Developing the ecosystem accounts / biophysical modelling of ecosystem services

Lars Hein
Contents

- The analytical framework
- Spatial modelling – recap
- Temporal modelling – recap
- Experiences in Palawan (results thesis Verna Duque)
- From models to accounts
Analytical Framework

Including provisioning, regulating and cultural services
Spatial modelling

Spatial modelling involves combining spatial datasets (maps, remote sensing images), point data and statistical data for administrative units to estimate ecosystem services flow and capacity. It can be used:

- For calculating flow and capacity of specific data points
  - Look-up tables
  - Geostatistical interpolation (e.g. kriging)
  - Statistical approaches
  - Process based modelling (e.g. USLE)

- For modelling spatial aspects of ecosystem services (in particular regulation services except carbon sequestration)
  - E.g. hydrological services, air filtration
# Mapping approaches

<table>
<thead>
<tr>
<th>Mapping Approach</th>
<th>Basic characteristic</th>
<th>Mapping techniques applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated ecosystem services mapping tool such as InVEST;</td>
<td>Predefined modules for mapping ecosystem services</td>
<td>Mostly based on Look-up Tables, predefined techniques for specific services.</td>
</tr>
<tr>
<td>Modeling framework such as ARIES</td>
<td>Enables designing specific algorithms for individual ecosystem services in a dedicated GIS environment, using predefined modules where appropriate</td>
<td>Flexible, different mapping techniques are supported in ARIES.</td>
</tr>
<tr>
<td>Using ArcGIS or a freeware GIS programs.</td>
<td>All services need to be modelled individually</td>
<td>Flexible, all mapping techniques can be used.</td>
</tr>
</tbody>
</table>
Mapping techniques

- **Look-up tables.** A specific value for an ecosystem service or other variable is attributed to every pixel in a certain class,

- **Geostatistical interpolation.** Use of statistical algorithms to predict the value of un-sampled pixels on the basis of nearby pixels in combination with other characteristics of the pixel. (e.g. kriging).

- **Statistical approaches.** For instance Maxent analyses the likelihood of occurrence of a species (or other services) as a function of predictor variables, based on an analysis of the occurrence of that species in those data points where the species occurrence has been recorded.

- **Process based modeling.** This method involves predicting ecosystem services flows or other variables based on a set of environmental properties, management variables and/or other spatial data sources.
Ecosystem services

- Spatial models are needed to
  - Map ecosystem condition
  - Map ecosystem services flows (depend on the supply - by the ecosystem, and the demand - from society)
  - Map ecosystem capacity (assets)
Ecosystem services Central Kalimantan

Carbon storage
- High : 7882.64 ton/ha
- Low : 32.34 ton/ha

Modelled using Look Up Tables

Timber production
- High : 1.67 m³/ha/year
- Low : 0.42 m³/ha/year

Kriging

Source: Sumarga and Hein, submitted
Ecosystem services in Central Kalimantan

Orangutan habitat

Modelled using Statistical models (Maxent)

Carbon sequestration

Look up tables (or: NPP minus soil respiration)

Source: Sumarga and Hein, submitted
Sometimes possible to apply different techniques: e.g. carbon sequestration

<table>
<thead>
<tr>
<th>Method</th>
<th>total seq in tC (forest)</th>
<th>seq tC/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Forest inventory data and maps</td>
<td>546 578</td>
<td>0.63</td>
</tr>
<tr>
<td>2. MODIS NPP minus soil respiration model after Raich et al. (2002)</td>
<td>1 070 123</td>
<td>1.28</td>
</tr>
<tr>
<td>3. NEP: MODIS GPP minus TER after Luyssaert et al. (2007)</td>
<td>911 651</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Source: Schröter et al., 2014)
Dynamic (temporal) Modelling is required for analysing changes in ecosystem capacity
Recording ecosystem services and assets in an account

Example of timber production

- Timber:
  - Opening stock (1 January): 1000
  - Natural additions: 100
  - Harvest: 50
  - Closing stock (1 December): 1050

The model underlying the account analyses: natural additions, as a function of capacity and, in turn, condition.

What is the benefit and what is the ecosystem service?
Basic methodologies - provisioning services

- Flows of provisioning services:
  - Data: Recording outputs of the ecosystem: production statistics, surveys, production models.
  - Mapping: Interpolation (spatial tools), allocation (allocation models)
  - Cross validation

- Analysis of capacity to generate provisioning services
  - Analyse current stock of the service involved (e.g. standing stock of timber)
  - Analyse regrowth (varies as a function of stock, carrying capacity and management; assumption: under current management)
The capacity to generate a provisioning service can be estimated for a given year, and may vary over time as a function of management and ecological processes.
Analysing capacity, an example

Moose populations per municipality estimated with a basic population model (Austrheim et al. 2011)

\[ N_t = Q_t \left\{ \left( \frac{C_t - M}{1 - C_t} \right) - (\lambda - 1) \right\}^{-1} \]

\( N_t \) = post-harvest population,
\( Q_t \) = annual harvest
\( C_t \) = pre-harvest proportion of calves in the population
\( M \) = natural mortality rate: 0.05
\( \lambda \) = population growth rate

Capacity–flow-balance for moose hunting in Telemark (Schröter et al., 2014)
Recording regulating services

Example of carbon sequestration

- Carbon sequestration
  - Opening stock (1 January): 10000 ton carbon
  - Natural additions (sequestration): 500 ton C
  - Emissions (e.g. LUC, degradation): 300 ton C
  - Closing stock: 10200 ton C

- What is the service? The benefit?
- Note: the service is the sequestration only....
Example of water storage (Laguna Lake)
- Opening stock: 1,000,000 m³
- Net additions: -100 m³ (input sediments)
- Closing stock: 999,900 m³

What is the service? The benefit? The capacity?
Basic methodologies - regulating services

Usually requires maps

- Carbon sequestration
  - Look-up tables / NPP models based on remote sensing / forest statistics
  - Aggregation per Land Cover Ecosystem Unit (LCEU)
- Validation

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

Source: Sumarga and Hein, 2014
Hydrological services:

- Define service, identify indicators
- Spatial modelling of effects of vegetation on water flows / Comparison of watersheds
- Cross validation

Trinidad: Relation between forest cover in catchments and flood damage costs. The value of the flood control service varies from US$ 60 to US$ 460 per ha forest/year.

Source: Brookhuis and Hein, in preparation
Basic methodologies - cultural services

- Recreation and tourism:
  - Flow: number of tourists per area per year
  - Capacity: maximum number of tourists that can be sustained and can be expected (given access to an area, facilities, etc.)

- Biodiversity (Biodiversity account)
  - Flow: presence of species (# red list, functional species, species in groups, species abundance)
  - Capacity: potential presence (may be higher or lower)

Suitability for orang utan, Central Kalimantan, from Sumarga and Hein 2014
Complex ecosystem dynamics

Gradual change

Threshold

Hysteresis

Irreversible change
How to model complex dynamics?

- Systems approach, using differential equations, for instance a logistic growth curve:
  \[
  \frac{dP}{dt} = rP \left(1 - \frac{P}{K}\right)
  \]

- The carrying capacity (K) may be related to environmental factors (condition indicators), introducing **feedback mechanisms**.

- These relations may be found using regression analysis provided that data are available.

- Regulating services (except carbon) often depend on spatial relations, spatial-temporal modelling is required.
Capacity, flows and pollution

- Increased pollution levels, or clean-up of waterways will be reflected in year-to-year changes of ecosystem accounts.

- Pollution may change the capacity of ecosystems to provide services, the flow of services itself, or the value of these services (e.g. more effort needed to harvest, or lower quality product).

- Trends (but not potential policy measures) can be considered...however often difficult to anticipate effects of changes in pollution loads on ecosystem services.
1. Land-use map

Source: pulot_lancover.shp
Palawan Council for Sustainable Development
Year: 2010
Results thesis Verna Duque Palawan (2)

1. Coconut production (Copra)

Figure 1 Map of Copra yield (tons pixel$^{-1}$) in Pulot Watershed

Table 2 Detailed statistics of Coconut Map (Copra)

<table>
<thead>
<tr>
<th>Average yield (tons ha$^{-1}$ yr$^{-1}$)</th>
<th>Mean (tons pixel$^{-1}$)</th>
<th>STDEV</th>
<th>MAX</th>
<th>MIN</th>
<th>Area (ha)</th>
<th># of Pixels</th>
<th>Area per pixel</th>
<th>Total Yield (tons yr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.32</td>
<td>0.38</td>
<td>0.01</td>
<td>0.38</td>
<td>0.23</td>
<td>903</td>
<td>6350</td>
<td>0.142205</td>
<td>1319</td>
</tr>
</tbody>
</table>
2. Paddy rice production (Palay)

Figure 3 Map of Palay yield (tons pixel\(^{-1}\)) in Pulot Watershed

Table 3 Detailed statistics of Paddi Rice Map (Palay)

<table>
<thead>
<tr>
<th>Average yield (tons ha(^{-1})yr(^{-1}))</th>
<th>Mean (tons pixel(^{-1}))</th>
<th>STDEV</th>
<th>MAX</th>
<th>MIN</th>
<th>Area (ha)</th>
<th># of Pixels</th>
<th>Area per pixel</th>
<th>Total Yield (tons yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.06</td>
<td>0.14</td>
<td>0.01</td>
<td>0.18</td>
<td>0.14</td>
<td>496</td>
<td>15057</td>
<td>0.032941</td>
<td>3689</td>
</tr>
</tbody>
</table>
3. Palm oil production (Palm fruit bunch)

Figure 5 Map of Palm fruit yield (tons pixel\(^{-1}\)) in Pulot Watershed

<table>
<thead>
<tr>
<th>Table 4 Detailed statistics of Palm Oil Map (Palm fruit bunch)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average yield (tons ha(^{-1}) yr(^{-1}))</strong></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>0.39</td>
</tr>
</tbody>
</table>

* Average yield was based on data from Cooperatives.  
** Represents the average value of the other two average values which was assigned for lot numbers not belonging to any Cooperatives but is classified as Palm oil plantation using SPOT 2.5 image.
4. Water Yield through InVEST

![Hydropower / Water Yield](image)

- **Workspace**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Water\INVEST\Final
- **Precipitation**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Water\Final maps for InVEST\ave_prec_ras1.tif
- **Reference Evapotranspiration**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Water\Final maps for InVEST\ave_eva_int1.tif
- **Depth To Root Restricting Layer**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Water\Final maps for InVEST\reclass_depth1.tif
- **Plant Available Water Fraction**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Water\Final maps for InVEST\soil_AWC_nm1.tif
- **Land Use**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Water\Final maps for InVEST\lc_pulot1.tif
- **Watersheds**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Processed\priority_catchment_Clip.shp
- **Sub-Watersheds (optional)**: C:\InVEST_3.0_0_x86\Base_Data\Freshwater\subwatersheds.shp
- **Biophysical Table**: C:\Users\sammie_elij\Documents\ArcGIS\Final Maps for thesis\Water\Bio-physical table\biophysical_table.csv
- **Seasonality Factor**: 1.5
- **Results Suffix (optional)**: 

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**Wageningen University**

[Logo]
Appendix 5. Derived maps for Water yield Model

1. Pulot SRTM DEM

DEM not needed in InVEST but would be needed in more sophisticated model

Source:

[SRTM DEM](http://www.philgis.org/freegisdata.htm) (Shuttle Radar Topography Mission - Digital Elevation)  
90-m spatial resolution mosaic of entire country (Philippines) Model
2. Average evapotranspiration

Source:
- MODIS Toolbox
  - Description: This toolbox contains scripts that download NASA satellite imagery from MODIS and import it into ArcMap.
3. Average precipitation

Source: PHILGIS
http://www.philgis.org/freegisdata.htm

Main Source: World Climate Data (www.worldclim.org/bioclim)
http://www.worldclim.org/current
4. Average soil depth as proxy to plant restrictive rooting depth

Source: pulot_soils.shp
Palawan Council for Sustainable Development

Specific data used: Soil depth qualitatively defined as: Deep, Moderately deep and Shallow
5. Soil available water content

Source: pulot_soils.shp
Palawan Council for Sustainable Development

Specific data used:

Soil texture

- Clay
- Clay loam to clay
- Loamy sand to clay
- No data on soil texture
- Sandy clay loam to clay
- Sandy to silt loam
- Silty clay loam to clay
6. Seasonality Factor

Source: InVEST User Guide 3.0.0


Description: According to InVEST User Guide (Release 3.0.0), Z is an empirical constant that captures the local precipitation pattern and hydrogeological characteristics, with typical values ranging from 1 to 20.

ω values = average value of 2.7 – 3.1 is 2.9 (values corresponding to Philippines)

P = average precipitation of 143.5 mm (derived from precipitation map)

AWC = average available water content of 162.9784 mm (derived from AWC map)

\[
Z = \frac{(\omega - 1.25)P}{AWC}
\]

\[
=\frac{(2.9-1.25)*143.5}{162.9784}
\]

= 1.4528
4. Water yield

But: the model only results in water yield, not in water storage (and water flows are not taken into account)

Figure 7 Map of water yield (mm pix$^3$) in Pulot Watershed

Table 5 Detailed statistics of water yield in Pulot Watershed

<table>
<thead>
<tr>
<th>ws_id</th>
<th>num_pixels</th>
<th>precip_mn (mm)</th>
<th>PET_mn (mm)</th>
<th>AET_mn (mm)</th>
<th>wyield_mn (mm)</th>
<th>wyield_vol (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>40942.00</td>
<td>137.46</td>
<td>81.66</td>
<td>68.05</td>
<td>78.62</td>
<td>14450093.34</td>
</tr>
</tbody>
</table>
From models to accounts
The System of National Accounts

Describes transactions (e.g. buying a product, or paying a tax) between institutional units such as households, the central government, or enterprises (classified in sectors such as agriculture or mining).

Transactions are described in a sequence of accounts:

- The current accounts (production, distribution and use of income) provide information on production, value added and income: gross and net domestic product (GDP and NDP) and national income (NNI).

- The accumulation accounts (capital, financial, other changes in volume) describe changes in assets by ownership. The resulting net worth and changes therein is recorded in the balance sheets.

Source: Edens and Hein, 2013
Production and assets

- **SNA**: economic production = “an activity carried out under the control and responsibility of an institutional unit that uses inputs of labour, capital and goods and services to produce outputs of goods or services” (6.24)

- **Criteria**: (i) presence of institutional unit; and (ii) ownership of output/ potential to be compensated/paid

- Excluding natural processes from the production boundary

- The SNA defines assets in terms of two necessary conditions of benefits and ownership

- The SEEA defines environmental assets more broadly as “the naturally occurring living and non-living components of the Earth, together comprising the bio-physical environment, that may provide benefits to humanity” (SEEA Central Framework, 2.17).
Why Ecosystem Accounts?

- Ecosystem assets not covered in the SNA
- In recognition of the holistic nature of ecosystems: the combination of biotic and abiotic components and processes, and human management leads to the generation of services and benefits to people
- An ecosystem services approach allows for a comprehensive recording of the various services of ecosystems, hence better insight in trade-offs and complexities
- Spatial approach allows more comprehensive assessment PLUS additional applications
The ecosystem accounts (as currently under development)

- Ecosystem condition account
- Physical ecosystem production account
- Monetary ecosystem production account
- Physical ecosystem asset account
- Monetary ecosystem asset account
- Supply- Use Table
- Biodiversity account

The system is somewhat flexible: allowing countries to select accounts and indicators that are most relevant to their setting.
Spatial approach

- The Ecosystem accounts follow a spatial approach: for each ecosystem account there is a map and a summary table.

- In the digital map, every grid cell has multiple values reflecting the various condition indicators, ecosystem service flow indicators (physical and monetary), asset indicators (physical and monetary) and biodiversity indicators.

- Only the input – output table is not spatial (even though a spatial application could in principle be designed, however this involves somewhat more complex GIS modelling, and this aspect requires further thinking).
The ecosystem condition account

- Contains indicators that reflect the condition/state of the ecosystem
- Indicators are specific to countries and ecosystems
- Contains indicators may reflect, e.g.:
  - Physical condition, e.g. soil fertility (for instance soil organic matter concentration), water table, (ground)water quality
  - Biological condition, e.g. crown cover, standing biomass
  - Processes: e.g. Net Primary Production
  - The presence of species that indicate ecological quality, e.g. species sensitive to pollution
  - The presence of conservation flagship species indicating ecological condition and important for ecotourism and biodiversity conservation such as the orangutan
  - The presence of species that reflect ecosystem functioning such as keystone species
## Ecosystem condition account (physical), e.g.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Indicator (e.g.)</th>
<th>Paddy fields</th>
<th>Annual cropland</th>
<th>Oil palm plantations</th>
<th>Forests</th>
<th>Rivers / lakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil fertility</td>
<td>% organic matter</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C/N ratio</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation status</td>
<td>Crown cover (%)</td>
<td>x</td>
<td>x</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biomass (ton/ha)</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>MSA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Occurrence of black rhino (n/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Water quality</td>
<td>BOD</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Algae content</td>
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<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Production account – physical and monetary

- Expresses the supply of ecosystem services in physical and monetary terms, in a map
- Supply of each ecosystem service is calculated for each grid cell (i.e. BSU)
- Information can also be organised in a table, for instance per land cover unit (LCEU) (or per administrative unit if relevant)
- With GIS, the spatial variability can be calculated (mean, standard deviation)
- The map is essential, examples of the summary tables are provided in the next slides
## Physical ecosystem production account, example

<table>
<thead>
<tr>
<th>Land cover/ ecosystem unit</th>
<th>Rice production (ton)/1</th>
<th>Vegetable production (ton)</th>
<th>Oil palm production (ton FFB)</th>
<th>Coconut production (ton)</th>
<th>Timber production (ton)</th>
<th>NTFP production (ton)</th>
<th>Carbon sequestration (ton C) (dry season)</th>
<th>River water generated (ton)</th>
<th>Erosion avoided (ton sediment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy field</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual cropland</td>
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<tr>
<td>Oil palm plantation</td>
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<tr>
<td>Forest</td>
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</tr>
<tr>
<td>Etc.</td>
<td></td>
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<td></td>
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<tr>
<td><strong>TOTAL</strong></td>
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</tr>
</tbody>
</table>

**Note:** in the map: all units in ton per ha; in the table: total ton per LCEU (plus SD)
### Monetary ecosystem production account, e.g.

<table>
<thead>
<tr>
<th>Land cover/ ecosystem unit</th>
<th>Rice production ($)</th>
<th>Vegetable production ($)</th>
<th>Oil palm production ($)</th>
<th>Coconut production ($)</th>
<th>Timber production ($)</th>
<th>NTFP production ($)</th>
<th>Carbon sequestration ($)</th>
<th>(dry season) River water generated ($)</th>
<th>Erosion avoided ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy field</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual cropland</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil palm plantation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Etc.</td>
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</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Valuation of provisioning services follows the same logic as the SNA production account, i.e. the resource rent approach. For regulating services different valuation methods apply as discussed.
Ecosystem asset account, principal components:

- Opening, changes in assets and closing stocks
- Challenges remain for including regulating services, perhaps for some services not useful to work with opening and closing stocks, in this case there is a need to reflect on different indicators to express the asset and its value.
- Again, the maps are essential, the summary tables just organise the data at a higher aggregation level to make it easier to communicate (see next ppt slides).
- Opening stock, natural increases and losses, harvest and closing balance are to be defined for every pixel (/BSU)
<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Paddy fields</th>
<th>Annual cropland</th>
<th>Oil palm plantations</th>
<th>Forests</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Rice production</td>
<td>Vegetable production</td>
<td>FFB production</td>
<td>Timber production</td>
<td>NTFP production</td>
<td>Carbon sequestration</td>
<td>Water regulation</td>
</tr>
<tr>
<td>Unit</td>
<td>Ton/ha</td>
<td>Ton/ha</td>
<td>ton/ha</td>
<td>ton/ha</td>
<td>Ton/ha</td>
<td>Ton/ha</td>
<td>Ton/ha</td>
</tr>
<tr>
<td>Opening stock</td>
<td>x (may be zero)</td>
<td>x (may be 0)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Natural replenishment</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x (sequestration)</td>
<td>? (e.g. soil formation)</td>
</tr>
<tr>
<td>Natural losses</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x (e.g. fire)</td>
<td>x (e.g. due to erosion or land use change)</td>
</tr>
<tr>
<td>Harvest</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x (e.g. wood)</td>
</tr>
<tr>
<td>Closing stock</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
## Monetary asset account, e.g.

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Paddy fields</th>
<th>Annual cropland</th>
<th>Oil palm plantations</th>
<th>Forests</th>
<th>Water regulation</th>
<th>Erosion control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>$/ha</td>
<td>$/ha</td>
<td>$/ha</td>
<td>$/ha</td>
<td>$/ha</td>
<td>$/ha (as a consequence of avoided floods or avoided water storage costs downstream)</td>
</tr>
</tbody>
</table>

- **Opening stock**: x (may be zero) x (may be 0) x x x ? x not relevant
- **Natural replenishment**: x x x x x x (? ) not relevant
- **Natural losses**: x x x x x x (e.g. fire) x (?) x
- **Harvest**: x x x x x x (e.g. wood) not relevant not relevant
- **Closing stock**: x x x x x Not relevant x not relevant
Biodiversity account

- Useful in order to capture biodiversity, which is of key interest for environmental management and policy making.

- Note that some biodiversity data may also be captured in the condition account, (the biodiversity account may build upon the condition account, for instance to express habitat quality)

- Relevant indicators depend on the country and ecosystem, but may include aspects such as species diversity, species numbers, red list species, mean species abundance, occurrence of specific flagship species, habitat quality etc.

- Complementary to the other ecosystem accounts, since many aspects of biodiversity are not reflected otherwise in the accounts.

- Also requires a spatial approach, i.e. a map expressing the selected indicators per pixel, complemented with summary tables organised as per the requirements of the user (e.g. per administrative unit, or land cover unit) – in particular to express trends over time (since biodiversity in different ecosystems is difficult to compare)
Supply – Use table

- Reflecting supply and use from non-financial, financial co-operations, central government, households, NPISHs and the ecosystem sector (see bullet point 1 next slide)

- The suppliers of the service are the land owners (in case of private goods) or the ‘ecosystem sector’ (in the case of intermediate or final regulating services) (– see Edens and Hein paper for details and an example)

- The final users of provisioning services may be industries (e.g. using oil palm fruit to produce palm oil), governments, or households (picking berries)

- The user of the regulating services may be the household sector (e.g. in case of reduced air pollution) or the government sector (perhaps in case of flood control)
Practical

- Identify which accounts you want to develop in the case study site
  - Condition
  - Physical and Monetary Ecosystem Services flow account
  - Physical and Monetary Ecosystem Asset account
  - Biodiversity account
  - Supply-Use table
- Which rows will be included?
- Which indicators will you use?
- Are the data available to map these indicators and populate the tables?
- How will this be done?