The InVEST tool

InVEST is a software tool for quantifying mapping and valuing the benefits provided by terrestrial, freshwater and marine systems. Specifically it includes models for:

- Wave Energy
- Coastal Vulnerability
- Coastal Protection
- Marine Fish Aquaculture
- Marine Aesthetic Quality
- Marine Overlap Analysis Model: Fisheries and Recreation
- Marine Habitat Risk Assessment
- Terrestrial Biodiversity: Habitat Quality and Rarity
- Carbon Storage and Sequestration
- Reservoir Hydropower Production
- Water Purification: Nutrient Retention
- Sediment Retention Model: Avoided Dredging and Water Quality Regulation
- Managed Timber Production
- Crop Pollination

Both biophysical models and simple valuation techniques are embedded in InVEST. Each model is based on a production function that shows how a change in ecosystem structure and function is likely to lead to a change in the provision of a specific ecosystem service and (for many models) the value of that service in monetary or social metrics. The tool is often used to evaluate change in ecosystem services under alternative scenarios. This helps practitioners to balance objectives, weigh up trade-offs and decide how to mitigate the likely impacts on ecosystem services.

InVEST includes terrestrial, freshwater and marine ecosystem service models. Each model uses local data to assess how changes in land or marine use are likely to affect the supply and value of ecosystem services, such as timber production, crop pollination recreation, aquaculture, fisheries, coastal protection, wave energy, aesthetic quality, and water quality. InVEST requires both biophysical and socio-economic information, such as the location and activity of beneficiaries, and their social preferences.

InVEST is most effectively used within a decision-making process that starts with a series of stakeholder consultations. Through discussion, questions of interest to policy makers, communities and conservation groups are identified. These questions may concern service delivery on a landscape today and how these services may be affected by new programs, policies, and conditions in the future. For questions regarding the future, stakeholders develop “scenarios” to explore the consequences of expected changes on natural resources. These scenarios typically include a map of future land use and land cover or, for the marine models, a map of future coastal and ocean uses and coastal/marine habitats.

Following stakeholder consultations and scenario development, InVEST can estimate the amount and value of environmental services that are provided on the current landscape or under future scenarios. InVEST models are spatially-explicit, using maps as information sources and producing maps as outputs. InVEST returns results in either biophysical terms (e.g., tons of carbon sequestered) or economic terms (e.g., net present value of that sequestered carbon). The spatial resolution of analyses is also flexible, allowing users to address questions at the local, regional or global scale. InVEST results can be shared with the stakeholders and decision-makers who created the scenarios to inform upcoming decisions. Using InVEST is an iterative process. These stakeholders may choose to create new scenarios based on the information revealed by the models until suitable solutions for management action are identified.

InVEST has a tiered design. **Tier 0** models map relative levels of environmental services and/or highlight regions where particular services are in high demand. For example, the coastal vulnerability model in InVEST maps regions of the coastline that are particularly susceptible to erosion and flooding. It does not use a production function to yield outputs of meters of shoreline eroded or to value coastal protection services provided by nearshore marine habitats. There is no valuation done in tier 0 models.

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. Tier 1 models can identify areas of high or low environmental service production and biodiversity across the landscape, and the trade-offs and synergies among services under current or future conditions. Tier 1 models give outputs in absolute terms and provide the option for economic valuation (except for biodiversity). For example, the Finfish Aquaculture model can provide outputs in lbs. of fish or in pounds sterling.

More complex **Tier 2** models are under development for biodiversity and some environmental services. Tier 2 models provide increasingly precise estimates of environmental services and values, which are especially important for establishing contracts for payments for environmental services programs or assessing scenarios that address change on a sub-annual basis. For example, scenarios that represent a change in the monthly or seasonal timing of fertilizer application or water extraction in agricultural systems cannot be assessed by Tier 1 models, but will be treated well by Tier 2 models.

It is expected that users mix and match Tier 0, 1 and (later) 2 models to create the best suite of models given past work, existing data, and the questions of interest. Although the more sophisticated models require substantial data and time to develop, once they are parameterized for a certain location, they will provide the best available science for new decisions. In some cases (e.g. for fisheries), complex tier 3-type models already exist in a particular location. NatCap will not develop new tier 3 models, but rather sees these as the sophisticated, dynamic models usually developed for individual sites or contexts. The project aims to develop the capability of InVEST to communicate with such existing, complex models so that InVEST inputs (e.g. scenarios) can be fed in, and outputs from those complex models can be compared with other InVEST outputs.

In terms of economic valuation techniques, InVEST uses production functions, and market valuation, avoided cost and replacement cost methods model, such as the avoided costs of dredging sediment. However, it does not produce monetary estimates of value for certain services, such as coastal vulnerability and aesthetic views. It also quantifies biodiversity habitat (quality and rarity) and risks to marine habitat, which are not treated as ecosystem services, but as attributes of ecosystems that users may be interested in when considering trade-offs of alternative decisions.

The Case of Belize

In Belize, NatCap worked with the Coastal Zone Management Authority and Institute (CZMAI) to help them include ecosystem service considerations in developing an Integrated Coastal Zone Management Plan, to ensure the balanced and sustainable use of coastal and marine environments. Ecosystem services were considered in very specific, spatially explicit ways, focusing on benefits from lobster fisheries, tourism, and coastal protection. Many of the coastal areas are low-lying and so there is concern about erosion and storm events.

Tourism and lobster fisheries are two major sectors in Belize. Using InVEST, different ecosystem service models were run for habitats, lobster fisheries, vulnerability to storms and areas of habitat at risk from degradation. The impacts on ecosystem services were assessed for various scenarios, with different levels and spatial configurations of human uses, development and conservation areas. Very specific scenarios were run with stakeholder groups, such as exploring the impacts of building a port in a specific spot.

Through a collaborative, iterative approach with stakeholders, ecosystem service models were run repeatedly over 18 months and gave some unexpected results. Stakeholders, including developers, began to realise the importance of coastal ecosystems in mitigating risks of storm surge. The Integrated Coastal Zone Management Plan (CZMP) is now being externally reviewed and is due to be finalised in summer 2013.

NatCap is in the process of publishing two papers on how ecosystem service information is being used in decision making and lessons learned from 20 pilot demonstrations. The Natural Capital project has so far learned that:

- Applying a BES approach is most effective in leading to policy change as part of an iterative science-policy process;
- Simple ecological production function models have been useful in a diverse set of decision contexts, across a broad range of biophysical, social, and governance systems. Key limitations of simple models arise at very small scales, and in predicting specific future BES values;
- Training local experts in the approaches and tools is important for building local capacity, ownership, trust, and long-term success;
- Decision makers and stakeholders prefer to use a variety of BES value metrics, not only monetary values;
- An important science gap exists in linking changes in BES to changes in livelihoods, health, cultural values, and other metrics of human wellbeing; and
- Communicating uncertainty in useful and transparent ways remains challenging.

A practical example: the Sediment Retention model

The model predicts annual sediment erosion/runoff and calculates sediment deposition as it travels along a flowpath towards a water outlet. The model considers land use, soil erodibility, rainfall erosivity, topography and land management factors to estimate soil erosion and retention. As sediment travels down a flowpath, a proportion of the eroded soil becomes deposited along each cell until either it reaches a waterway or all of the eroded soil has been deposited.

Valuation is based on ‘critical loading’, the sediment threshold where reservoirs require dredging or efforts will be needed to improve water quality. An assumption is made that all soil that reaches the stream will end up in a reservoir.

The model is based on a modified version of the Universal Soil Loss Equation (USLE). The following biophysical data are required as inputs to the model:

- Land use and land cover.
- Topography (digital elevation model).
- Erosivity (the contribution of precipitation on soil erosion).
- Soil erodibility (the type of soil involved, for example sand will erode faster than clay).
- The crop and conservation factors which accounts for agricultural practices and the varying degrees of till.
- Watershed area (catchments going into reservoirs).
- Reservoir features – capacity of dam, lifetime of reservoir to give net value across years.

Major outputs

- Potential soil loss (calculated from the modified USLE per watershed and sub-watershed)/sediment retained (per watershed and sub-watershed).
- Valuation is the cost of avoided sedimentation based on the critical loads.

Assumptions/limitations

- The model only predicts erosion from sheet wash and ignores in-stream processes (which will be incorporated in the future).
- There are no limits to the amount of soil deposition but NatCap is currently making adjustments to limit retention capacity based on topographic convexity.
- The ArcGIS toolbox uses an eight-directional flow algorithm whereas the standalone 3.0 version of InVEST incorporates the D-infinity algorithm which allows sediment to flow across multiple directions form each cell.