CIHEAM training course

Module 2

Analysis of ecosystem services provided by grazing systems in the Mediterranean: trends, approaches and gaps

Presenters:
- Mohamed Tarhouni (Tunisia)
- Paride D’Ottavio (Italy)
- Mondher Fetoui (Tunisia)

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**Topic 2.** Ecosystem services provided by grazing systems in the Mediterranean (D’Ottavio)

**Topic 3.** Methods and approaches for assessing ecosystem services in grazing systems (Fetoui)
Topic 1. Overview of pastoral and agro-pastoral systems in the Mediterranean

Mohamed Tarhouni & Paride D'Ottavio
Rangelands are found all over the world, encompassing almost half of the earth’s land surface,
• Rangelands are usually characterized by severe climate, limited precipitation, highly variable soils, frequent soil salinity, diverse topography, and generally sparse vegetation,
• They are dynamic ecosystems (year to year variations) with spatial and temporal variability,
• The majority of rangelands are either state or communally-owned.
The Near East and North Africa region (NENA)

The NENA region includes Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen.

According to climate:
- Desert range
- Steppe range
- Mountain range
- Forests
Constrains Facing NENA Region

- Extreme aridity
- Overgrazing & degraded Rangeland
- Higher demand for food as a result of increasing population
- Limited renewable water resources
- Weakness of extension/Technology transfer
Grazing system (in the past)

<table>
<thead>
<tr>
<th>System</th>
<th>Social and economic impact</th>
<th>Technical impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nomadism and fencing system: Until the end of the 1940s, most of the Bedouin were fully nomadic and transhumant, relying on natural grazing as feed for their flocks: Following rainfall</td>
<td>• Absence of conflicts between communities (Law: rights to grazing and water).</td>
<td>This sort of rotational grazing with adjusted animal number in relation to forage availability permitted a sustainable use of rangelands resources</td>
</tr>
<tr>
<td></td>
<td>• Livestock were raised for subsistence,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Animal numbers were subjected to environmental regulation</td>
<td></td>
</tr>
</tbody>
</table>
## Grazing system (Now)

<table>
<thead>
<tr>
<th>System</th>
<th>Social and economic impact</th>
<th>Technical impact</th>
</tr>
</thead>
</table>
| Settlement of communities due to political decisions | • Deep socioeconomic changes (agro-pastoral instead of pastoral)  
• Disappearance of traditional community base organizations  
• Privatization and cultivation of grazing land  
• Conflict intra and inter communities  
• Disappearance of community local knowledge in managing rangelands and drought | Increased number of animals versus reduced rangeland areas |
| Continuous grazing *(waiting rainfall instead following it)* without any restriction on stocking rate | Overgrazing |
| Animal feed resources subsidies | Cultivation |
| | Wood harvesting |
| | Loss of biodiversity |
| | Reduced animal production |
| | Desertification |
Causes of Rangeland Degradation

**Disruption of the traditional grazing system:** Use of vehicles for transportation of water to the herds and of the animals to new pastures fosters prolonged grazing on rangelands and uncontrolled movement of the herds.

The shift from the traditional pastoral systems “nomadism” to the agro-pastoral way of life have lead to the **Disruption of the traditional grazing system.**

The traditional grazing system sustained people in this area for thousands of years. Typically an area was grazed, then the flocks moved to a new location allowing the plants to recover and regenerate. Flocks could return on an annual basis or, if the site was not productive might only return once in several years. Modern grazing systems that mimic this graze and rest process hold promise for reversing the downward trend in rangeland health.
Causes of Rangeland Degradation

The conversion of the best rangelands (deeper soils with higher nutrient status) to cropland.

Encroachment of Agricultural Practices into Traditional Rangeland Areas:

* Cereals in Jordan,
* Olive trees in Tunisia.
Monocropping of barley has resulted in the depletion of soil nutrients and the elimination of perennial range species (total eradication of natural vegetation)
Causes of Rangeland Degradation

**Improper grazing practices:** Overgrazing and early grazing

- **Overgrazing occurs:**
  - Too many animals (high SR)
  - Bad timing: early grazing or prolonged grazing period
Causes of Rangeland Degradation

The destruction of woody plant species (uprooting) for:

Fuel, Herbal, Aromatic & Medicinal Purposes
Situation will be worst with CC

- Decrease in rain frequency
- Temperature rise
- Increase in seasonal variability

Predicted mean annual rainfall in 2080/2099

Climate Stimulus

Predicted mean annual temperature in 2080/2099
Rangeland managements
<table>
<thead>
<tr>
<th>Micro-catchments</th>
<th>Semicircular bunds</th>
<th>Stone contour wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contour ridges</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Water Harvesting Techniques**

- Micro-catchments
- Contour ridges
- Semicircular bunds
- Stone contour wall
Soil Surface Scarification

• Crust soils and shallow soils do not allow the establishment of good pastures.
• In order to avoid runoffs and to create niches” where plant species can develop, it is necessary to break the upper layer of the soil through the use of appropriate machinery.
• Good results are obtained by combining crusting and reseeding, because often the seed bank is very poor under this environment.

Fall before rainy season

Spring during peak growing season
Rest

Resting is an efficient tool to regenerate degraded rangelands. Better results are achieved with deep, permeable and fertile soil, and under less harsh climatic environments.

The duration of resting depends on the degree of degradation and the rainfall.
Rest

Advantages

• Easy to implement,
• Low cost (social fencing),
• Rest technique to improve rangelands productivity

Constraints

• Inefficient if livestock number is not controlled;
• Increased grazing pressure on other pastures (especially open pastures);
• Difficult to implement (consensus of community)
  - Motivation (compensation for lack of grazing)
Seed collection of pastoral species
Reseeding

- Reseeding techniques may have positive result if enough moisture is available in the soil.

- It is appropriate for moderate to highly-degraded rangelands. Nevertheless, good results were obtained in Southern Tunisia on sandy soils by using Stipa lagascae under low rainfall conditions (150 mm per
Reeseeding

- One of the main constraint is the availability of appropriate (well adapted) species (seeds).
- It is recommended to use native species (seeds collected from the same site).
- The seeds collected are a mixture of several species of grasses and legumes (such as medics).
- Under favorable conditions, reseeding may be associated with fertilizers, mainly phosphates.
Shrub Plantations

• At least 2 irrigations are needed the first year of establishment?
• For Jordan region it is recommended to plant in which season?
Advantages of Trees/Shrub Plantations

Efficient intervention

- Integral part of the agro-pastoral ecosystems
- Some shrub and tree fodder species are highly tolerant to drought and salt (halophytes);
- Easy to implement with high success rates;
- Self regeneration (no. of seedlings /shrub);
- Longevity (years of economic production).
- Provide shade
Advantages of Trees/Shrub Plantations

Enhance productivity

- Fodder reserves are useful in situations of fodder scarcity and drought periods;
- Ability to valorize out of season rains;
- Rain use efficiency (kg DM mm\(^{-1}\) ha\(^{-1}\) year\(^{-1}\)).
- Ability to use underground water, varying according to species from 2 to 20 meters;
Constraints of fodder shrubs plantations

• Require long-term planning and a secure land tenure system.
• Require managerial skills.
  • No grazing during establishment phase (1-2 years)
  • Access restrictions that allow stands to regenerate after defoliation are essential.
• High cost of establishment and maintenance.
• Availability of seeds/seedlings.
• Anti-quality factors (secondary chemical compounds or toxins).
Alley Cropping?

When we think about increasing the availability of forages, we believe that agro-pastoral production systems, in particular alley cropping system with the use of shrubs and cactus between cereal crops or in rangelands have high potential.

Plantation of Cactus in Tunisia

Grazing low quality stubble supplemented by the high protein fodder shrubs, Khanasri - Syrian Badia
**Topic 2.** Ecosystem services provided by grazing systems in the Mediterranean

Paride D'Ottavio
Ecosystem Services provided by grazing systems: a systematic review with a focus on Mediterranean climate areas

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Concept of Ecosystem service (ES)

• First references from mid-1960s (de Groot et al., 2002)

• Scientific papers concerning ES increased greatly especially after Millennium Ecosystem Assessment (Fisher et al., 2009)
Millennium Ecosystem Assessment (MA) (Alcamo et al., 2003)

- A four-year international work program launched by United Nations in June 2001

- **Aim:** to establish the *scientific basis* for actions needed to enhance the contribution of ecosystems to human *well-being*, without undermining their *long-term* productivity

- The MA represents one of the most *extensive and widely accepted studies* on the links between human *well-being* and the world’s *Ecosystems*
Ecosystem Services: 4 main groups

<table>
<thead>
<tr>
<th>Supporting Services</th>
<th>Provisioning Services</th>
<th>Regulating Services</th>
<th>Cultural Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Services necessary for the production of all other ecosystem services</td>
<td>Products obtained from ecosystems</td>
<td>Benefits obtained from regulation of ecosystem processes</td>
<td>Nonmaterial benefits obtained from ecosystems</td>
</tr>
<tr>
<td>Soil formation</td>
<td>Food</td>
<td>Climate regulation</td>
<td>Spiritual and religious</td>
</tr>
<tr>
<td>Nutrient cycling</td>
<td>Fresh water</td>
<td>Disease regulation</td>
<td>Recreation and ecotourism</td>
</tr>
<tr>
<td>Primary production</td>
<td>Fuelwood</td>
<td>Water regulation</td>
<td>Aesthetic</td>
</tr>
<tr>
<td></td>
<td>Fiber</td>
<td>Water purification</td>
<td>Inspirational</td>
</tr>
<tr>
<td></td>
<td>Biochemicals</td>
<td>Pollination</td>
<td>Educational</td>
</tr>
<tr>
<td></td>
<td>Genetic resources</td>
<td></td>
<td>Sense of place</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cultural heritage</td>
</tr>
</tbody>
</table>
ES and links to human well-being

**Ecosystem**
“A dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit”

**Ecosystem services**
“The benefits people obtain from ecosystems”

**Well-being**
“Human well-being with multiple constituents, including basic material for a good life, freedom and choice, health, good social relations, and security”
MA Conceptual Framework: Key elements

• A multi-scale approach is required to fully assess the interactions between people and ecosystems

• A multi-sectoral approach is essential to fully evaluate changes in ecosystem services, their interactions and impacts on people

• Effective incorporation of different types of knowledge can both improve the findings and help to increase their adoption
Biodiversity and ecosystem services in the MA

- **Biodiversity**: the necessary condition for the delivery of all ES:
  - ✓ is affected by *global change* drivers (e.g. climate or land use change, legal framework)
  - ✓ is a *factor modifying* ecosystem processes (e.g. soil erosion) and, through ES, the human well-being

- Changes in human well-being may lead to modify *management practices* with direct effects on ecosystem processes and biodiversity
ES analysis: the need for a multisectoral approach

• Grazing lands are associated to high biodiversity and provide a wide array of ES (D’Ottavio et al., 2018)

• Level and quality of such ES are strictly dependent on:
  ✓ management practices intensities (e.g., abandonment, overgrazing)
  ✓ drivers of change (e.g., land use, climate, socio-cultural changes)

• Amplified effects on ES provision are expected under climate change in Med climate areas (Giannakopoulos et al., 2009)

• Grazing systems are complex structures emerging from the interaction of human behavior and natural resources, requiring a multisectoral analysis (Caballero et al., 2009)
Main aims

• Analysis of the relevant literature on ES provided by grazing systems in Med-climate areas
  ✓ to highlight the lack of knowledge
  ✓ focusing on the adoption of a multisectoral approach

• This research is part of the WP2 of PACTORES Project (Pastoral ACTORs, Ecosystem services and Society as key elements of agro-pastoral systems in the Mediterranean) aiming also to analyse ES synergies and trade-offs as well as their impact on people
Extracted and excluded papers

• Extracted papers: #296

• Excluded papers: #33
  ✓ papers not addressing the focused grazing systems
  ✓ reviews, editorials and meta-analyses
  ✓ papers listed in WOS but not available (4 papers)

• Analysed papers according to the review criteria: #263
Geographic distribution of the study sites in the analysed papers
Distribution of analysed papers according to Köppen-Geiger climate groups

1\textsuperscript{st} Level
- C = temperate
- B = arid
- D = continental

2\textsuperscript{nd} Level
- W = desert
- S = steppe
- s = dry summer
- w = dry winter
- f = without dry season

3\textsuperscript{rd} Level
- h = hot
- k = cold
- a = hot summer
- b = warm summer
- c = cold summer
- d = very cold winter

Kottek et al. (2006)
## Number of findings per ES in the analysed papers (n=263)

<table>
<thead>
<tr>
<th>ES group</th>
<th>Ecosystem Service</th>
<th>Finding s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supporting</td>
<td>Maintenance of soil structure and fertility</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Primary Production</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>Maintenance of Life Cycle and Species</td>
<td>172</td>
</tr>
<tr>
<td></td>
<td>Habitat connectivity</td>
<td>20</td>
</tr>
<tr>
<td>Provisioning</td>
<td>Food</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Genetic Resources</td>
<td>19</td>
</tr>
<tr>
<td>Regulating</td>
<td>Land Degradation</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Regulation of Water Flows</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Climate Regulation</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Moderation of Extreme Events</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Pollination</td>
<td>35</td>
</tr>
<tr>
<td>Cultural</td>
<td>Opportunity for Recreation</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Knowledge System / Educational Values</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Cultural and Historical Heritage</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Inspiration for Culture Art and Design</td>
<td>3</td>
</tr>
</tbody>
</table>
# papers dealing with the main system topics

### Grazing System
- **Pastoral**: 105 papers
- **Agro-pastoral**: 70 papers
- **Agro-silvo-pastoral**: 35 papers
- **Silvo-pastoral**: 140 papers
- **Other**: 0 papers
- **NA**: 0 papers

### Grazing management
- **Continuous stocking**: 140 papers
- **Rotational stocking**: 105 papers
- **Strip grazing**: 70 papers
- **Not grazed**: 35 papers
- **Others**: 0 papers
- **NA**: 0 papers

### Forage resources
- **Rangelands**: 225 papers
- **Artificial pastures**: 150 papers
- **NA**: 75 papers

### Grazing species
- **Cattle**: 100 papers
- **Horses**: 75 papers
- **Sheep**: 50 papers
- **Goats**: 25 papers
- **Mixed system**: 0 papers
- **NA**: 0 papers
Papers eligible for the analysis (n=263) dealing with one or more ES
Multisectoral approach in the analysis of the ES in the revised papers

- In general, a low level of multisectorial analysis of all ES emerged.
Multisectoral approach in the analysis of the ES in the revised papers

- In general, a low level of multisectorial analysis of all ES emerged
- Many ES were analysed alone
- Some analysed with only another or very few ES
- Few analysed with many others
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Ecosystem Services (and relative groups) analysed in combination with each of the others

Concerning the ES groups:
- **Supporting** are generally analysed with other ES from the same group
- **Provisioning** (food) and **Regulating** ES are analysed alone
- Similarly to the **Cultural**, with exception of the Landscape ES that was analysed with a multisectorial approach
Ecosystem Services (and relative groups) analysed in combination with each of the others

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…but 3/263 papers!
Conclusions

Lack of knowledge

• **Increasing trend of studies** in Med climate areas, but
  ✓ Med basin most represented
  ✓ mostly within **Temperate with dry/hot summer** climate

• **Supporting** services most studied, much less the other groups

• **Pastoral systems using rangelands with continuous stocking** mainly studied, but others need to be considered (e.g., agro- and silvo-pastoral systems, artificial pastures)

ES multisectorial approach

• About 2/3 of the analysed papers deals with **only one or two ES** simultaneously...

• **Supporting** services mostly studied, but with other ES from the same group

• **Food** poorly studied: need to be integrated with the system features

• **Landscape** is the most studied cultural ES and the most linked with other ES groups, not all the others
Topic 3. Methods and approaches for assessing ecosystem services in grazing systems

Mondher Fetoui
à Define and introduce some basic elements and terminology related to ecosystem services (ES) valuation and assessment

à Present a review of ES assessment tools that can be applied to measure or model ES.

à Present a comparison of ES tools based on different criteria
1. What is ecosystem services valuation and assessment?

- **Ecosystem Services** (provisioning, regulating, cultural, ......) flow to people in the form of benefits or goods, supporting human well-being.

- ‘**Valuation**’ refers to the process of identifying and assessing diverse kinds of values through (but not limited to) qualitative, quantitative, monetary and nonmonetary approaches.

- **Ecosystem valuation** is a process which assigns a value (either monetary, biophysical, or other) to an ecosystem and/or its ES.
2. Why measures, model or value Ecosystem Services?

Grazing systems in Mediterranean provide value to humanity not only for the biodiversity they contain, but also because they sequester and store carbon, purify water, provide recreation and tourism opportunities, contain cultural or spiritual values, and deliver a range of other benefits.

→ Quantifying and mapping these benefits can help managers and decision makers justify the importance of these ES for conservation, attract new sources of funding, manage the sites more effectively, ....
Information provided by ES valuation can be useful for many reasons:

- **increasing support** for safeguarding the multiple benefits provided,
- **informing** management decisions,
- **ensuring equity** in resource use and benefits sharing,
- **support protection and management of natural ecosystems** to ensure an ongoing sustainable flow of benefits for current and future generations.
- establish a baseline to **monitor changes** over time,
- enable **evaluation of the consequences of management decisions or policy changes** on ES delivery.
- **achieving international conservation targets** (UN Convention on Biological Diversity, ...) and the goals of the 2030 Agenda for Sustainable Development.
Defining the purpose and objectives should be the starting point for carrying out an ES assessment.

An ES assessment is worthwhile when there is a need for additional ES understanding, there are clear objectives for the assessment, and there is a clear plan as to how the results will be used to support site conservation or management.
Ecosystem Service Assessments and Valuations (ESAVs) can help to meet the challenge to integrate ecosystem services into development decision-making (‘right kind of information’ for more sustainable development trajectories, and concrete options and instruments).

ESAVs can influence public perceptions by conveying the importance of functioning ecosystems to all economic sectors and social groups for their survival, security and growth (income, employment, food, energy, disaster risk reduction, healthcare, cultural and spiritual wellbeing).

ESAVs have to generate credible (precise and trustworthy), acceptable (recognizes different views) and useful/relevant information (responsiveness of an assessment to policy processes and societal needs and interests).
TOOLS FOR MEASURING, MODELLING, AND VALUING ECOSYSTEMS

1. Review of Ecosystem Services Valuation and Assessment Tools

- The increasing interest in measuring, modelling and valuing ecosystem services (ES), the benefits that ecosystems provide to people, have resulted in the development of an array of ES assessment tools in recent years.
According to the Millennium Assessment of ES, ESAV tools are divided into two types:

- **Written step-by-step guidance tools**: written guidance documents with specific measurement protocols enabling ES assessment of a site (Ex. The Sitebased Assessment (TESSA); Peh et al., 2017), the Protected Areas Benefits Assessment Tool (PA-BAT); Dudley & Stolton, 2008), and the Ecosystem Services Toolkit (EST); Value of Nature to Canadians Study Taskforce, 2017).

- **Computer-based modelling tools**: software or web-based tools that enable ES assessment of one or more sites (Artificial Intelligence for Ecosystem Services (ARIES; Villa et al., 2014), Co$ting Nature (Mulligan, 2015), Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST; Sharp et al., 2018), the Multiscale Integrated Model of Ecosystem Services (MIMES; Boumans et al., 2015), WaterWorld (Mulligan, 2013)
Table 1. Examples of Ecosystem services assessment tools

<table>
<thead>
<tr>
<th>Tool name</th>
<th>Acronym</th>
<th>Tool description</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Written step-by-step tools</strong></td>
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</tbody>
</table>
| Ecosystem Services Toolkit                        | EST     | - It is a guidance document consisting of steps with practical worksheets for conducting qualitative and/or quantitative ES assessment, indicators, advice on relevant issues, and a compendium of tools, methods, and models that might be applied.  
- It is a freely available dynamic PDF.  
- does not require computer modelling but guides a practitioner to select appropriate measurement, modelling or other assessment methods. | Value of Nature to Canadians Study Taskforce, 2017)                                          |
| Protected Areas Benefits Assessment Tool           | PA-BAT  | - It is a rapid, workshop-driven and standardised assessment of different stakeholders’ perceptions about ES benefits  
- It is freely available in PDF format,  
- does not require modelling or other computer skills  
- It requires stakeholder engagement such as a workshop.                                                                 | (Dudley & Stolton 2008; Ivanić et al. in press)                                              |
| Toolkit for Ecosystem Service Site-based Assessment v.2.0 | TESSA   | - It is a PDF manual that provides accessible guidance and low-cost methods to evaluate ES.  
- It generates information that can be used to influence decision making.  
- does not require computer modelling but it does require stakeholder participation.                                                                 | (Peh et al., 2017)                                                                           |
<table>
<thead>
<tr>
<th>Computer-based modelling tools</th>
<th>ARIES</th>
<th>Co$ting Nature v.3</th>
<th>InVEST</th>
<th>Multiscale Integrated Models of Ecosystem Services</th>
<th>Social Values for Ecosystem Services</th>
<th>WaterWorld v.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Intelligence for Ecosystem Services</td>
<td>ecosystem services modelling platform -designed for integrated socioeconomic-environmental modelling -Provides spatial assessment and economic valuation of ES, optimisation of payments for ecosystem services programs, and spatial policy planning. -requires modelling skills and GIS.</td>
<td>web-based tool for spatially analysing ES and assessing the impacts of human interventions such as land use change scenarios, conservation prioritisation, analysis of co-benefits (economic/monetary valuation), pressures and threats. -does not require modelling skills or GIS.</td>
<td>It is a suite of software models for mapping and quantifying ES in biophysical or economic terms under different scenarios (e.g., policy or management options). -InVEST models are based on simple, generalised production functions and require commonly available input data. -requires GIS but not modelling skills.</td>
<td>It is an analytical framework designed to integrate different ecological and economic models to understand and visualise ES values. - requires modelling skills and GIS.</td>
<td>It is an ArcGIS-dependent application that allows the user to identify, assess and map the perceived social values that people attribute to cultural ES - requires GIS.</td>
<td>It is a web-based tool for modelling hydrological services associated with land use, land management and climate change scenarios. -does not require GIS or modelling skills.</td>
</tr>
<tr>
<td>(Villa et al., 2014)</td>
<td>(Mulligan, 2015)</td>
<td>(Sharp et al., 2018)</td>
<td>(Boumans et al., 2015)</td>
<td>(Sherrouse et al., 2011)</td>
<td>(Mulligan, 2013)</td>
<td></td>
</tr>
</tbody>
</table>
Each of these tools was developed for a different purpose, and therefore each one has different strengths and limitations and provides different kinds of information.
2. Comparison of ecosystem services tools

→ The challenge is to select an **appropriate tool** for measuring and modelling ES.

➢ Selecting an appropriate tool is informed by three main factors:

1) **Purpose of the assessment** (Spatial planning, finance, etc.)

2) **Required outputs** (Qualitative/quantitative, Spatial/non-spatial, Monetary/non-monetary, Single site/multi-site)

3) **Practical considerations** (Time, Financial resources, Expertise, …)
Standard criteria have to be considered where we want to apply an adapted and effective tool for ES assessment:

- Availability
- Time requirements
- Data input demand
- Skill requirements
- Scale of analysis
- Outputs requirements
- Generalisability / Applicability in new contexts
- Level of stakeholder engagement required
We compare a set of ES assessment tools that are:

(a) most commonly applied,

(b) available to practitioners at no cost,

(c) can be applied in new contexts.
Some differences between ES assessment tools

➢ MIMES, ARIES and SolVES require conducting stakeholder surveys and running models (GIS) to produce spatial outputs. Currently, these three tools require GIS capacity as well as relatively high levels of data, time and technical skills when compared to some of the other tools.

➢ This contrasts with InVEST where the model parameters have all been defined for the user, who simply must provide the input data and parameter values in the correct format.

➢ All of the spatial models presented (ARIES, Co$ting Nature, InVEST, MIMES, SolVES and WaterWorld) allow scenario analysis, for example allowing assessment of the implications of different land use or climate change scenarios on ES.

➢ The other tools (EST, PA-BAT) can also be used for comparison or impact analysis if they are applied in a consistent way to multiple sites or to the same site over time.

➢ InVEST is the only tool reviewed that includes fully developed models for multiple marine and coastal ES; some of the other tools (such as ARIES or MIMES) could be applied in the marine if appropriate data and methods were available, while TESSA and Co$ting Nature contain methods for assessing coastal defence services.
Where time and resources allow, combining tools can be used to harness their individual strengths (ex. biophysical and economic tools, cultural and economic, etc.)

In summary, selecting an appropriate tool requires identifying the specific question being addressed (the goal of the assessment), the type of results or outputs required, and consideration of practical factors such as the level of expertise, time, and data required for applying any given tool.

While each tool is different, all of the tools provide an opportunity to shed light on ES issues and support management and policy decisions.

The comparison between tools based on standard criteria allows identifying which tool is most appropriate for specific contexts and needs → Decision trees
Example of decision trees

(c) Data collecting, mapping and economic valuation types of ES tools

DATA COLLECTING TOOLS
- Do you want to be able to collect new quantitative data?
  - YES: TESSA
  - NO: Do you want to assess cultural ES only?
    - NO: PA-BAT
    - YES: SolVES

MAPPING TOOLS
- Do you have spatial data already (e.g. land cover data)?
  - YES: InVEST
  - NO: ARIES

  - Do you have resources to collect data?
    - NO: CoSting Nature
    - YES: Water World

  - Do you want to map only cultural services?
    - NO: InVEST
    - YES: SolIVES

ECONOMIC VALUATION TOOLS
- Do you have economic data from your site?
  - NO: TESSA
  - YES: InVEST
Figure 4. Decision tree for ES tool selection based on practical considerations. This decision tree is based on a complete application of the tools; some tools can also be used just for qualitative scoping (e.g., TESSA). EST was excluded because it is high-level guidance that can lead to the selection of any other tool or method. For additional decision trees comparing other biophysical, socio-cultural and monetary ES assessment methods, see Harrison et al., 2018.

- requires paid software
- marine (coastal)
- quantitative
- monetary values
- primary data required
- designed for scenarios comparison

Do you want GIS-based maps?

- YES
  - Do you have GIS capacity?
    - YES
      - Do you have modelling capacity or the opportunity to attend a training?
        - YES
          - Do you already have data for your site or the opportunity to collect it?
            - YES
              - MIMES
            - NO
              - ARIES
        - NO
          - Do you have the capacity to conduct a survey?
            - YES
              - SolVES
            - NO
              - InVEST
    - NO
      - Do you have capacity for biophysical data collection?
        - YES
          - Water World
        - NO
          - Co$ting Nature

- NO
  - Are you primarily interested in water-related services?
    - YES
      - TESSA
    - NO
      - PA-BAT
For a more comprehensive compilation of ES assessment tools and methods, see the ValuES Database (www.aboutvalues.net/) or the EST (Value of Nature to Canadians Study Taskforce, 2017).
THANK YOU FOR YOUR ATTENTION