The Natural Capital Project
InVEST

INTEGRATED VALUATION OF ECOSYSTEM SERVICES & TRADEOFFS

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The aim of the Natural Capital Project is to align economic forces with conservation. Our focus is on ecosystems, Earth's living natural capital. If properly managed, natural capital yields a flow of vital "ecosystem services," including the production of goods (e.g., food), life support processes (water purification), and life fulfilling conditions (beauty, opportunity for recreation), as well as the conservation of options (genetic diversity for future use).

Despite its importance, natural capital is poorly understood, scarcely monitored, and—in many cases—undergoing rapid degradation and depletion. This often translates, directly or indirectly, into losses in corporations' bottom lines and society's well-being. Often the worth of ecosystem services is widely appreciated only upon their loss. As a result, natural capital is typically undervalued, to the extent that it is considered at all.

We are developing a practical and credible toolbox for quantifying ecosystem service values across land and seascapes, to enable better consideration of natural capital in decision-making.

We model key benefits of carbon sequestration; water quality, quantity, and timing of flows (for irrigation, drinking water, hydropower and flood control); pollination of crops; production of crops, timber, and non-timber forest products; recreation, and other cultural benefits.

Our approach identifies where ecosystem service benefits originate and where they are consumed. It reveals how alternative choices about resource management will affect multiple aspects of the economy, human well-being and the environment. Our methodology can help answer these types of urgent questions:

- How does a proposed hydropower management plan affect hydropower production, biodiversity, water quality and recreation?
- Which parts of a watershed provide the greatest value for biodiversity protection, carbon sequestration and poverty alleviation?
- Where would reforestation or a new timber management plan achieve both the greatest timber production and value to pollination?

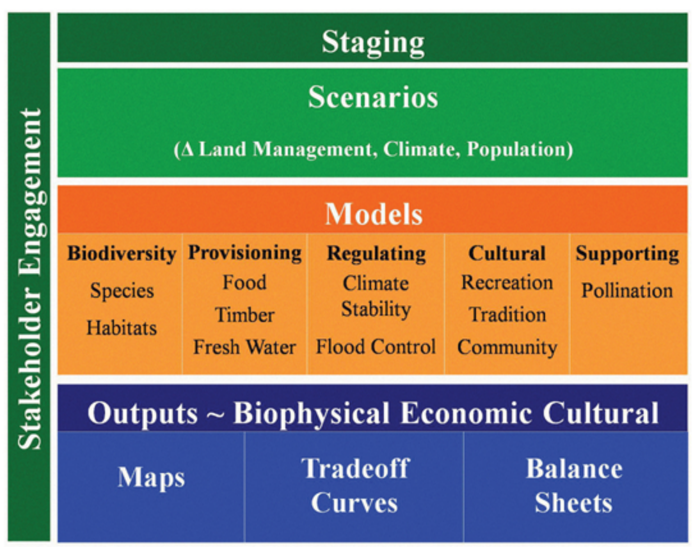

Figure 1: The InVEST Process

The first step in our approach is to identify the critical choices being considered by decision-makers or other stakeholders. From these we develop scenarios to explore answers to questions like those above, about resource management, conservation, and human well-being. These scenarios may deal with an existing landscape and identify how services are delivered today, or they can look to the future and explore the implications of new policies or a changing climate. Our approach estimates the amount and value of ecosystem services that would be provided under each scenario and represents them in many forms including maps. This modeling helps focus investments in ecosystem services provisions and also estimates the costs and benefits in ecological and economic terms of each decision.

The Models

Our advanced set of interacting models shows how different sectors, from agriculture to energy, are affected by different choices. Users can show the tradeoffs between sectors in biophysical or economic terms. For instance, this tool can assess how a new forestry management plan will change water quality in reservoirs as well as revenues from hydropower downstream. The full set of biophysical outputs we can provide is listed in Figure 2.

Currently, it is difficult to include ecosystem services in cost-benefit approaches to planning, because understanding of how ecosystems generate benefits, and the value of these benefits, has not been integrated. InVEST integrates and describes these aspects, in biophysical terms and translates them into economic estimates (see Figure 2).

Our approach requires some basic information about the landscape, management practices, infrastructure and governance. Additional, specialized information is needed for each service. Since data are often scarce, we offer a simple model with few input requirements as well as a more complex, data intensive model for each service. This unique, "tiered" feature of our tool is described more in Figure 3.

The outputs of our models include maps showing the parts of a landscape most important for the production of each resource and ecosystem service. With these maps we can see which sectors and communities gain, in terms of income and resources, from a policy or program. We can also see who will lose income or resources, and redesign programs to reduce their loss.

Our approach also reveals how funds or regulations can achieve the biggest payoff for a conservation investment in the landscape. For instance, where would payments be most effective in reducing erosion and sedimentation? Where would reforestation most benefit water quality and biodiversity? Where could we optimize landscape use based on specific goals and objectives?

The use of this approach can also minimize conflict among sectors and potentially maximize benefits from land-uses for both people and the environment. Trade-off curves will be the most useful outputs in this sense, showing the relationship between two sectors. For example, trade-off curves can reveal how much timber can be harvested before causing major profit loss to hydropower, major flood damage costs or severe loss of biodiversity.

Finally, balance sheets reveal the trade-offs and synergies among all services in one simple table.

Biophysical Terms

Fresh Water
- Water supply by sector (agriculture, hydropower, etc.)
- Water quality by sector

Flood Regulation
- Avoided flood volume

Wood, Timber
- Timber Yield
- Wood yield
- Non-Timber Forest Product (NTFP) yield

Climate Regulation
- Carbon stocks
- Carbon sequestration
- Who participates in the market

Biodiversity
- Habitat representation – area and quality
- Species richness

Non-use
- Attributes of cultural sites

Pollination
- Pollinator abundance on farms
- Crop yield due to native pollination

Agriculture
- Crop type
- Crop yield

Recreation
- Site visitation rate

Economic Terms

Fresh Water
- Hydropower income
- Crop value of irrigation water
- Drinking water cost
- Industrial water cost

Flood Regulation
- Avoided flood damage costs

Wood, Timber
- Net Present Value (NPV) of timber
- NPV of wood
- NPV of NTFPs

Climate Regulation
- NPV of carbon credits
- Income from markets

Biodiversity
- Existence value

Non-use
- Way of life value

Pollination
- Crop value of native habitat
- Crop value due to native pollination

Agriculture
- Net Present Value of crop yield

Recreation
- Site income

Figure 2: Biophysical Terms and Economic Estimates

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Keeping It Simple

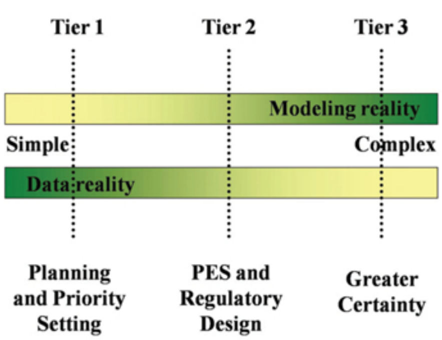

Figure 3: A Tiered Approach to Ecosystem Service Modeling

Our "tiered" modeling approach ensures that our models will be useful worldwide, even in places with sparse data. The Tier 1 model for each ecosystem service is the simplest possible model that gives a credible, scientifically sound estimate of ecosystem service levels and values. Tier 1 models have few data requirements and are meant to be useful anywhere in the world. These models are best suited for identifying patterns in ecosystem service production and value across a landscape, an activity useful in planning or priority setting exercises.

Tier 2 models are more complex, represent more of the natural and social processes that determine ecosystem service delivery and value, and require more data. These models are more useful for the design of payment for ecosystem service (PES) programs, licensing and permitting activities, or mitigation and offset programs.

For example, a hydropower company may want to design and implement a payment program to encourage land management practices that increase water yield and decrease soil erosion in a watershed upstream from an important reservoir. The Tier 1 water for hydropower model will usefully identify areas of the landscape that should be targeted for best management practices in this program. The Tier 2 models would be needed to help set payment levels and estimate the real return on investment that could be expected from the program.

Finally, Tier 3 models are even more complex models that include time steps and feedbacks. We will not develop these kinds of models since this is the most common type of model developed by others. When Tier 3 models have already been developed for a region, we can integrate those models into our approach. For instance, many river basins already have sophisticated hydrology models. These can be incorporated as the best available water models, building on existing knowledge and efforts, and providing the most refined and detailed estimates.

The Results

Figure 4: The Willamette Basin, Oregon, USA

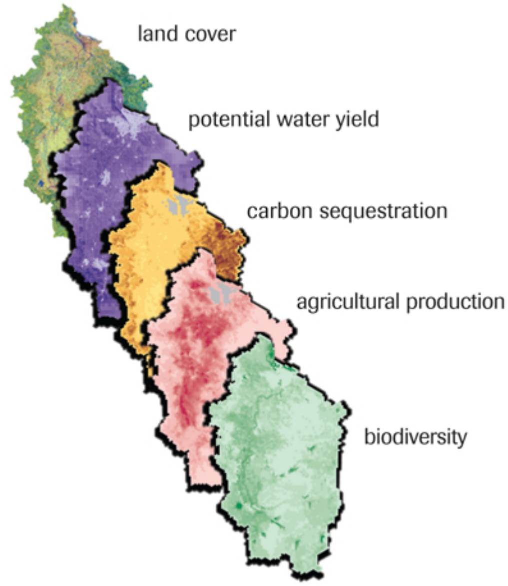

Figure 5: InVEST Maps of Biodiversity and Ecosystem Services in the Willamette Basin

The R&D team of the Natural Capital Project is developing maps showing the production and distribution of ecosystem services. These maps of the Willamette Basin, a watershed in Oregon (USA) provide a sample illustration in Figure 5. The watershed runs 270 km from north to south, and the capital city of Portland is in the northeast (Figure 4). The current landscape is shown as the "land cover map" in the cascade of maps in Figure 5.

Each of the other maps show where the current landscape provides more or less of one specific ecosystem service. Dollar values can be used, as in the case of the agriculture map, where dark red areas show high levels of profit for that service. In the other maps, we use biophysical terms rather than dollar values. For example, dark brown areas on the carbon sequestration map show areas with more tons of carbon per hectare. These maps allow us to see where the provision of several services overlap on the landscape and where there are tradeoffs among services.

The InVEST tool can also assess and map how the provision and value of services will change under new policies, plans or climate conditions. For example, the maps in Figure 6 show how services would change over the next 50 years under a proposed loosening of restrictions on development in the Willamette Basin. These "change' maps show the difference between service levels and values today and in the year 2050, making it easier to see just how services have shifted. Areas in green have a higher service level in 2050, while areas in red lose services. With these maps, decision-makers can see how much will be gained and lost, as well as who will benefit and who will lose under a new management plan.

Another way to look at these changes is by looking at the overall landscape scale. Instead of focusing on patterns in space, we can simply focus on the overall levels of services provided in the Basin, or any other place of interest. One way to represent landscape level services is in trade-off curves like the one in Figure 7. These let us look at the relationship between specific sets of services.

The same group that created the "development trend" shown in Figure 6 also created a "plan trend" that projects policies like those in place today through 2050 and a "conservation trend" that focuses more on protecting natural habitats. The dots on the left hand side of the graph in Figure 7 show the expected levels of biodiversity and commodity value for the whole Willamette Basin for each option in 2050. Looking at these points, we see the classically perceived tradeoff between biodiversity protection and economic development. When biodiversity values are high (conservation trend, green dot), commodity value (real estate, agriculture and timber values) is relatively low. When commodity value is high (plan and development trends, brown and orange dots respectively), biodiversity values are relatively low.

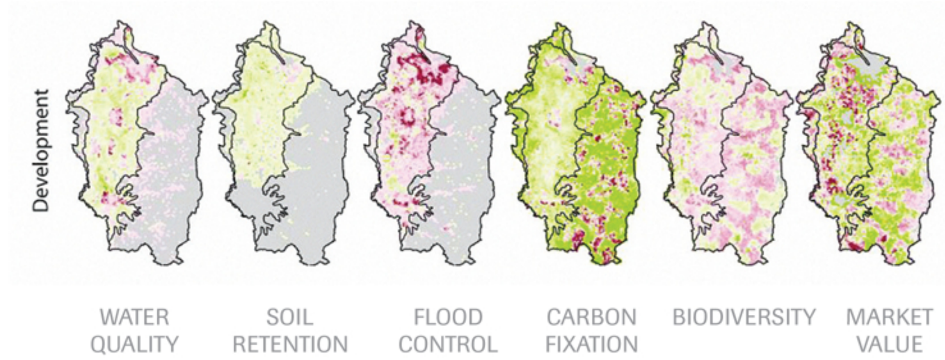

Figure 6: InVEST Maps of Change in Ecosystem Services as a Result of Development Between 1990-2050 in the Willamette Basin

Shifting the Balance

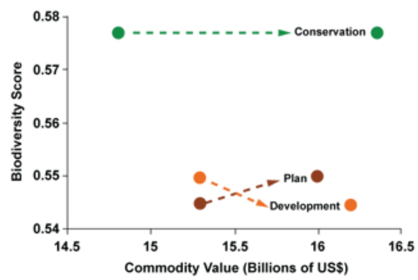

Figure 7: How a Carbon Market Could Erase Trade-offs Between Biodiversity and Market Revenues in the Willamette Basin

Realizing the value of just one ecosystem service can completely change the picture. We asked what would happen if the carbon sequestration market was formalized in Oregon, allowing landowners to gain revenue from carbon sequestration on their property. Formalizing the carbon market, an action already being considered by the Oregon legislature, moved all the points on the graph to the right, showing the increase in revenue the carbon market would add. This new revenue changes the balance. The conservation trend now provides the highest biodiversity score and the highest commodity value for the Basin. Exercises like this show how InVEST can improve the decision-making process and reveal win-win opportunities.

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