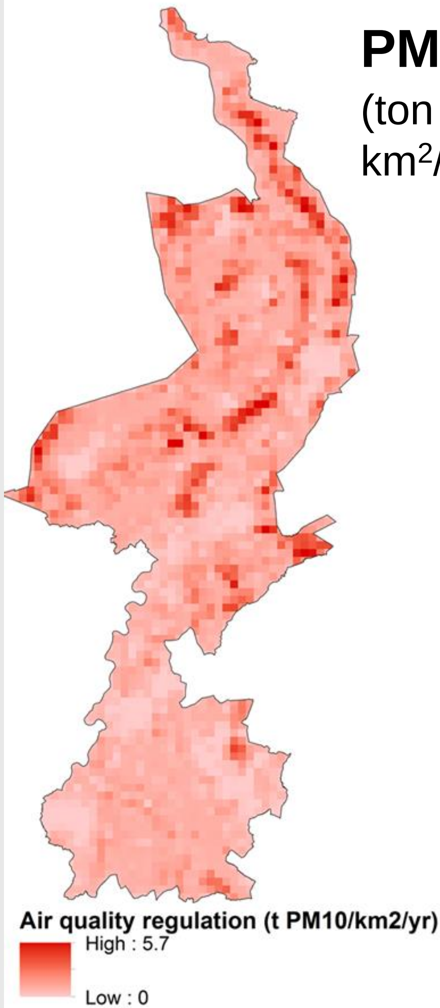
- Ecosystem accounts have been developed for Limburg Province, the Netherlands
- Including 7 ecosystem services provided by 8 types of land cover



Ecosystem accounts example: Limburg

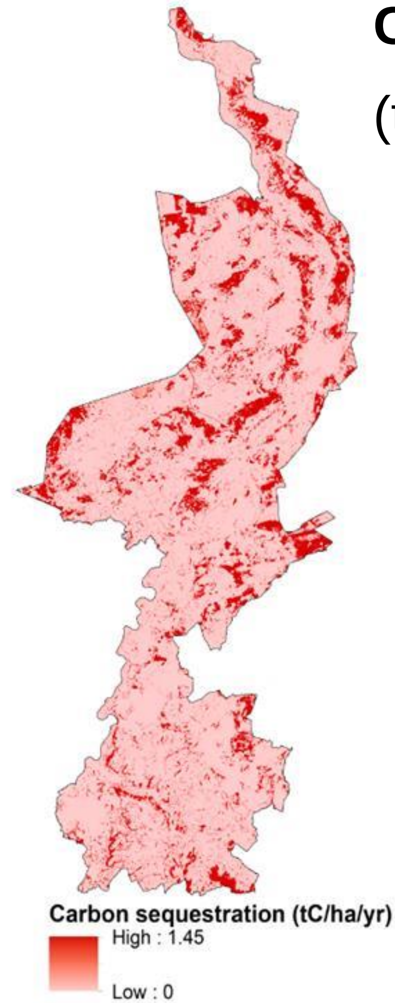
PM10 capture

(ton PM10 captured/ km²/year)



C sequestration

(ton C/ha/year)



Source: Remme et al., 2014

Physical ES supply and use table Limburg

Ecosystem type	Ecosystem service					
	Hunting		Air quality regulation		Carbon sequestration	
	Total	Mean	Total	Mean	Total	Mean
	kg meat	kg meat/km^2/yr	ton PM_{10}	kg PM_{10} /km^2/yr	1000 kg C	1000 kg C/ha/yr
Pasture	9,100	21	404	909	8019	0.18
Cropland	14,732	20	717	956	273	0.03
Forest	8,100	23	700	2,001	51000	1.5
Water	-	-	40	613	0	0
Urban	-	-	272	535	875	0.02
Provincial total	34,193		2,254		61400	

Source: Remme et al., 2014

Modelling temporal changes in ecosystems

- Temporal models are required to analyse changes in ecosystem assets over time – hence for the monetary ecosystem asset account
- When there is degradation, the flow of ecosystem services may decrease over time. This needs to be reflected in the NPV of the ecosystem asset
- Often it is very difficult to assess such changes, in particular over a period of several decades
- It is recommended to only develop these models for ecosystems and ecosystem services where there are clear indications of degradation.
- This type of modelling involves either process based or statistical models

Modelling temporal variability

- With process based models, the change in an ecosystem, for example due to overharvesting, can be related to the supply of ecosystem services by that ecosystem.
- For instance, if a forest is overharvested, it's regenerative capacity may decrease (i.e. the regrowth of the forests is reduced).
- With a process based model, the regeneration rate of the forest can be modelled,
- This can be done, for example, using a simple logistic growth model, with:
  - dP/dt = growth rate (e.g. of timber)
  - r = growth rate (which may decline)
  - P = state variable (e.g. timber stock)
  - K = carrying capacity

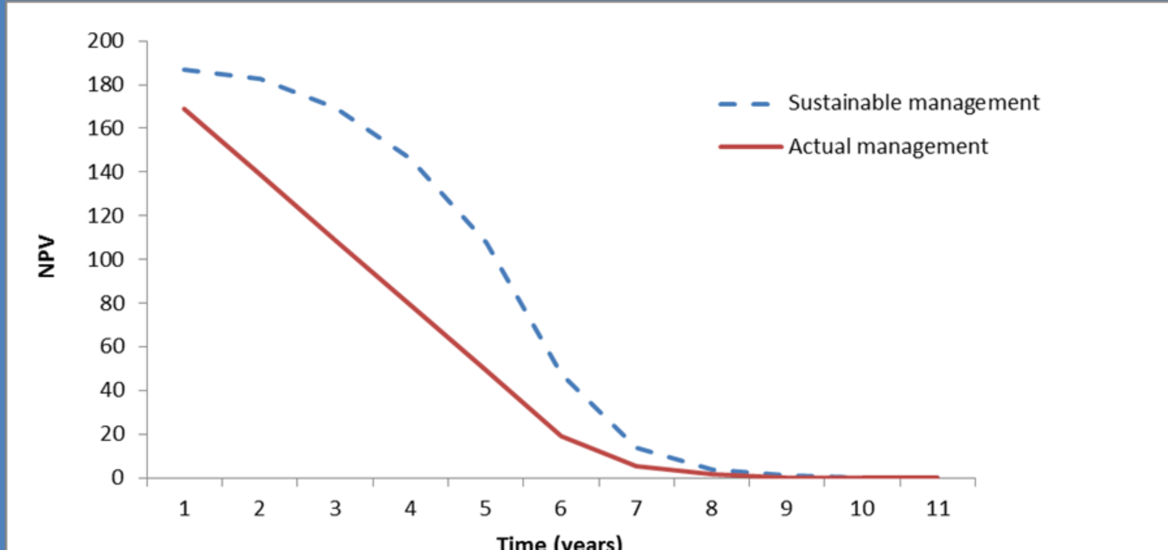
$$\frac{dP}{dt} = rP \cdot \left(1 - \frac{P}{K}\right)$$

- In the context of SEEA EEA, such temporal changes in ecosystem asset have not yet been modelled in any country

Stylised example asset value

- The monetary ecosystem asset account uses NPV
- Assets are valued based on actual use, not sustainable or optimal use
- This example shows how the asset value can be modelled

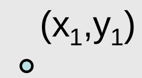
year	1	2	3	4	5	6	7	8	9	10
Stock (ton)	100	85	70	53	35	14	4	1	0	0
Sustainable yield (ton)	15	15	14	12	9	4	1	0	0	0
Actual harvest (ton)	30	30	30	30	30	14	4	1	0	0
Net value per ton (euro)	1	1	1	1	1	1	1	1	1	1
Revenue sustainable yield (euro)	15	15	14	12	9	4	1	0	0	0
Revenue actual management (euro)	30	30	30	30	30	14	4	1	0	0
NPV at sustainable management (euro)	187	183	170	146	108	48	14	4	1	0
NPV at actual management (euro)	169	139	109	79	49	19	5	2	0	0



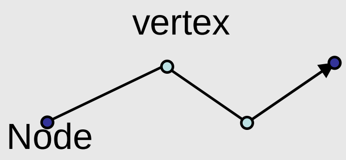
Spatial Data: Vector format

Vector data are defined spatially:

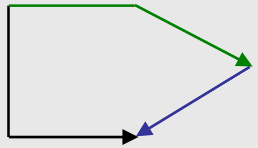
Point - a pair of x and y coordinates



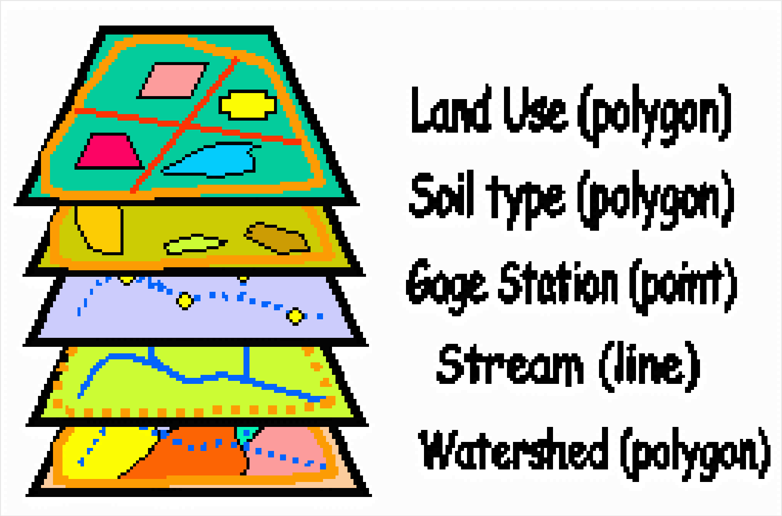
Line - a sequence of points



Polygon - a closed set of lines

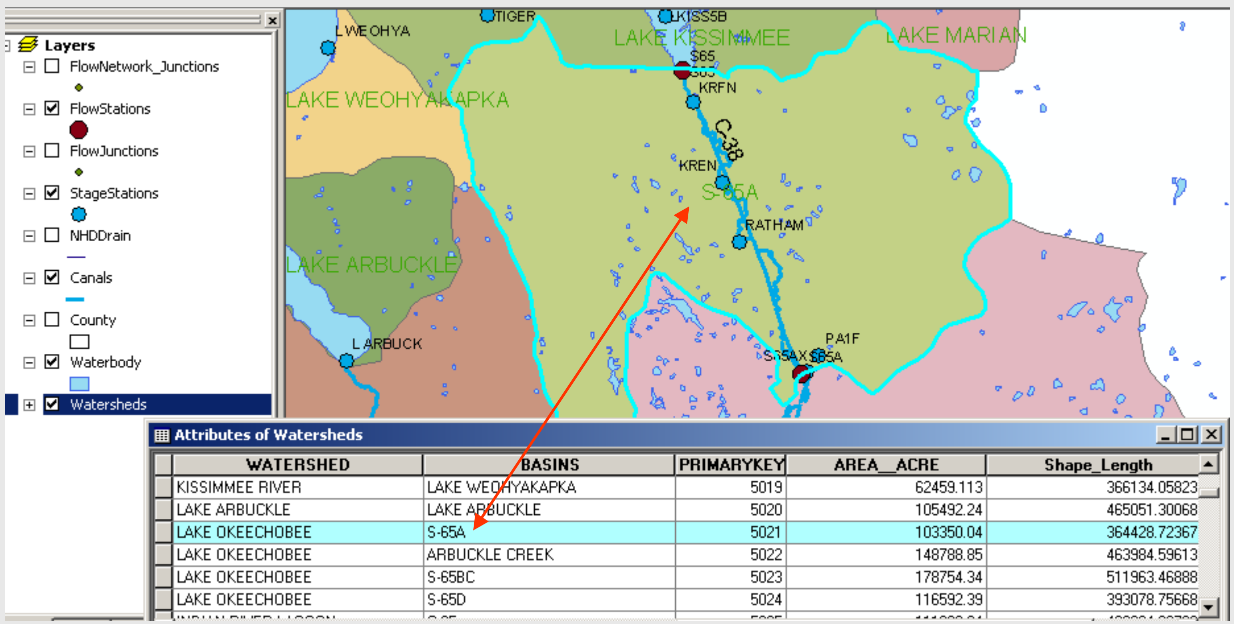


Themes or Data Layers



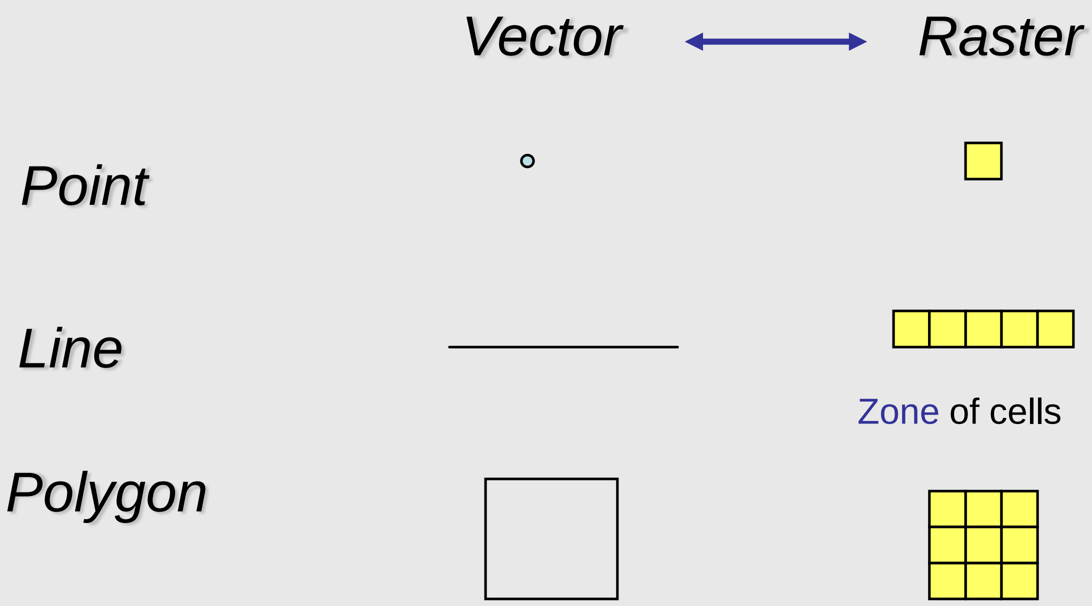
Vector data: point, line or polygon features

Attributes of a Selected Feature



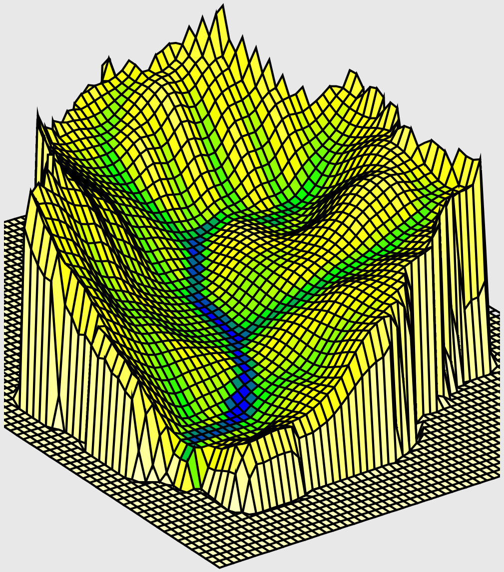
Raster and Vector Data

Raster data are described by a cell grid, one value per cell

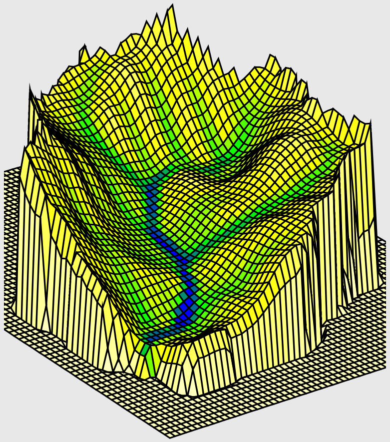


Digital Elevation Model Based Watershed and Stream Network Delineation

- Conceptual Basis
- Flow direction
- Flow accumulation
- Pit removal and DEM reconditioning
- Stream delineation
- Catchment and watershed delineation
- Geomorphology, topographic texture and drainage density
- Generalized and objective stream network delineation

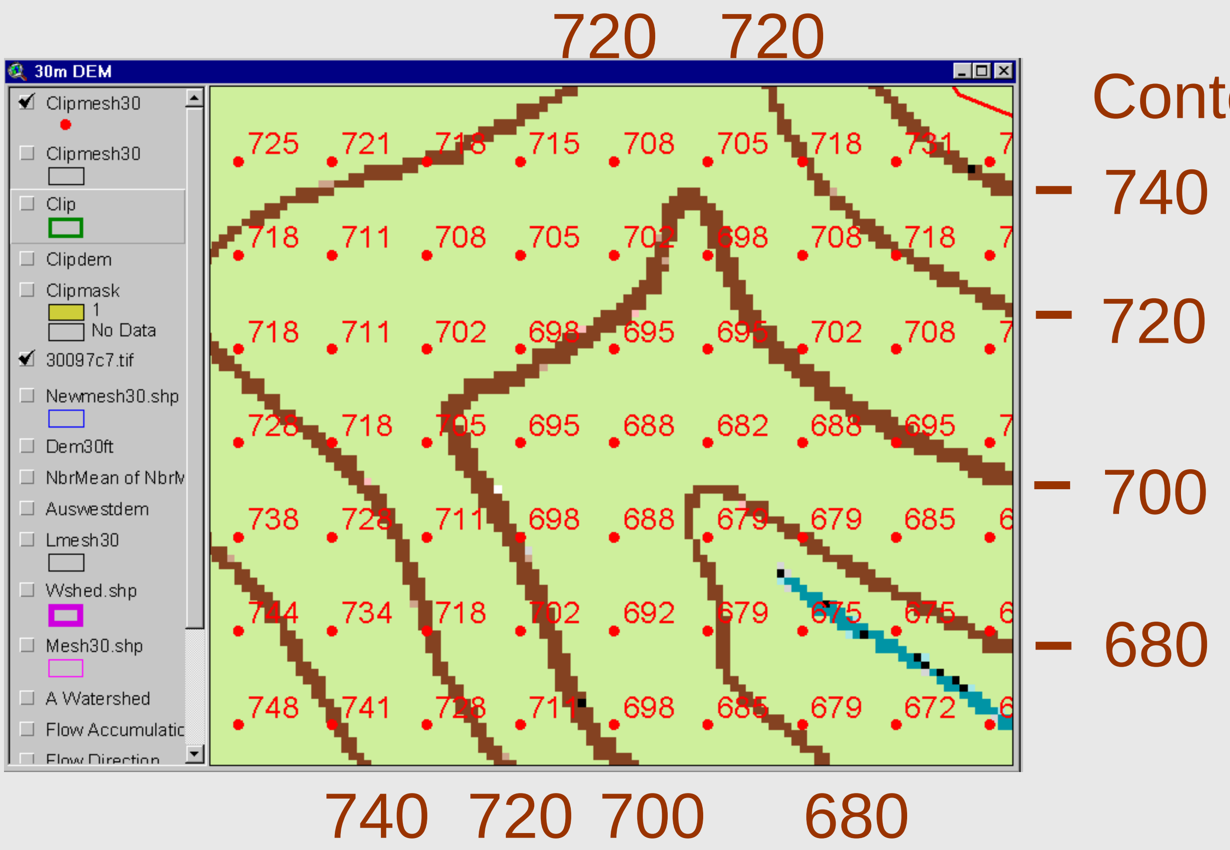


Conceptual Basis



- Based on an information model for the topographic representation of downslope flow derived from a DEM
- Enriches the information content of digital elevation data.
  - Sink removal
  - Flow field derivation
  - Calculating of flow based derivative surfaces

DEM Elevations



Hydrologic Slope
- Direction of Steepest Descent

30

80	**74**	**63**
69	**67**	**56**
60	**52**	**48**

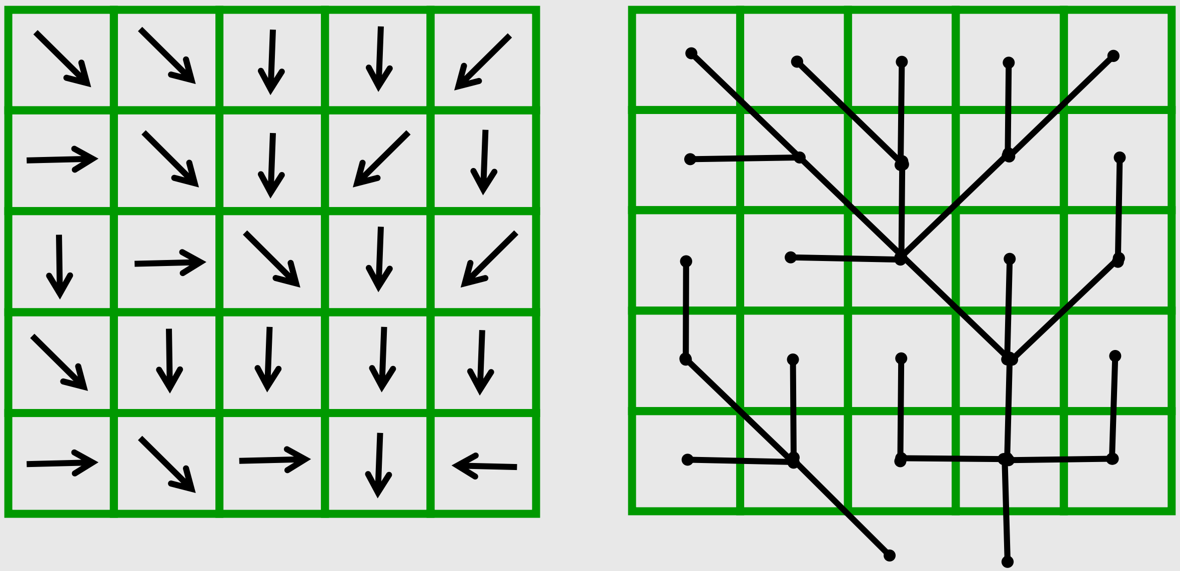
30

80	**74**	**63**
69	**67**	**56**
60	**52**	**48**

Slope: $\frac{67-48}{30\sqrt{2}} = 0.45$

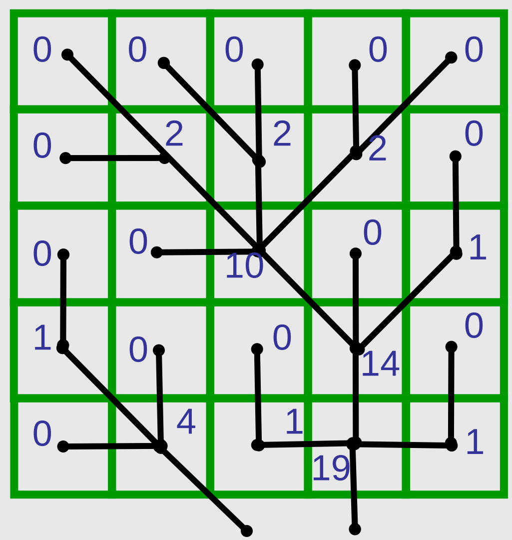
$$\boxed{\frac{67-52}{30} = 0.50}$$

Grid Network



Flow Accumulation Grid.
Area draining **in** to a grid cell

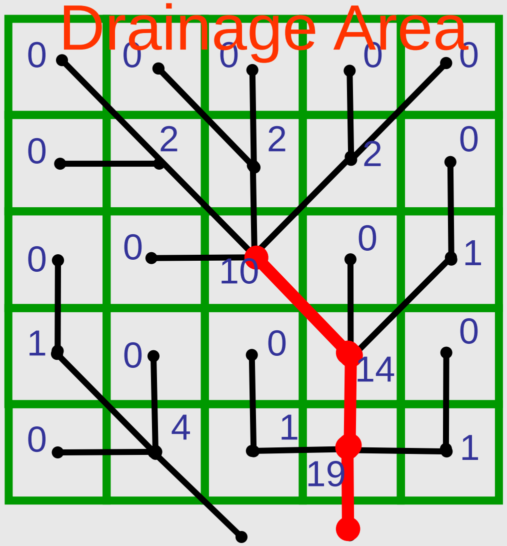
0	0	0	0	0
0	2	2	2	0
0	0	10	0	1
1	0	0	14	0
0	4	1	19	1



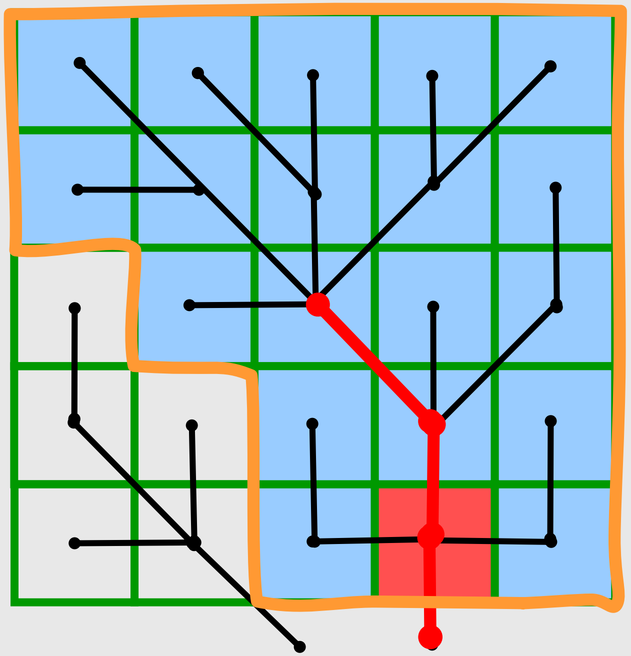
Flow Accumulation > 10 Cell Threshold

0	0	0	0	0
0	2	2	2	0
0	0	10	0	1
1	0	0	14	0
0	4	1	19	1

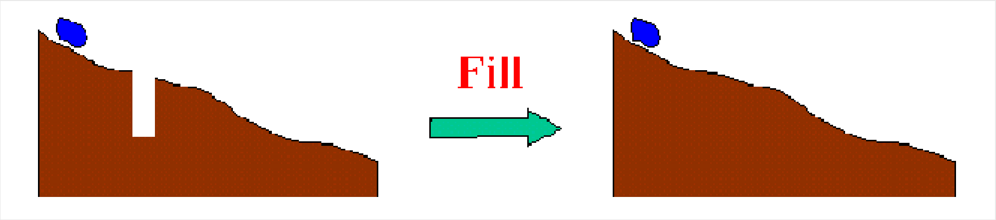
Stream Network for 10 cell Threshold Drainage Area



Watershed Draining to Outlet



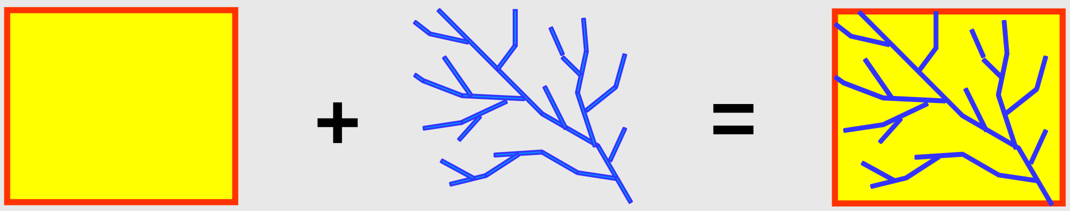
The Pit Removal Problem



- DEM creation results in artificial pits in the landscape
- A pit is a set of one or more cells which has no downstream cells around it
- Unless these pits are removed they become sinks and isolate portions of the watershed
- Pit removal is first thing done

"Burning In" the Streams

- Take a mapped stream network and a DEM
- Make a grid of the streams
- Raise the off-stream DEM cells by an arbitrary elevation increment
- Produces "burned in" DEM streams = mapped streams



What is a model?

- “A **model** is a pattern, plan, representation or description designed to show the main object or workings of an object, system, or concept.”

(Wikipedia, 2009)

“A **model** is a simplified version of the real system that approximately simulates the excitation-response relations”

(Bear, 1987)

What makes a model suitable for the SEEA-EEA?

Why was the model developed?

- Determine the effects of management decisions on catchments (e.g. groundwater extraction, stream restoration, gravel extraction, agricultural intensification, etc)
- Forecasting: weather, flood, hazard, climate change etc.
- Assess impact of change (e.g. land use and climate) on resources and hazards
- Hypothesis testing - improve our understanding (does this pathway exist? Is this process significant?)
- ***A model is not always an equation or a computer software package- you are modelling the world in your head all the time...***

We use models, data and process understanding together to:

- improve understanding of current functioning of a system- hypothesis testing (does this pathway exist, is this process significant)
- better understand the sensitivity of a system to change (do we need to worry about land use, climate change, etc, in this catchment)
- To predict the past (why?), the future, and interpolate or extrapolate in space (predicting the past and future are extrapolation in time)
- ***Question: why are we distinguishing between extrapolation and interpolation***?

What type of model (1)?

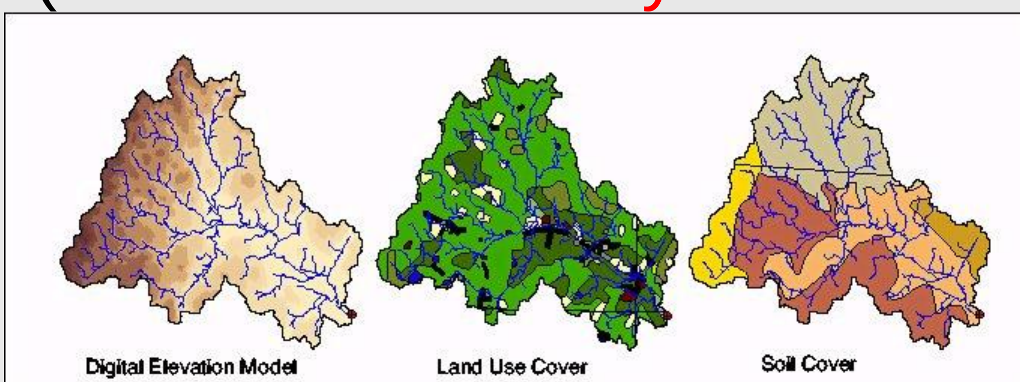
- Empirical or metric (based on observation, “data driven”, e.g. artificial neural networks)
- Conceptual – conceptualisation of the system- e.g. my soil acts as an analog to a set of pipes with different diameters…
- “Physics” based (mathematical-physics form based on continuum mechanics)
- Hybrid – mix of two or three types of the above (most models are hybrids!)
- ***What’s best often depends on whether we are interpolating or extrapolating***:

What type of model (2)?

- Lumped: spatially averaged

input → Model → output

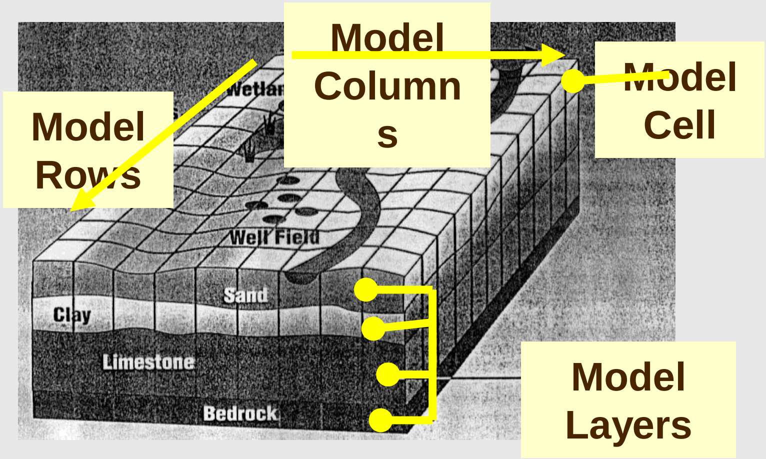
- Distributed: variables vary in space
  (can be semi or fully distributed)

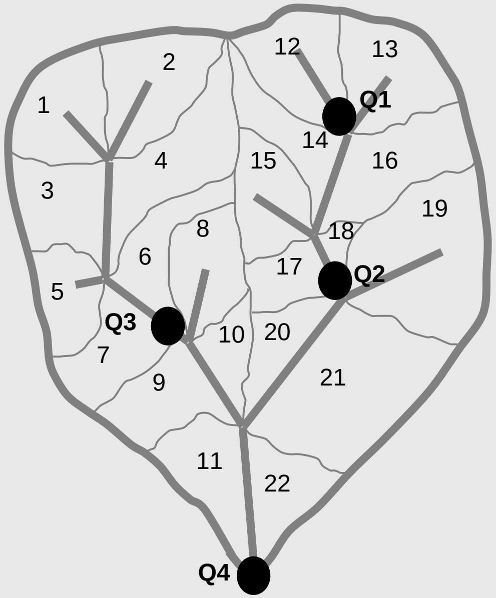


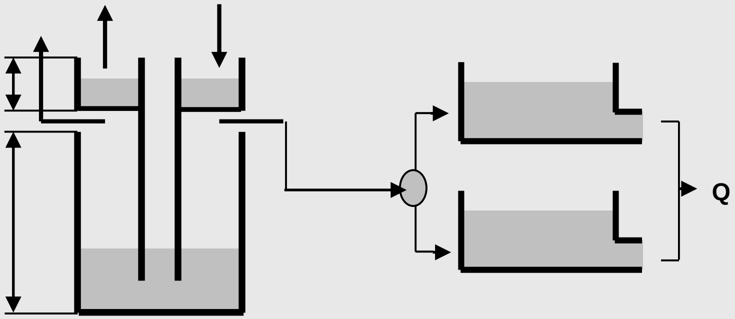
What scale?

- Spatial
  - *Local or Regional, Plot, Hillslope, Small Catchment, Large Catchment, Global...*
- Temporal
  - *Short or Long Term, Resolution of Data (15 min, Hourly, Daily, Weekly, Yearly...)*
- Model Validity
  - *Models are set up for particular spatial and temporal scales*
  - *Beware of using established models outside these limits*
- Data Validity
  - *Point (sampling, drilling)*
  - *Bulk (geophysics, remote sensed, integrated (e.g. flow))*
  - *Beware of using point data for regional models*

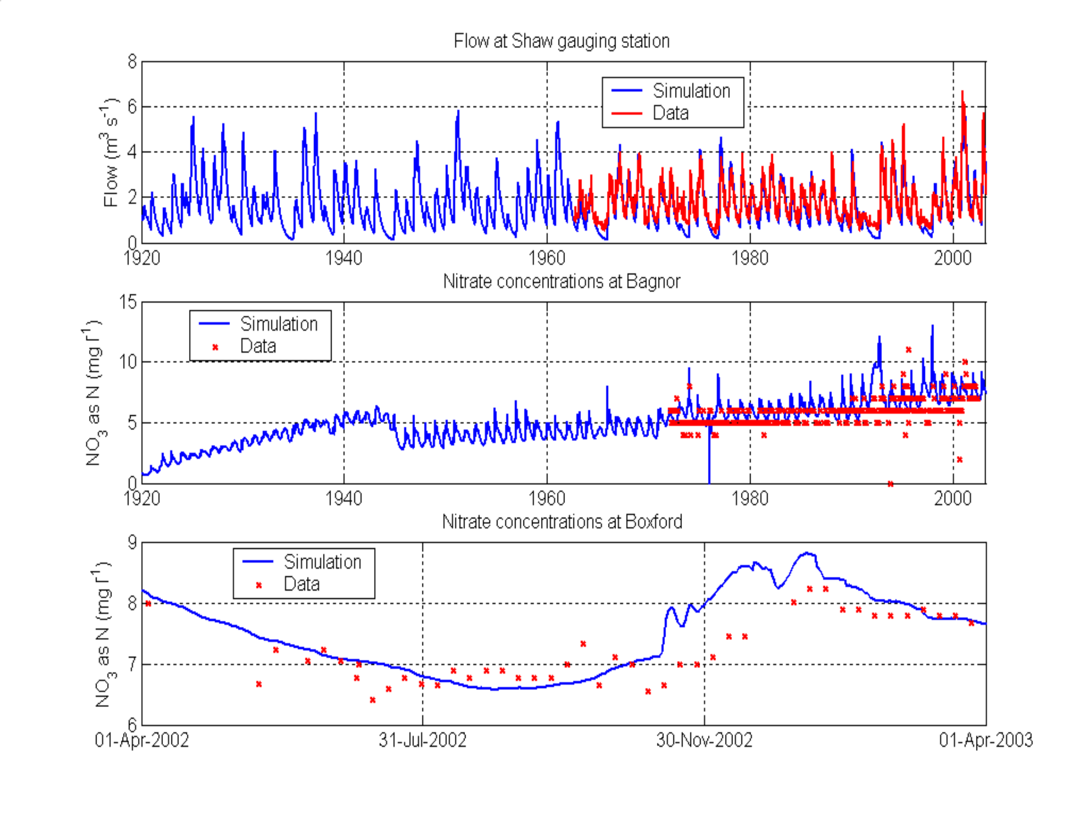
Fully distributed (1D-3D), semi-distributed, lumped…







How do we decide what constitutes a "good fit?"

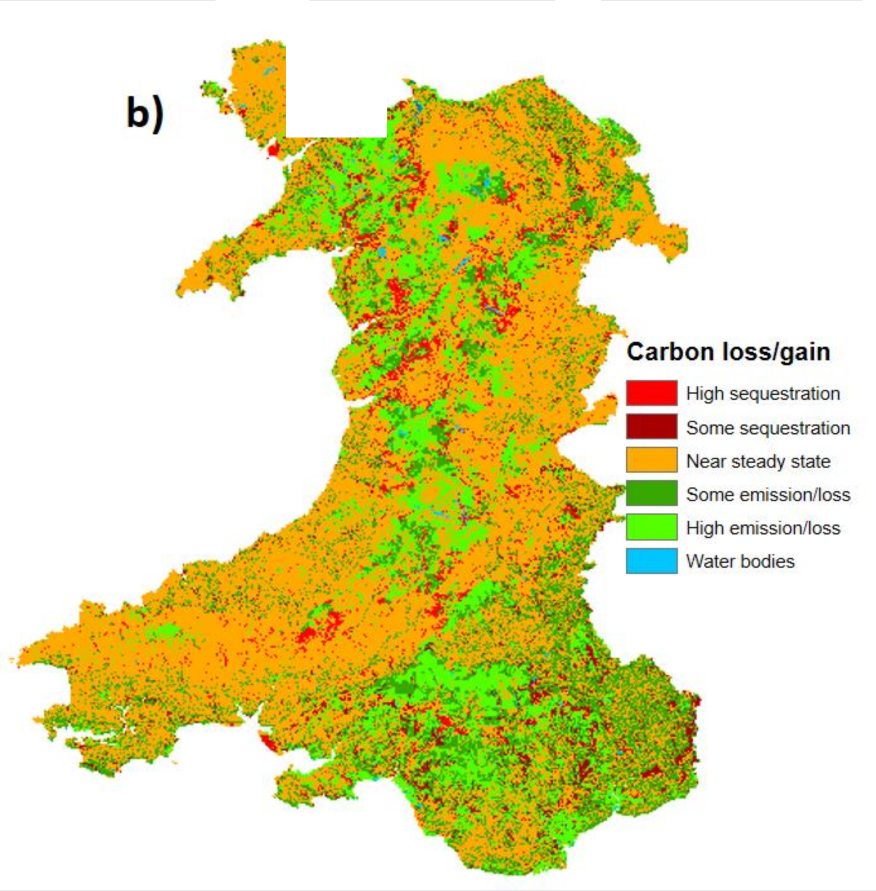


Calibration issues

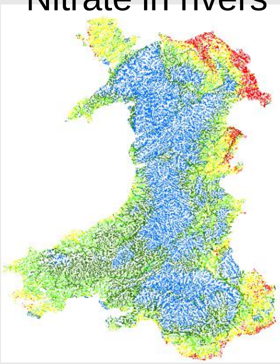
- Objective function/ measure of fit: one or many?
- “Equifinality” /“Behavioural solutions”
- These aren’t necessarily going to be the ones that look the best on a time series- or a cumulative plot…
- Context – e.g. flood peaks? Drought? Cumulative flows into a reservoir?
- Still some (black) art in most calibrations

National ecosystem service modelling

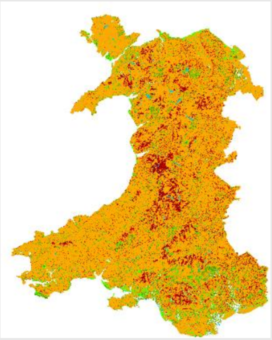
Carbon emissions



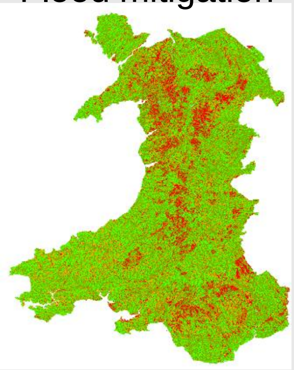
Nitrate in rivers



Agricultural use



Flood mitigation



Woodland priorities

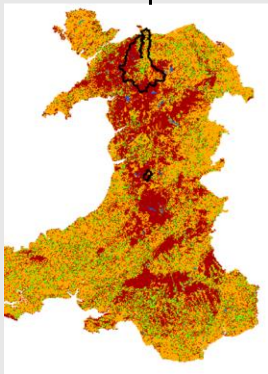
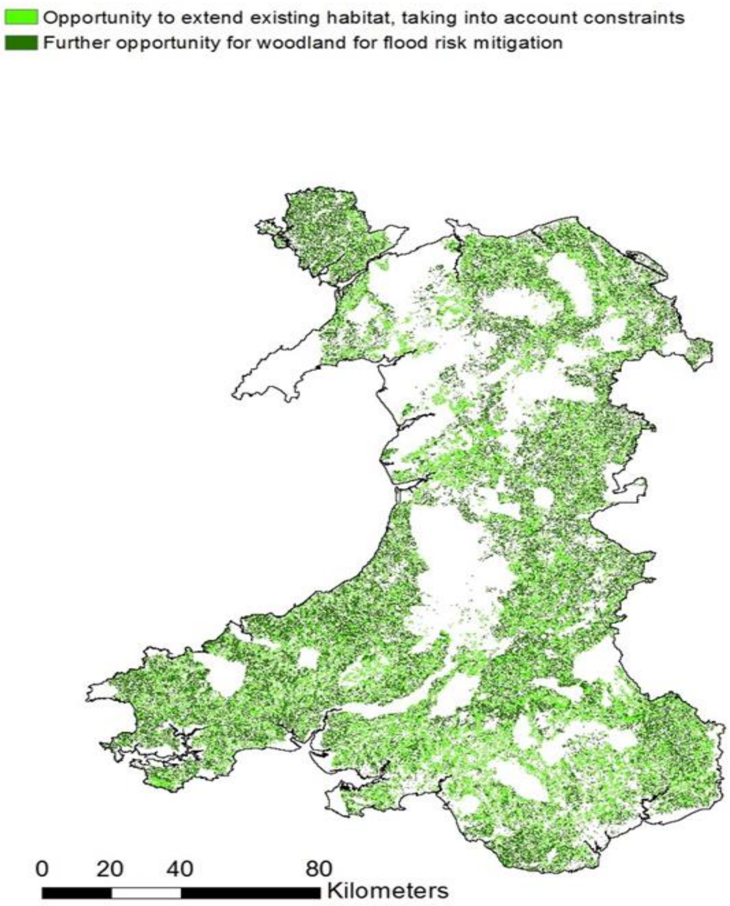


FIGURE-GMEP-NRM-P-1: Opportunity for afforestation to extend woodland or reduce flood risk by 616,067 ha excluding areas which would include inappropriate trade-offs.

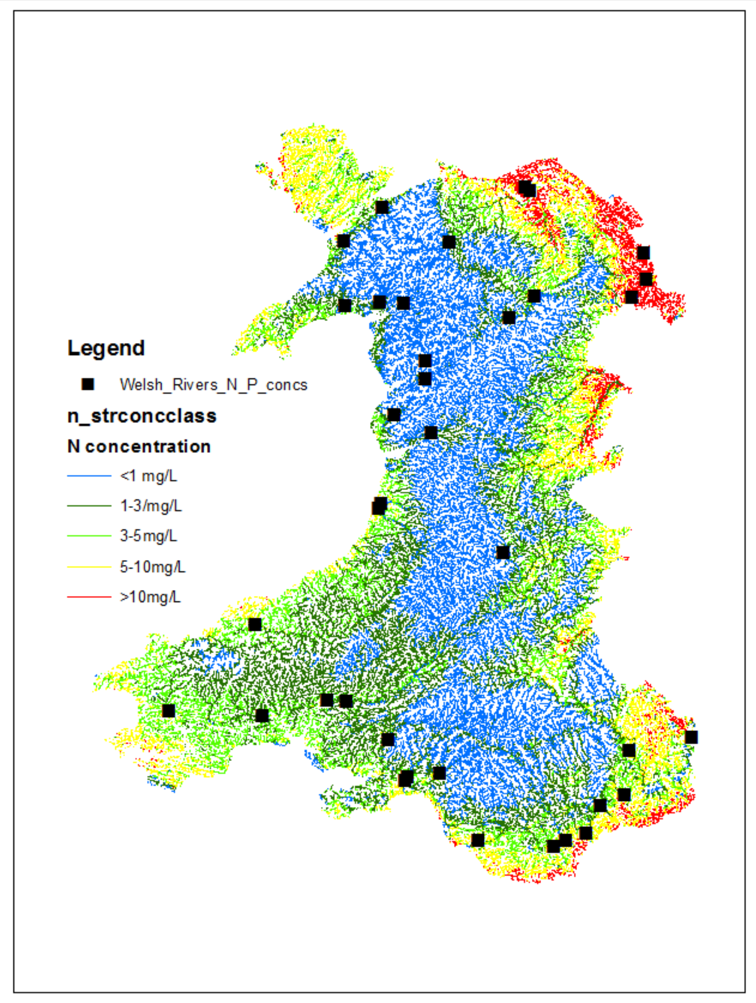
Exclusions are: Section 15 priority habitats, historic landscapes, red squirrel habitats, peats, urban areas, areas of more than 2 Ecosystem Services with existing good condition, protected areas such as national nature reserves, national parks, areas of outstanding natural beauty, sites of special scientific interest, special protection areas, special areas of conservation and acid sensitive areas.

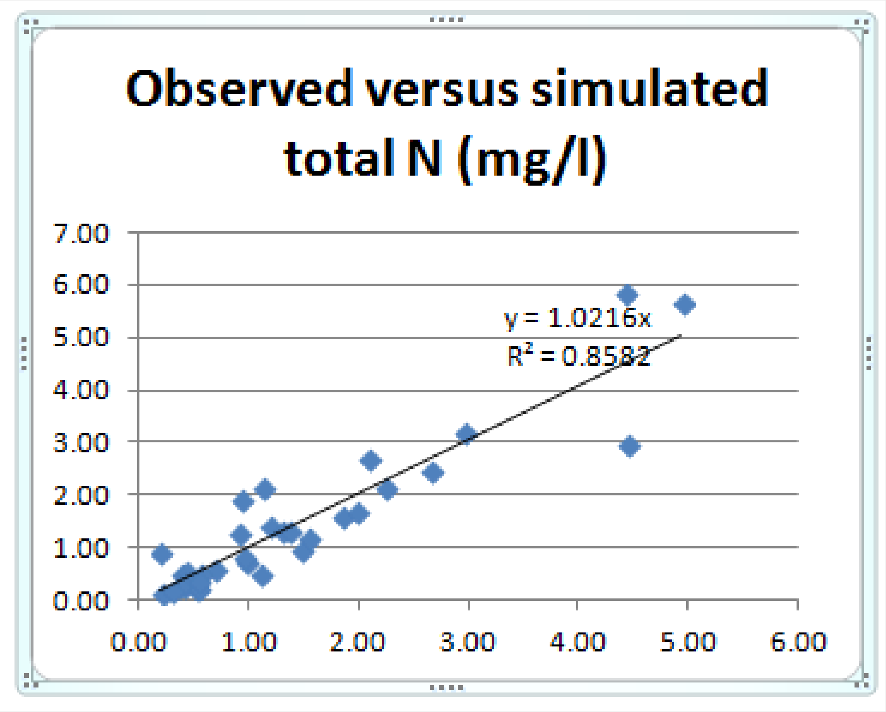
Areas where trees could provide added benefits in terms of flood mitigation by increasing infiltration to soils in areas where accumulating surface water is routed to the river is also indicated.

Note: These results should be used to target for further exploration at a local level as they have not been ground-truthed.

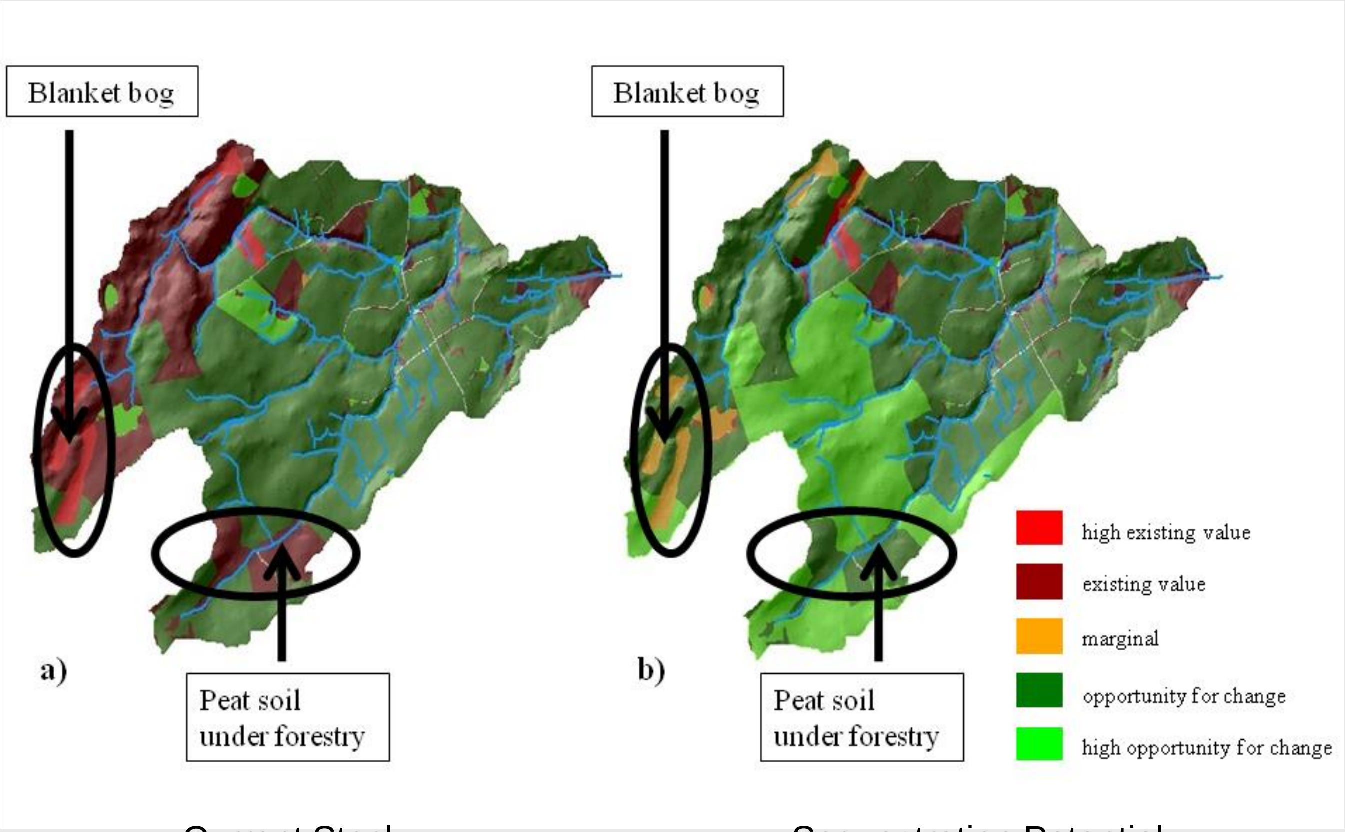


Evaluating model versus data output e.g. Water quality





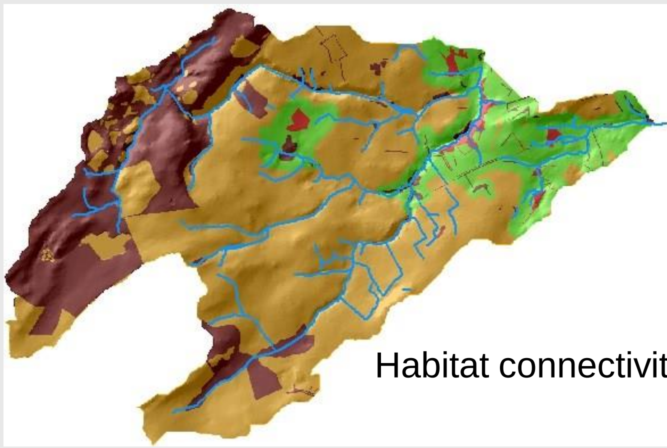
Carbon layer

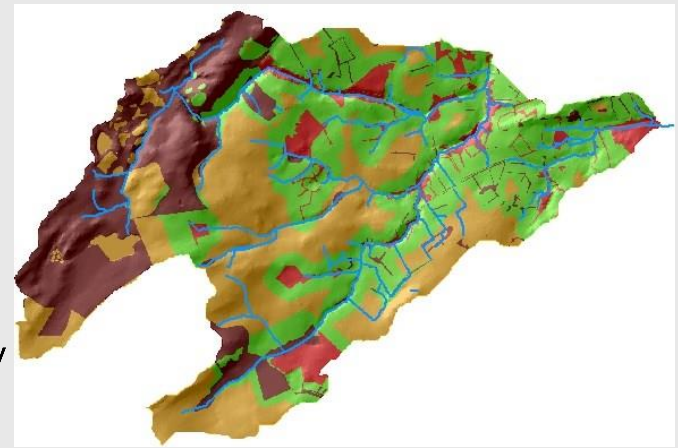


Current Stock Sequestration Potential

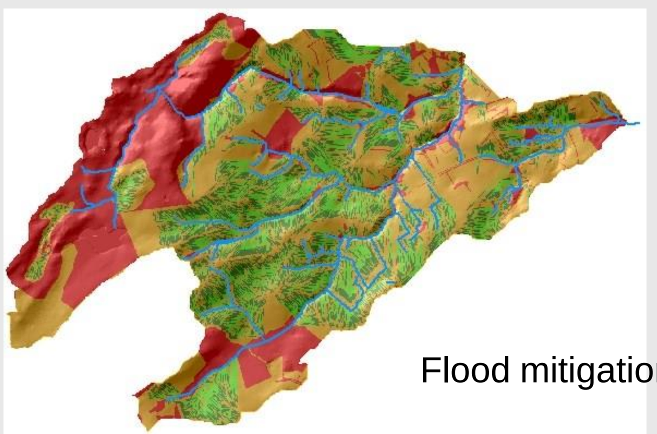
Scenario Analysis: habitat connectivity and flood risk layers

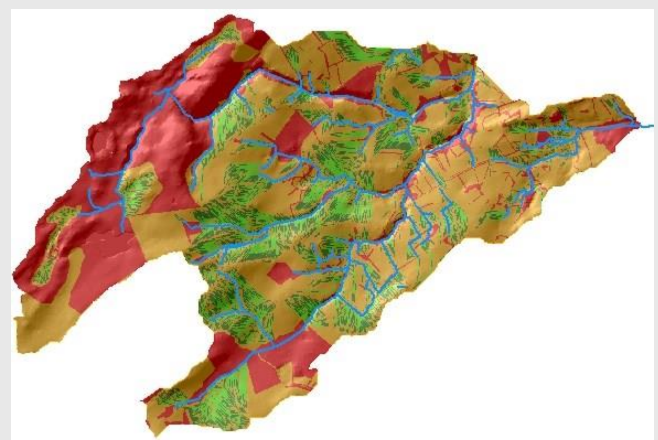
Original vegetation and habitat survey data | Corrected for recent planting





Habitat connectivity





Flood mitigation

Environmental Stewardship (Env St) outcomes with and without LUCI: Bassenthwaite catchment

Metric	Units	Before Env St	After Env St	Optim Area with LUCI*	Optim Outcome with LUCI*
Total present carbon	kg/ha	199	207	221	212
Total future carbon	kg/ha	172	193	209	198

***Optim area= same area/payment,more outcome;**

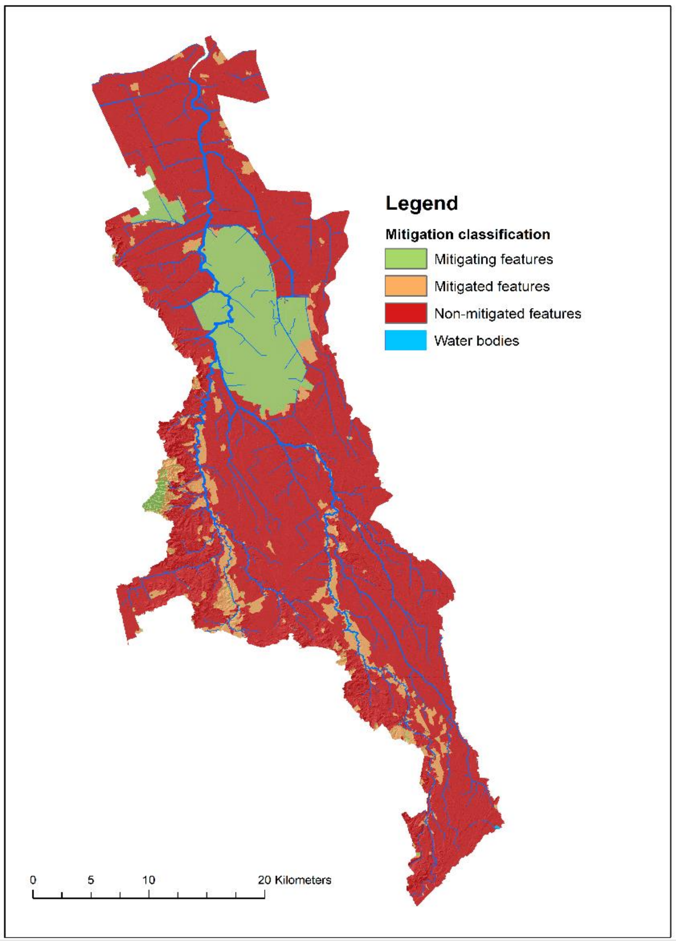
***Optim outcome = less area/payment, similar outcome**

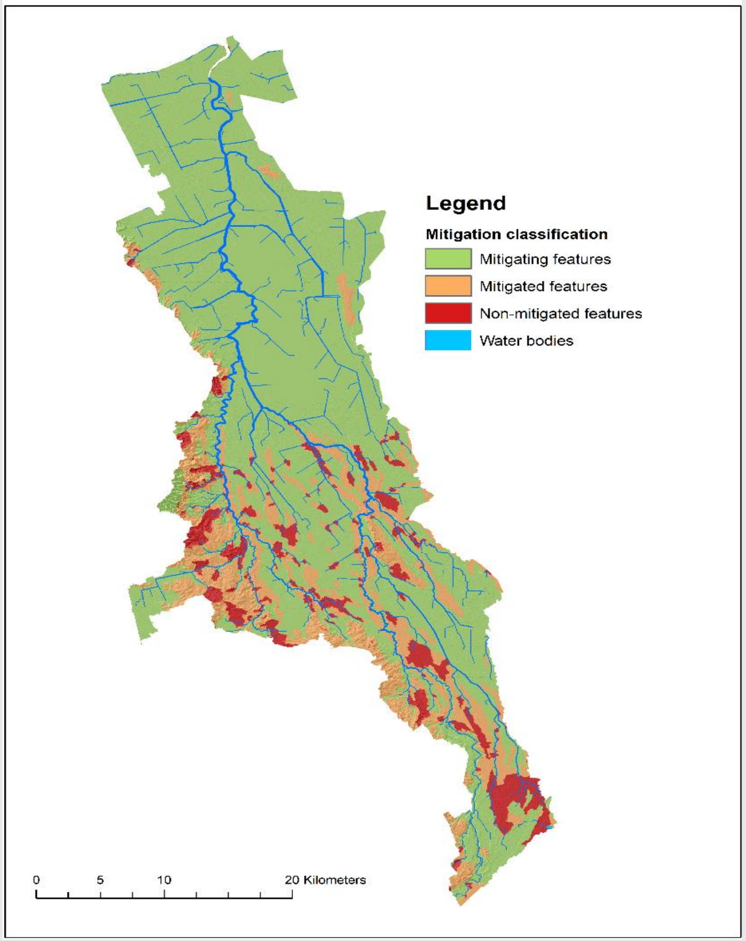
Environmental Stewardship (Env St) outcomes with and without LUCI: Bassenthwaite catchment

Metric	Units	Before Env St	After Env St	Optim Area with LUCI*	Optim Outcome with LUCI*
Total present carbon	kg/ha	199	207	221	212
Total future carbon	kg/ha	172	193	209	198
Broadleaf woodland	km^2	18	34	32	26
Area accessible to BLW species	%	45	70	74	69
Potential wet grassland	%	0.9	0.7	0.1	0.3
Land in production	%	47	39	43	44
Non-“mitigated” land	%	37.7	25.5	24.3	32.7
Connected sediment generating land	%	11.3	6.7	3.6	5.9
P export to rivers/lake	kg/ha/yr	0.178	0.173	0.164	0.171
Peak flow change in max. Summer flood	%	baseline	-2.3	-9.3	-3.1

***Optim area= same area/payment, more outcome;**
***Optim outcome = less area/payment, similar outcome**

Flood mitigation; current compared to historic land use





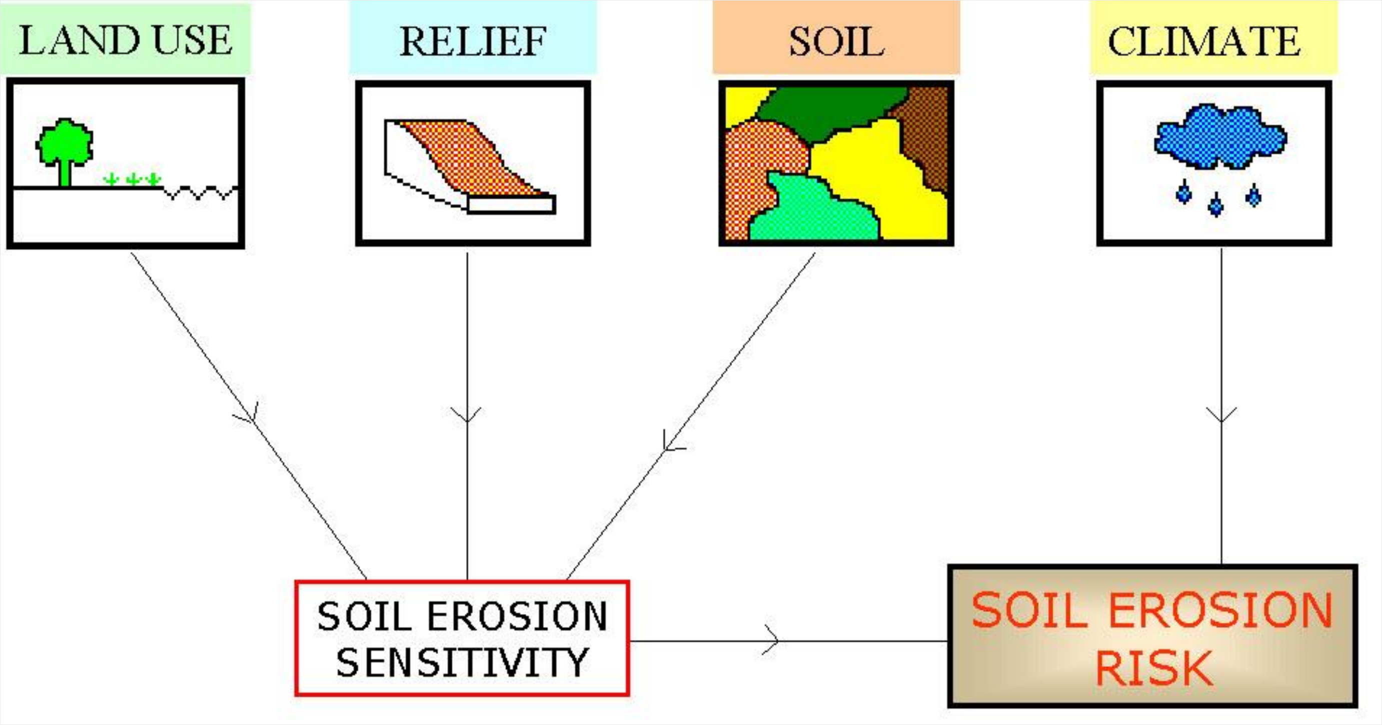
Flood summary: baseline, historic wetlands and future1:

Table 9. Comparison of how flow changes between baseline and restored wetland under a range of design rainfall scenarios.

Site and scenario	2 year current (cumecs)	5 year current (cumecs)	10 year current (cumecs)	50 year current (cumecs)	2 year 2090 (cumecs)	50 year 2090 (cumecs)
Piako at PT- current	316.8	500.9	595.8	747.9	339.8	925.1
Waitoa at Mellon- current	100.7	159.0	189.1	237.36	108.0	293.5
Piako at PT- wetlands	175.7	274.9	326.3	408.3	186.2	504.6
Waitoa at Mellon- wetlands	55.0	86.0	102.0	127.5	58.3	157.5
Piako at PT- >1ha wetlands	208.4	450.3	548.2	698.3	280.7	887.9
Waitoa at Mellon >1ha wetlands	69.3	130.7	177.4	203.4	64.3	276.4

How could we predict soil erosion?

What’s important?
What’s our conceptual “model”?


LAND USE
RELIEF
SOIL
CLIMATE
SOIL EROSION SENSITIVITY
SOIL EROSION RISK

(Revised) Universal Soil Loss Equation

Both RUSLE and USLE are expressed as:

A = R * K * LS * C * P

Where
A = estimated average soil loss in tons per acre per year
R = rainfall-runoff erosivity factor
K = soil erodibility factor
L = slope length factor
S = slope steepness factor
C = cover-management factor
P = support practice factor

(See http://www.iwr.msu.edu/rusle/ for further detail)

Models of soil erosion by overland flow

simplified, semi-empirical models for special cases → realistic, process-based, general models

(R)USLE2D

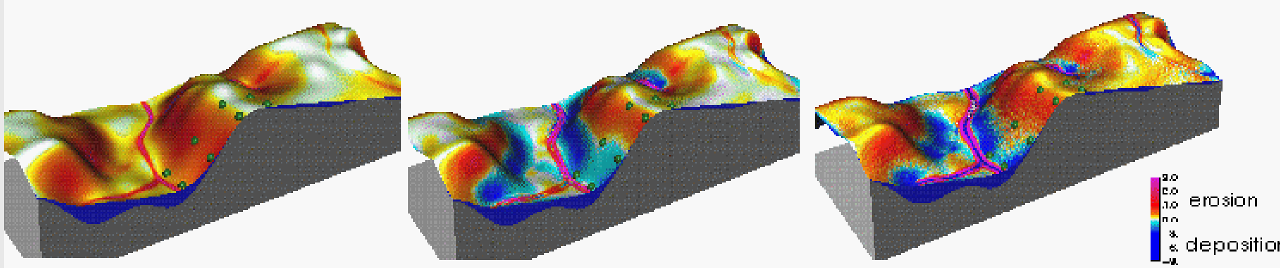
- detachment limited
- no deposition
- new LS based on upslope area
- standard RKCP
- standard GIS tools

USPED

- transport capacity limited
- net erosion/deposition as div q_s ~ div T_c . s_0
- standard RKCP, but new par. would be better
- standard GIS tools

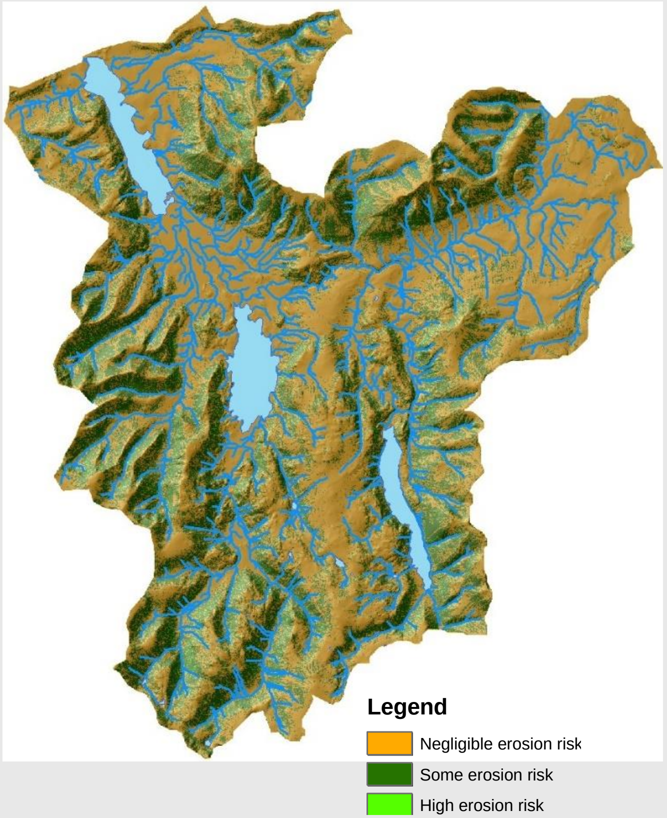
SIMWE .....

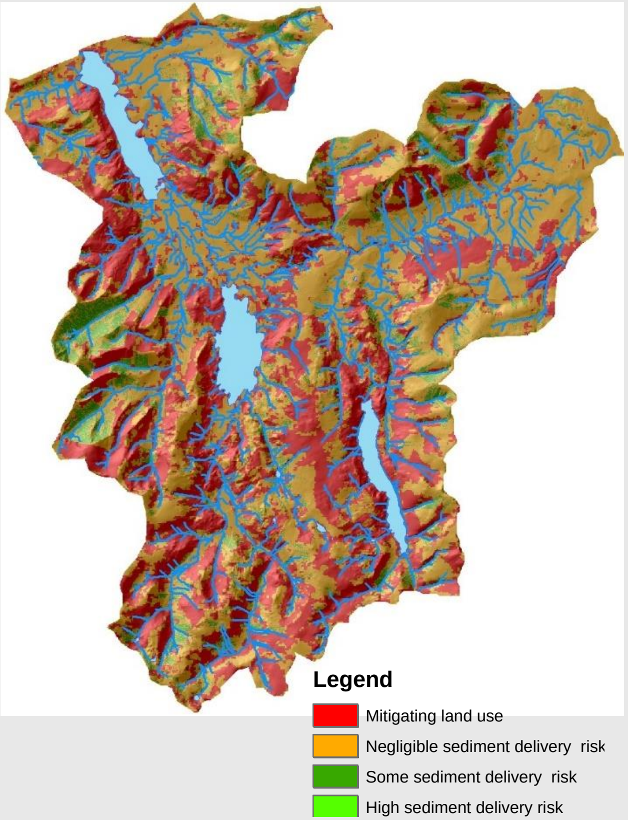
- detachment through transport capacity ltd.
- continuity equation
- event based
- simplified WEPP parameters
- new tool linked to GIS



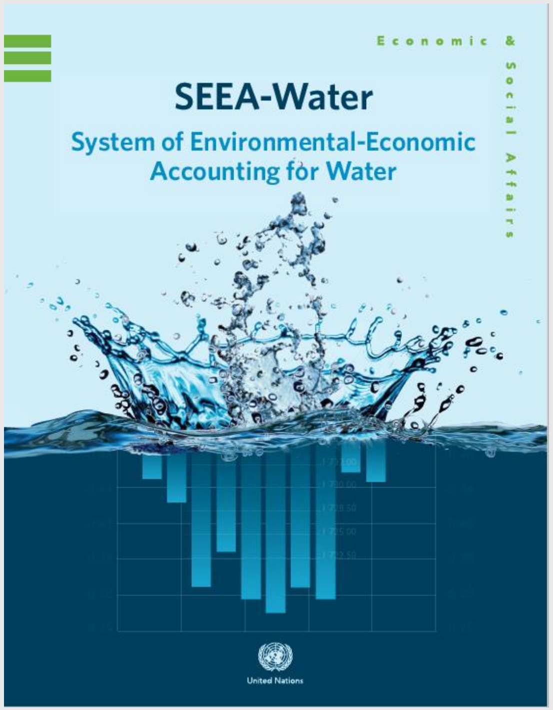
Mitasova & Mitas

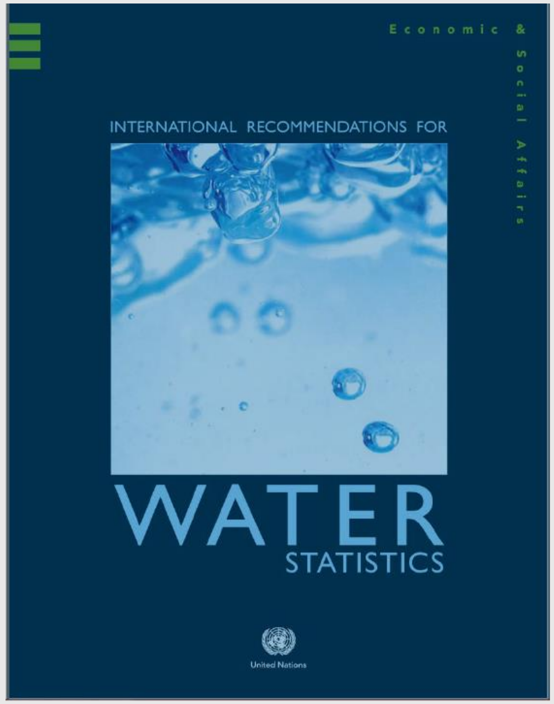
Erosion and sediment delivery prediction (Bassenthwaite catchment, England)

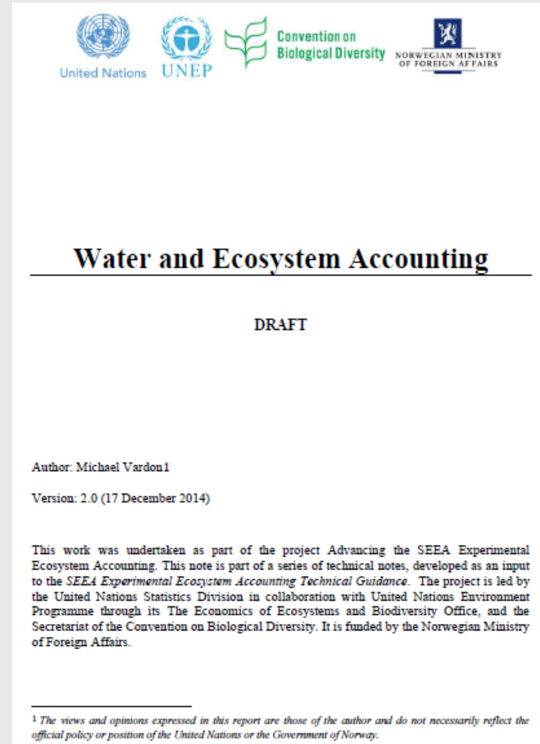




SEEA and Water







Water and Ecosystem Accounting

DRAFT

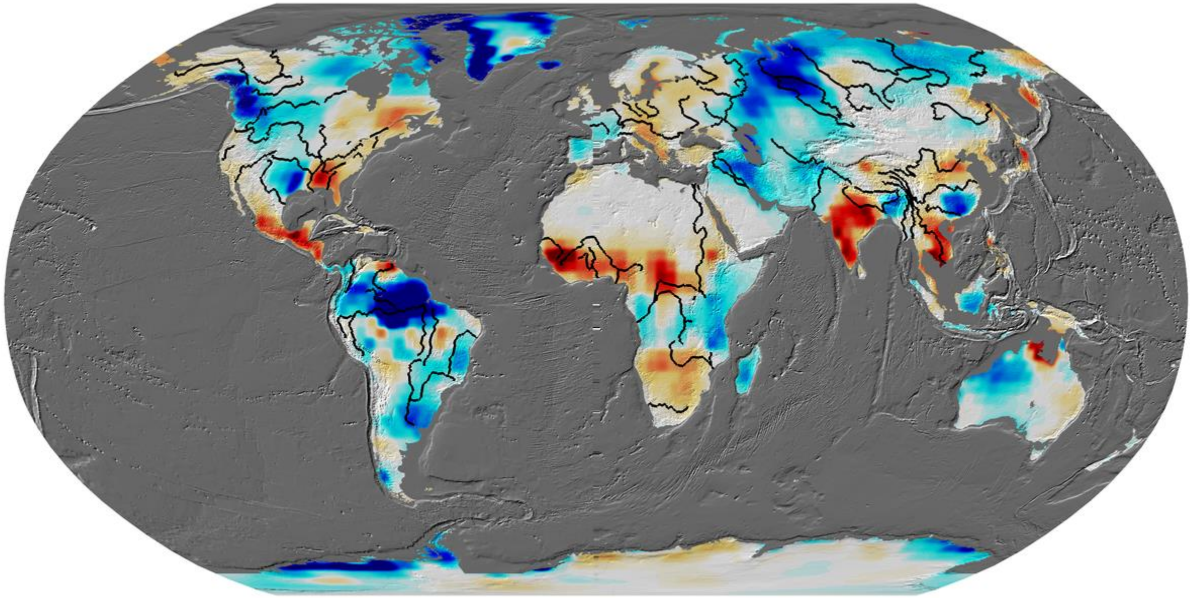
Author: Michael Vardon1

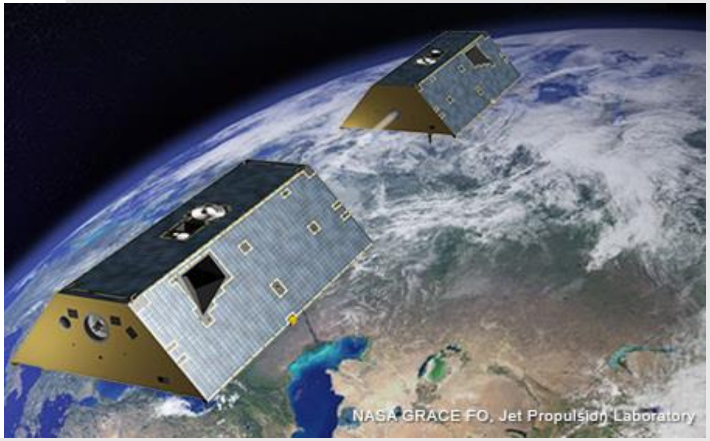
Version: 2.0 (17 December 2014)

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.

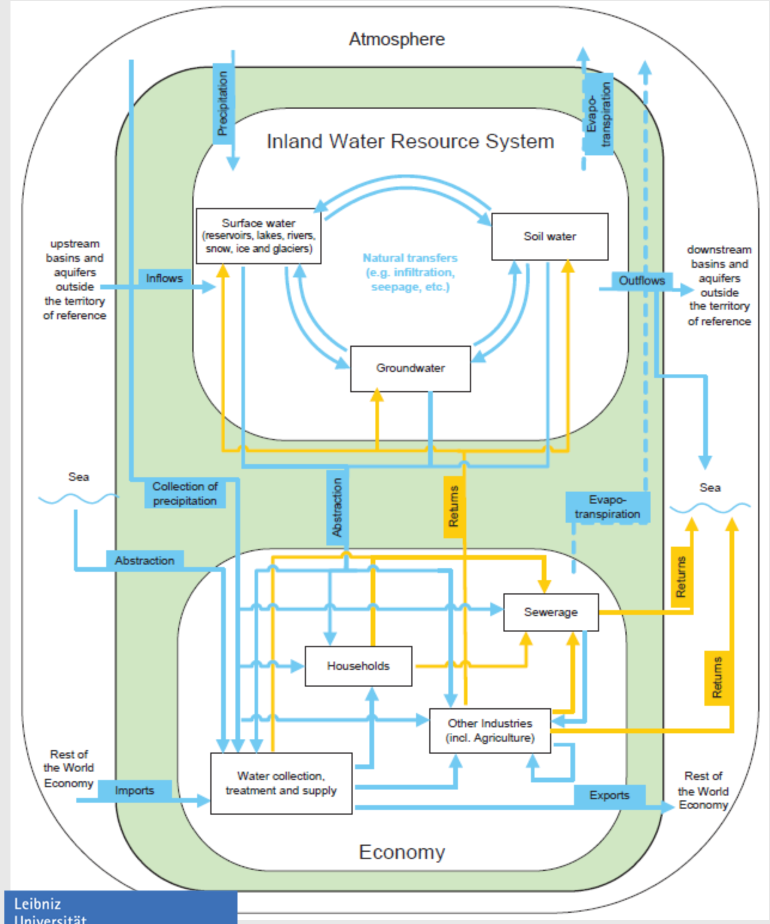
[1] *The views and opinions expressed in this report are those of the author and do not necessarily reflect the official policy or position of the United Nations or the Government of Norway.*

GRACE – mm water anomaly at ~100km

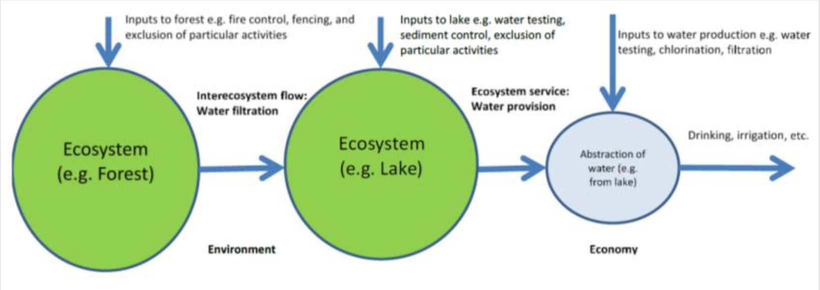




The main elements of the water accounts



Provisioning of water



Summary

- **Four types of spatial models:**
  - **Look-up tables**: specific values are attributed to every pixel in a certain class, usually a land cover class.
  - **Statistical approaches**: ecosystem services flow, asset or condition is related to explanatory variables such as soils, land cover, climate, distance form a road, etc., using a statistical relation derived from survey data.
  - **Geostatistical interpolation**: techniques such as kriging rely on statistical algorithms to predict the value of un-sampled pixels on the basis of nearby pixels in combination with other characteristics of the pixel.
  - **Process based modeling**: involves predicting ecosystem services flows based on modelling of the ecological and/or ecosystem management processes involved.

Take home points

- Biophysical modelling can help fill data gaps
- Biophysical modelling can help estimate future conditions, services and capacity
- Many biophysical models are spatial and combine data from many sources
- Geographic Information Systems (GIS) and pre-defined modelling packages have methods and formulas included
- In any given situation, which model is “best” depends on purpose of analysis and data context

Further reading

- The SEEA EEA Technical Recommendations (available at: www.seea.un.org)
- The various websites of the modeling platforms, e.g.
  - https://www.naturalcapitalproject.org/
  - https://ensym.biodiversity.vic.gov.au/cms/
  - aries.integratedmodelling.org
- The ArcGIS and QGIS websites (that also offer free, on-line training modules)
- The scientific literature