Land Use Planning with InVEST

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) can support the design and implementation of land-use plans by identifying regions most critical to the supply and delivery of ecosystem services (ES). Given the diversity of land-use and spatial plans, they will benefit from InVEST analysis to varying degrees. InVEST can support the planning process by providing a coarse assessment of ES provisioning. Running InVEST models under alternative land-use scenarios can reveal areas that are particularly important for securing ES in the future. Spatially-explicit, quantified InVEST outputs enable planners to efficiently account for both development and conservation priorities.
Outlined below are InVEST's key contributions to the spatial planning process:

Planning step	How InVEST can help
1. Review context and goals	*N/A*
2. Design process and engage stakeholders	Determine where ES are supplied and delivered. Provide data and visual aids for discussion.
3. Assess land use and ecosystem services	Locate areas or current and potential ES provision
4. Establish and compare land-use planning alternatives	Compare ES outcomes of different land use and development options
5. Share results and refine management plan	Provide data and visual aids for discussion, and inform plan revisions based on ES goals
6. Monitoring and evaluation	Inform design of monitoring program, and analyze monitoring data to compare to ES goals
7. Adaptive management	Inform evolving spatial plans through iterative scenario design and analysis

InVEST

In Practice

The *InVEST in Practice* Series outlines the InVEST software's applicability to policy and planning processes. This guidance is based on our experiences developing and applying InVEST in more than 20 places around the world.

The applicability of InVEST depends on the quality and availability of data, modeling capacity, local institutional and governance structures, and the policy time-frame. The guidance should be considered in context of local social, environmental, and institutional conditions where InVEST is used.

Land-use planning assesses land and water resources, alternative planning options, and economic and social conditions in order to select land-use options.[1] This is part of the broader spatial planning process, which organizes and regulates the conversion of land[2]. Spatial plans guide decisions about which extractive and land management activities (e.g. timber harvesting) will be allowed, where infrastructure development will occur, and which land is reserved for conservation and restoration. Spatial planning can reconcile competing policy goals at local, regional, national and international scales, and can be used to coordinate the spatial impacts of various sectors (e.g. transport, agriculture, and environment) in the medium- and long-term.

1: Review context and goals

What is the purpose of the spatial planning process? Which activities are likely and feasible under current policy constraints and plans for development?

Define your spatial planning goal and objectives. Specify the location, frequency, and duration of key activities in the planning area. Review the regulations and policies that shape the planning process at national, regional, and local scales, as they may promote certain types of priority conservation activities. Determine whether there are any relevant conflicts between sectors, and if an Environmental Impact Assessment (EIA) is required.

2: Design process and engage stakeholders

How will the planning process be structured, and who will be involved?

Identify relevant stakeholders to ensure that future land-use plans are socially acceptable and feasible. InVEST can identify where ecosystem services are supplied on the landscape, enabling a comparison of their delivery to beneficiaries. Delineating servicesheds (the area providing beneficiaries with a specific service[3]) with the Serviceshed Mapper can help target relevant populations who may experience a change in ecosystem benefits due to land-use changes. InVEST outputs, such as ES maps, provide visual aids to enable discussion among stakeholders about future land uses.

3: Assess land use and ecosystem services

Where are ES supplied and delivered throughout the landscape?

Users can approximate the areas important to future ES provision based on modeled scenario runs of InVEST. Combined with information on biodiversity, this enables decision makers to specify where ecosystem services and conservation priorities overlap. Analyses can also focus on priority conservation goals defined by the government or local stakeholders. For example, InVEST analyses in Sumatra focused on five government priorities: forest restoration, forest carbon payments, payments and programs for watershed services, and best management practices for forestry and plantations[4].

4: Establish and compare land-use planning alternatives

How will ES change under alternative planning options?

InVEST can examine how ES provision may change under future land-use scenarios by comparing planning options with "business-as-usual" activities. Alternative scenarios are most effectively developed with stakeholder input, and often employ scenario development tools, such as InSEAM. InVEST can be used together with other tools, such as Marxan, a conservation planning tool, to identify efficient land-use arrangements for meeting ES supply goals. See the InVEST Scenarios Guide[5] for more information.

InVEST can quantify ES impacts of land-use alternatives in biophysical terms (e.g. tons of carbon sequestered) and in economic terms, by employing valuation techniques that consider avoided costs and the market prices of ecosystem goods. Alternative methods, including collection of field-based observations, can help address the full set of land-use related impacts. In addition, social, economic, and demographic data can be used to fully assess how land-use changes impact the distribution of benefits among stakeholders.

5: Share results & refine management plan

How will InVEST results be used?

Disseminate InVEST results so that they can be used to refine land-use options and inform a plan to meet objectives for ES outcomes. InVEST does not generate automated reports, but provides spatially-explicit model outputs which can be used to create ecosystem service maps and summary tables. These outputs can underpin final planning documents that designate alternative land uses based on impacts to biodiversity, ES losses and gains for different stakeholders, compatibility with regulatory requirements, and priority areas for conservation and development. InVEST results can also help evaluate the potential for economic incentive mechanisms, such as payment for ecosystem service (PES) programs, which compensate landowners for sustainable land use and conservation practices.

6: Monitoring and evaluation

How can sustained improvement in ES outcomes be ensured?

Effective spatial planning depends on the sustained delivery of ecosystem services to fulfill biodiversity priorities and development activities and to support human well-being. InVEST is *not* a monitoring tool. Rather, InVEST models estimate how ES are expected to change under land-use arrangements. It is therefore not useful for direct assessment of a particular spatial plan's performance, and is not a substitute for field measures of delivery towards objectives. However, InVEST can help inform the placement of monitoring stations, thereby improving the efficiency of the monitoring design. After monitoring has been conducted, field data inputs regarding current ecosystem service provision can be plugged into InVEST to determine whether identified goals have been met.

7: Adaptive management

What are methods to optimize land use over time?

As spatial plans are designed and monitored, re-running InVEST models can provide insight into how plans can be adapted to fit changing economic and environmental conditions, or to sustain ES outcomes. As outlined in Step 4, InVEST is used to evaluate the ES impacts of alternative land-use scenarios, thereby enabling ongoing adaptive management.

Key Issues for Spatial Planning

Applicable ecosystem services.

The InVEST models most appropriate for spatial planning projects are sediment retention/erosion control, annual water yield/hydropower potential, carbon storage and sequestration, forage products (including NTFPs), crop pollination, water purification, habitat quality and timber production. In the future, InVEST will also include models for flood control, irrigation water for agriculture, and agricultural production. Other tools are likely to be needed in order to assess water supply-related services when groundwater is a significant component of yield, or when ES impacts will greatly affect groundwater or the ground/surface water balance. A monthly water yield model, which includes consideration of groundwater, is under development. InVEST also has a simple biodiversity module, which estimates habitat integrity and rarity as a proxy for biodiversity. This tool can be easily integrated with existing approaches for assessing impacts to biodiversity.

Geographic scale.

InVEST has been applied to decisions made at the global, national, provincial, district, basin, and sub-basin levels. The most appropriate spatial scale for InVEST models depends on the ecosystem services modeled, the resolution of the available data, and the decision context. In general, hydrological models are best interpreted at the sub-watershed level (>1km^2), since the processes they represent are better understood at that scale, rather than at the pixel level. Results from other non-hydrological models (e.g., carbon, pollination, habitat quality) or from RIOS may be adequately interpreted at the pixel level, keeping in mind that the quality and resolution of input data relative to the size of the area of interest will still impact these results.

Relative vs. absolute values.

Without calibration to on-the-ground data, InVEST is most useful for identifying where to focus development and conservation activities based on relative contributions of ecosystem services across the landscape. However, if InVEST models are calibrated and there is good correlation between modeled results and direct observations, InVEST may prove useful for land-use decisions based on absolute values, such as determining whether a district can reach a specific water quality goal.

Alternative measures for InVEST outputs.

InVEST can quantify ecosystem services in biophysical terms (e.g. cubic meters of water), which can be useful for targeting decisions across landscapes. It can also estimate economic values, in dollar terms, using a range of techniques such as avoided damage or treatment costs and market valuation. Valuation can only be completed once the biophysical parts of the models are calibrated to time series data. Future versions of InVEST will allow users to consider additional dimensions of human well-being, such as health, livelihood outcomes, and cultural values.

Time and resources required.

The scope of the project and availability of data affect the amount of time and capacity required to apply InVEST. On the lower end, it will take 1-3 people two months to a year to compile data and run the InVEST models. In our experience, the parts of the process requiring the most time include data collection, scenario development and iteration (re-running the models with better data, for refined decision-making). A full application of InVEST results within the context of land-use planning will take longer, and require a team-member with intermediate GIS proficiency. For more detail on data requirements, see the InVEST User's Guide.

InVEST in Practice: Example Applications

Balanced development planning: Sumatra

In 2010, InVEST supported district and provincial policy makers in conducting ecosystem-based spatial planning to balance development and conservation goals in central Sumatra, Indonesia. Planners applied InVEST models to assess the quantity and location of high quality habitat, carbon storage, annual water yield, erosion control, and water purification under contrasting land-use scenarios. Results were used to inform the siting of land concessions for economic activities such as oil palm and pulp production, and for prioritizing conservation activities such as forest restoration, forest carbon payments and forestry best management practices. A 2012 report led by WWF and the Natural Capital Project provided specific recommendations for sustainable land-use planning in Sumatra, and was endorsed by Indonesian government ministries.
naturalcapitalproject.org/where/sumatra.html

Further Resources

The Natural Capital Project
naturalcapitalproject.org

InVEST User's Guide
naturalcapitalproject.org/InVEST.html

InVEST download
naturalcapitalproject.org/download.html

InVEST Toolbox
naturalcapitalproject.org/toolbox.html

InVEST and Scenarios
naturalcapitalproject.org/decisions/scenarios.html

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Zoning for conservation: China

InVEST was used to designate Ecosystem Function Conservation Areas (EFCAs) in China, covering 24% of the country's land area.[6] With the support of the InVEST sediment retention, water quality and carbon storage models, policy makers are mapping the delivery of valued ecosystem services and identifying areas most suitable for restricted development. Analyses have supported the design of EFCAs in Sichuan Province, Hainan Island, and the upper Yangtze River basin.
naturalcapitalproject.org/where/china.html

Mitigating environmental impacts: Colombia

InVEST was applied in Colombia to support the Ministry of the Environment in incorporating ecosystem services into impact assessments and permitting decisions. In 2011, scientists used InVEST models to evaluate the impacts of new and proposed coal mine permits on drinking water quality regulation services in the Cesar Department of northern Colombia. InVEST analysis evaluated the potential to mitigate mining impacts to communities through protection or restoration activities, and identified areas where full mitigation was not possible.
naturalcapitalproject.org/where/colombia.html

[1] Food and Agriculture Organization of the United Nations (1993). Guidelines for land-use planning. FAO Development Series 1, Inter-Departmental Working Group on Land-use Planning. Available at http://www.mpl.ird.fr/crea/taller-colombia/FAO/AGLL/pdfdocs/guidelup.pdf

[2] The United Nations (2008). Spatial Planning: Key Instrument for Development and Effective Governance, with Special Reference to Countries in Transition. UNECE, Information Service, Geneva.

[3] Tallis, H., Wolny, S., Lozano, J.S., Benitez, S., Saenz, S., Ramos, A. (2012). Working Paper: "Servicesheds" Enable Mitigation of Development Impacts on Ecosystem Services. The Natural Capital Project.

[4] Bhagabati, N., Barano, T., Conte, M., Ennaanay, D., Hadian, O. McKenzie, E., Olwero, N., Rosenthal, A., Suparmoko, Shapiro, A., Tallis, H., and Wolny, S. (2012). A Green Vision for Sumatra: Using ecosystem services information to make recommendations for sustainable land use planning at the province and district level. The Natural Capital Project, WWF-US, and WWF-Indonesia

[5] McKenzie, E., A. Rosenthal et al. (2012). Developing scenarios to assess ecosystem service tradeoffs: Guidance and case studies for InVEST users. World Wildlife Fund, Washington, D.C.

[6] Yukuan, W., Bin, F., Colvin, C., Ennaanay, D., McKenzie, E., and Min, C. (2010). Mapping conservation areas for ecosystem services in land-use planning, China. TEEBcase, available at TEEBweb.org

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