METHOD FACTSHEET

InVEST

Introduction

InVEST is a set of models for mapping and valuing the ecological or economic value of multiple ES at a local to regional scale. InVEST has a tiered design, from a simple Tier 0 to Tier 1 and 2 models, and is constantly under development. In recent years it has evolved from mapping only ES supply to also incorporate ES demand for some services. InVEST requires a land use map and spatial and non-spatial data associated to land use types.

In general Tier 0 models map relative levels of ES and thus highlight regions where particular services are in high supply or demand. Tier 1 models are theoretically grounded but simple. They are suitable when more data are available than are required for Tier 0, but they still have relatively simple data requirements. More complex Tier 2 models are under development for biodiversity and some ES. Currently, InVEST covers levels 0 and 1 in terms of complexity.

InVEST can be downloaded for free and most of the models run on a stand-alone platform, not directly connected to ArcGIS. Since the InVEST model is fully documented (see section on further reading), we do not aim to repeat this here. Instead, we only introduce the InVEST model as a potential and interesting tool for mapping single or multiple ES within the OpenNESS case studies.

InVEST currently includes 16 models that analyse different aspects of marine and terrestrial environments:

- **Aesthetic quality**: Maps the visibility of features on a seascape or landscape.
- **Biodiversity**: Characterizes habitat quality and quantifies relative habitat loss.
- **Carbon**: Quantifies and values carbon storage and sequestration in terrestrial ecosystems.
- **Coastal protection**: Quantifies and values the benefits of nearshore habitats for coastal protection.
- **Coastal vulnerability**: Assesses the relative risk to coastal areas from storms.
- **Crop pollination**: Quantifies and values the contribution of wild pollinators to agricultural production.
- **Habitat risk assessment**: Evaluates the risk to marine or terrestrial habitats from anthropogenic factors.
- **Managed timber production**: Values timber harvest.
- **Marine fish aquaculture**: Estimates the harvest weight and value of farmed salmon.
- **Marine water quality**: Models concentration of pollutants at sea.
- **Offshore wind energy**: Measures the electricity generation potential of wind over ocean and large lake surfaces.
- **Recreation**: Maps recreational use across a landscape and predicts future recreational use under alternative scenarios.

- **Reservoir hydropower production** (water yield): Quantifies water yield in a catchment and the amount and value of hydropower produced by a reservoir.
- **Sediment retention**: Quantifies soil loss and retention and values the avoided cost of water treatment or dredging.
- **Water purification**: Quantifies nutrient retention, and values the avoided cost of water treatment.
- **Wave energy**: Models and values harvested energy from wave power facilities.
- **Overlap analysis**: Identifies areas of potential conflict between various human uses.

Keywords

Multiple ecosystem service supply; Mapping; Valuation; Multiple scales; Process models.

Why would I chose this approach?

The power of InVEST lies mainly in the capacity to map multiple ES which enable users to do a trade-off assessment of certain land use or management scenarios (Goldstein et al., 2012). The InVEST platform provides associated tools such as the scenario generator that allows creating different land use scenarios to compare ecosystem services under these scenarios. Case studies can also map and model single ES. The carbon module, for instance, is frequently used as a model to map carbon stocks at local and regional levels.

What are the main advantages of the approach?

- The Natural Capital Project (http://www.naturalcapitalproject.org/index-2015.html) provides a standalone version of the tool, so there is no need for ArcGIS; any GIS software can be used;
- A complete set of tools is available, and a wide community of users is active around the world, all information is available here: http://www.naturalcapitalproject.org/models/models.html;
- It allows modelling of ES using multiple datasets, thus results are presumably more accurate than single-indicator based ES maps;
- It is possible to compare ES under different land use scenarios.

What are the constraints/limitations of the approach?

- Previous versions of InVEST were provided as a toolbox to ArcInfo from ESRI but the latest version is a stand-alone version;
- Typically, working with InVEST requires a good command of GIS and good knowledge of spatial data formats;
- Data preparation needs vary with the individual sub-models. Some such as climate regulation are not intensive in terms of data needs, however, data preparation for other ES can be quite long and demanding. A good knowledge of spatial data formats is needed;
- The user can not verify and control the intermediate steps of the models.

What types of value can the approach help me understand?

InVEST is designed to provide both biophysical and monetary values for the ecosystem services it includes.

How does the approach address uncertainty?

Early versions of InVEST did not account for uncertainty. However, recent versions have incorporated uncertainty analysis. Uncertainty analysis with InVEST helps when there is lack of data (or when there is uncertainty associated with data) for some of the variables that are needed to run the different models. The outputs of the uncertainty analysis include confidence rasters and standard deviations.

How do I apply the approach?

An InVEST project would include the following steps:

1. Getting familiar with the models and data needs by reading the manual. It is available on the Natural Capital InVEST web page (http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/);
2. Deciding which ES to model;
3. Collecting, managing and handling the spatial data needed as input;
4. Running the models for current ES delivery/demand and/or for different land use scenarios;
5. Reporting and interpreting the results.

The suite of ES models within InVEST each require different understanding and implementation. These specific details are provided in the User Guide (see further reading).

An illustration of the application of InVEST is provided for the two Spanish case studies. In Sierra Nevada (CS10) and Doñana (CS19), InVEST has been used to model climate regulation (see Palomo et al., 2014 for details). Data requirements to run this model have been a land use map and the following variables associated with carbon storage: carbon storage in above and below ground biomass, soil organic matter, and dead organic matter. To run the model it was necessary to perform a literature review to gather the values of these variables for the different land use types that exist in the study areas assessed. Outputs are presented in tons of elemental carbon, but their economic value could be estimated as well. Figure 1 shows different ES mapped in the Doñana Case study. Climate regulation (as carbon storage) was mapped using InVEST while the others where mapped based on indicators or on other existing models.

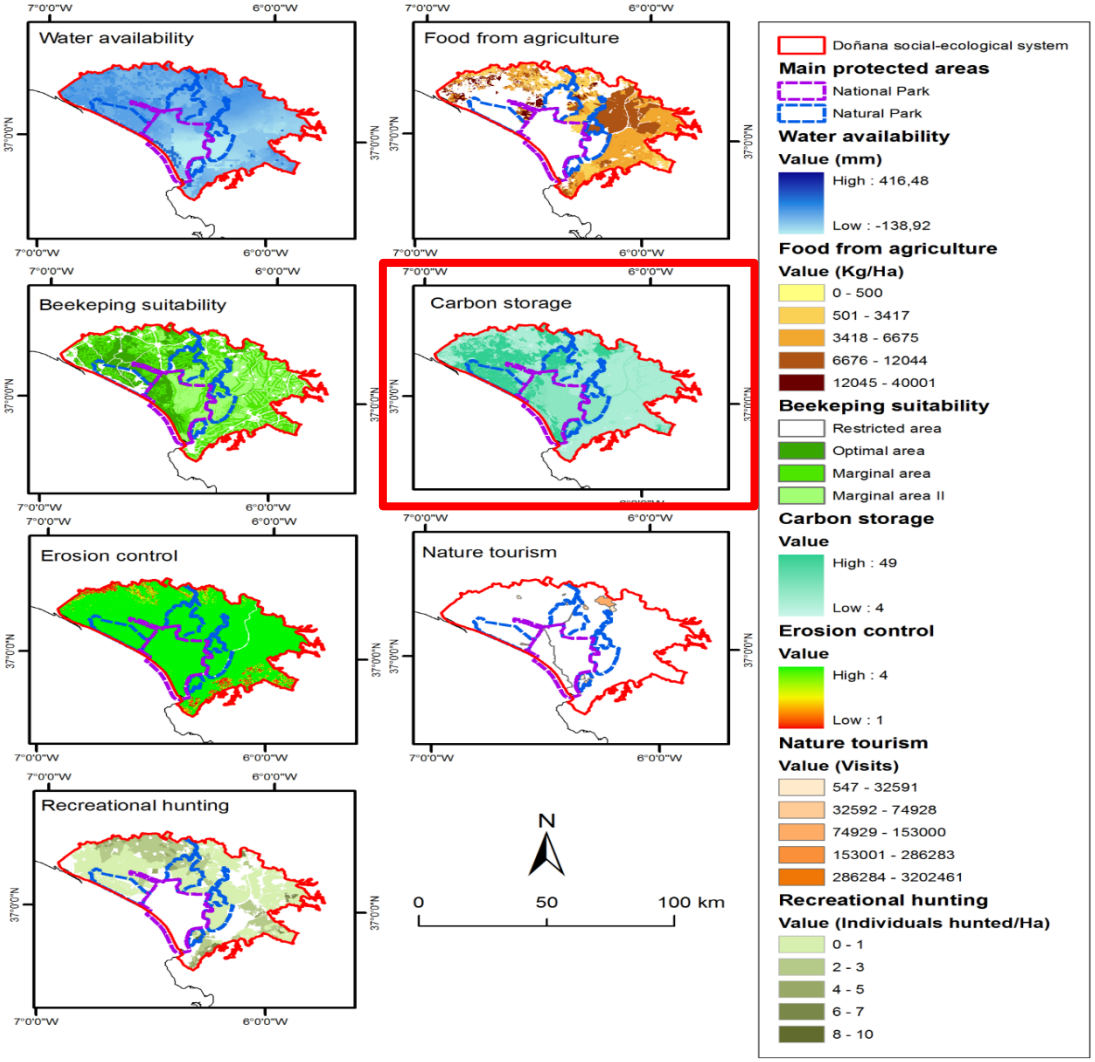

Figure 1: The different ES mapped in the Doñana Case study. InVEST was used for the carbon storage model (red box) which can then be compared with the other ES.

Requirements

Data	☐ Data is available ☑ Need to collect some new data ☑ Need to collect lots of new data	
Type of data	☑ Qualitative ☑ Quantitative	Spatially-explicit data sets (vector or raster) and additional information such as the values for different different variables for the existing land use types in the study area.
Expertise and production of knowledge	☑ Work with researchers within your own field ☑ Work with researchers from other fields ☑ Work with non-academic stakeholders	

Software	☑ Freely available ☐ Software licence required ☐ Advanced software knowledge required	A stand-alone software is provided and is freely available
Time resources	☐ Short-term (< 1 year) ☑ Medium-term (1-2 years) ☐ Long-term (more than 2 years)	Time and economic resources depend on the expertise of the researchers and GIS specialists and on the existing data. Case studies which use InVEST to quantify four to five ES should probably assume 3-5 person-months to set up a complete InVEST project.
Economic resources	☐ < 6 person-months ☑ 6-12 person-months ☐ > 12 person-months	
Other requirements		

Where do I go for more information?

All information on InVEST is available here: http://www.naturalcapitalproject.org/
The software can be downloaded here: http://www.naturalcapitalproject.org/download.html
The user forum is an additional tool which provides information and real support about different topics and practical problems: http://ncp-yamato.stanford.edu/natcapforums/discussion/7/welcome-to-the-natural-capital-project-forums/p1

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Palomo, I., Martín-López, B., Alcorlo, P., & Montes, C. (2014). Limitations of Protected Areas Zoning in Mediterranean Cultural Landscapes Under the Ecosystem Services Approach. Ecosystems, 17(7), 1202-1215.

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