InVEST Scenarios Case Study:
Eastern Arc Mountains, Tanzania

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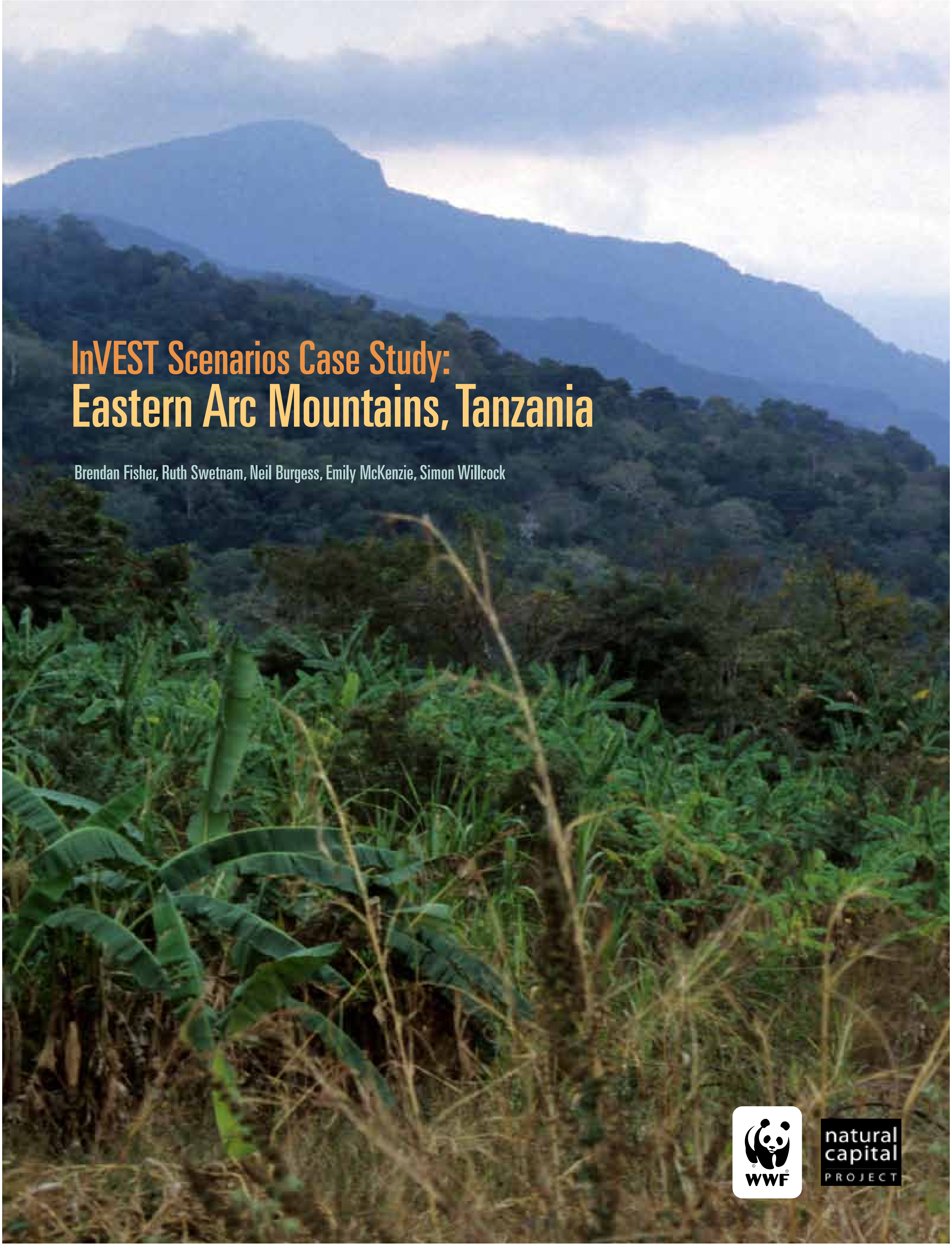


excerpted from

Developing Scenarios to Assess Ecosystem Service Tradeoffs

This case study highlights a real-world example of using InVEST scenarios to inform decisions about land use. In this example, scenarios were developed, ecosystem service impacts were assessed, and the results were used to make sound policy decisions. The case study offers background on the policy context and goals, and then delves deeply into the experience with scenarios and draws out lessons.

Background

One of the richest areas in the world for biological diversity is the Eastern Arc Mountains, which harbor around 100 vertebrate species and at least 550 plant species found nowhere else. However, arguments based on biodiversity alone have failed to halt the conversion of Eastern Arc forests to farmland: Less than 30 percent of the original forest now remains, almost all within protected areas of various kinds.

The mountains provide benefits to people too—water regulation for farming purposes, water flow for hydroelectric power generation, and water for domestic and industrial use by almost 4 million users in Dar es Salaam. Other services derived from the forest include fuelwood, food, medicine, timber and building poles for nearby villagers, and carbon storage and sequestration for the global community. In 2007, a 5-year research program called Valuing the Arc was established to research the value of these ecosystem services, and thereby strengthen the case for conservation of the Eastern Arc Mountains. This major endeavor involved over 30 researchers in Tanzania, the UK and the U.S., and aimed to demonstrate the true contribution of ecosystems in the Eastern Arc Mountains to the Tanzanian economy and society, and integrate these values into important decisions and support novel policy solutions.

While this research was under way, Tanzania was selected as a pilot country under the UN-REDD (Reducing Emissions from Deforestation and forest Degradation) pilot program and the bilateral Norwegian government support for REDD readiness work, and the Tanzanian government was therefore involved in a variety of activities to prepare for REDD. These included building capacity and developing a national strategy for REDD, in the expectation that REDD would be included in the UN Framework Convention on Climate Change.

Tanzania also experimented with equitable payments for watershed services (PWS) with pilot feasibility studies in the Pangani and Rufiji water basins, and one operational project in the Uluguru Mountains that was established by WWF and CARE. The Eastern Arc Mountains provide drinking water for at least 60 percent of the urban population of Tanzania. The mountains are also the source for more than 90 percent of the nation's hydroelectricity generation capacity (which constitutes half of total power production) (Burgess et al. 2007).

Within the Uluguru mountain block, poor farming practices and conversion of forest to farmland were leading to heavy sediment loading and turbidity of feeder streams leading into the main river, affecting water treatment costs of industries and utilities downstream (Zahabu, Malimbwi, and Ngaga 2005). The PWS project aimed to create incentives to conserve and improve the reliable flow and quality of water downstream, and at the same time improve the quality of life of rural poor communities. As Valuing the Arc conducted their research, there was interest in scaling up PWS schemes to additional water catchments.

Across developed and developing countries, governments are striving to improve the integration of policies across ministries and departments. Such is the case in Tanzania. The Valuing the Arc research program used the ecosystem service framework to show how different sectors affect—and depend on—the achievement of goals in other sectors. For example, the delivery of freshwater depends on the regulation capacity of upland forests and woodlands. Therefore an integrated approach to policy and project implementation is required, involving both forestry and water sectors.

What policy questions did the analysis set out to address?

The mapping of ecosystem services in the Eastern Arc Mountains was designed to meet both research and policy goals. In terms of research, the program aimed to develop cutting-edge ecosystem service analytical methods and develop new insights on the contribution of ecosystem services to a range of beneficiaries—from the global community to poor, local, rural communities. At the broadest policy scale, the program aimed to demonstrate to policy makers in Tanzania the value of ecosystem services and thereby strengthen support for conservation where the benefits outweighed the costs.

More specifically, the project aimed to provide information needed for scaling up market mechanisms to maintain ecosystem services, answering policy questions such as: “Where are REDD pilots most likely to be economically viable compared with other land-use choices?” and “Where does conservation make the most sense in terms of the net social benefits and costs across a range of services and land uses?” Valuing the Arc also aimed to demonstrate the practicality of mapping ecosystem services in a region with moderate data availability and with emerging capacity for GIS-based mapping and modeling approaches.

What scenarios were selected?

Scenarios were developed to shed light on how land-use change due to socioeconomic factors affected ecosystem service delivery. These socioeconomic factors were pinned to the level of success of the implementation of various national policies or changes in such policies.

The scenario development process created a framework for exploring how driving factors—such as policy shifts and their attendant socioeconomic effects (e.g., population growth)—might change in the future. The Tanzania study team built scenarios that represented possible futures that were grounded in policy and practical realities in Tanzania and looked plausible to stakeholders.

The study team assessed ecosystem services under three scenarios:

- **Matazamio Mazuri (Hopeful Expectations):** This scenario reflects an optimistic vision of the future, where Tanzania meets all its stated policy goals to alleviate poverty and manage natural resources sustainably. REDD policies and payments for watershed services are successfully implemented. The population continues to grow, but more slowly, and exogenous economic pressures continue.
- **Kama Kawaida (Business as Usual):** This scenario represents stakeholders' expectations of the future in Tanzania if current policy and practice continue. REDD is not implemented at any meaningful scale. There is a growing population and ongoing resource exploitation, leading to environmental degradation and declining family income.
- **Sideswipe Scenario:** The team also developed a scenario sideswipe that explored the possibility of an agricultural land grab, following a recent trend in Africa. In this scenario the area of agricultural land expands dramatically. This scenario was developed outside of the participatory process, but in response to priority "what if...?" questions presented by decision makers.

How were scenarios developed?

Valuing the Arc researchers broke new ground by developing a process to move from narrative scenario storylines to quantitative, spatially explicit scenario maps that described the direction and magnitude of land-cover change (Swetnam et al. 2011). The entire process involved extensive stakeholder input and participation through a policy review, interviews, and workshops (Fisher 2008).

Scenario development was led and facilitated by a social science team with some expertise in scenario development. First, current sectoral and national policies and strategies were reviewed, such as the agriculture strategy, tourism strategy, the Mkukuta Poverty Reduction Strategy Papers, and the Tanzania Vision 2025. This review highlighted the sectors, interventions and policy goals that are likely to interact directly with ecosystem services in the Eastern Arc Mountains. Relevant sectors included agriculture, water, livestock, tourism, health, forestry, transport and energy.

Semi-structured interviews were conducted with government, academic and NGO representatives. The first round of interviews helped researchers gain an understanding of current trends, key policies and interventions, and perceptions of the major impediments to, and environmental impacts of, growth in different sectors. The interviews also helped to draw together a commonly shared vision for Tanzania's future.

A participatory workshop was then held to develop a first draft of the scenarios. Participants came from government ministries, universities and NGOs. Stakeholders gave their perspectives on the state, trends, opportunities and challenges facing relevant sectors. They also shared insights on the drivers of change in Tanzania, clarifying important linkages among development, the state of the Eastern Arc Mountains, and the ecosystem services they provide.

The workshop included exercises to elucidate the impacts of, and interactions among, sectors, policies and ecosystem services. Stakeholders situated each sector along axes of economic importance and environmental impact, and assessed how this might change over the next 25 years under a business-as-usual and an ecologically optimistic trajectory. Participants were also asked to list policies, interventions, opportunities and threats that might drive these trajectories.

For example, the forestry sector was assessed as currently having little negative impact on the environment and as being of limited economic importance. Under a business-as-usual trajectory, the group listed informal logging activities and low monitoring capacity as threats to forestry. Under an optimistic trajectory, the group saw the growth of a regulated carbon market and adequate funding for PWS schemes as opportunities to improve both the biophysical state of the forests and their economic importance.

On the basis of information and stakeholder input gleaned from the policy review, interviews and the first workshop, qualitative narrative scenario storylines were developed. These scenarios were then sent back to workshop participants for review and comment. A second round of interviews were undertaken to test the plausibility and utility of the draft scenarios. One of the original storylines (representing a situation of low economic growth and high environmental sustainability) was subsequently rejected, as it was not deemed to be relevant, realistic or useful by many stakeholders.

A second workshop was held a year after the first, to revise and build consensus on the final scenarios. A major part of this workshop involved translating the qualitative narrative storylines into quantitative changes in different land-cover classes expected under each scenario. Stakeholders ranked the impacts of particular drivers on land-cover inputs needed for the ecosystem service models. The direction and magnitude of the land-cover impacts were ranked.

For example, the group assessed how population is likely to affect forest cover, and how markets for biofuels are likely to affect agricultural lands. To simplify the process, the 30 land-cover classes were combined into six categories. Two separate groups undertook the process, and there was minimal disagreement across them. The interactions were then checked for consistency.

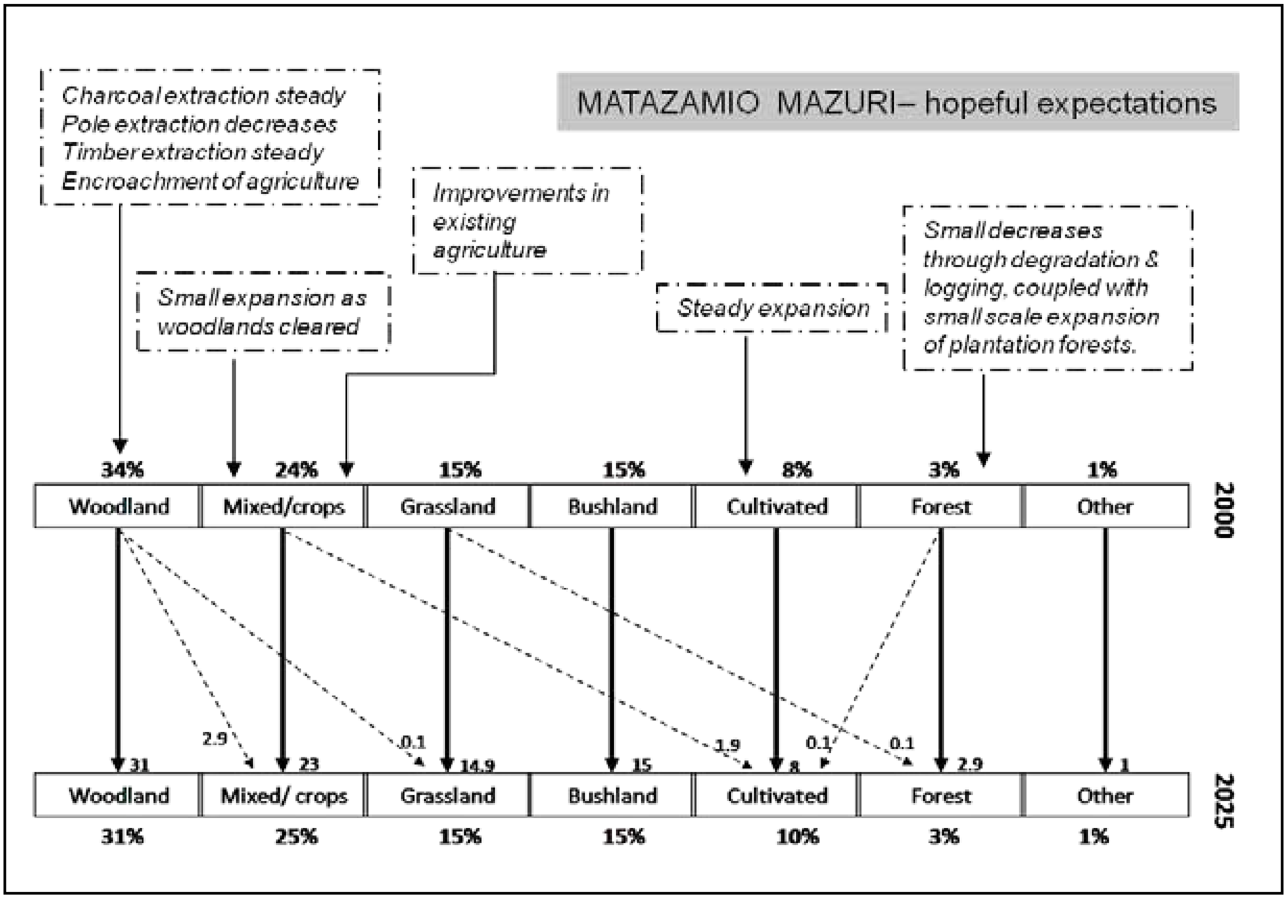
The participants then considered how these trends could impact land cover across the region and helped to construct simple diagrams which captured the current and future state of land cover and contained information on the flows between classes (see Figure 1, p. 5).

How were scenarios translated into land-cover maps?

Once the team had quantitative impacts on land cover for each scenario, the next step was to determine where these changes might happen across the landscape (Swetnam et al. 2011). The research team—with stakeholder input from the second workshop—constructed rules for each land-cover group to govern where changes could occur. These included both biophysical rules, based on factors such as soil type or climate variables, and socioeconomic rules, based on factors such as the administrative region or population level.

The workshop facilitator questioned the participants to make general rules more specific and quantitative. For example, participants clarified that land was targeted for agricultural expansion based on climate suitability and the proximity of transport infrastructure. Expert knowledge, existing data and literature reviews were used to define a specific, quantitative rule: agricultural land increases where

FIGURE 1 Interactions among sectors and land-cover change under an optimistic scenario in Tanzania



Expected land cover transitions under the Matazamio Mazuri scenario, with the top line of boxes showing the distribution of the main land-cover groups in 2000 and the bottom the estimated situation in 2025. Bold arrows between classes show those components which have remained unchanged; dashed arrows indicate fluxes between classes. *Figure 2 in Swetnam et al. (2011) Journal of Environmental Management.*

rainfall is at least 800 mm yr and closest to current transportation routes. This process was repeated to move from qualitative to quantitatively expressed rules. Each time, participants started with a broad qualitative statement. Participants then developed more specific quantitative rules, facilitated by questions from the modelers who needed to implement the rule. In many cases, participants could not provide exact values but instead gave general guidance that could be checked in the published literature later—e.g., the minimum rainfall value for sorghum/maize/wheat.

Each land-cover group had its own associated set of rules. These were then coded into the Geographic Information System (GIS) by combining different digital datasets. The final map for each land-cover group only contained those areas which met all the conditions specified in the rules (these were termed “spatial masks,” and there was one for each land-cover group). Agricultural expansion was deemed to be the most important driver of land-cover change in the region and as a consequence it attracted the most attention. The rules for agriculture are summarized in Table 1 (p. 6).

TABLE 1 Rules determining the location of agricultural expansion

Qualitative rules	Quantitative rules
Agriculture can expand where the climate is suitable	800mm ≥ Annual Rainfall ≤ 1800mm AND 155mm ≥ Dry Season Rainfall ≤ 740mm
Agriculture can expand where the soils are good	Soil type must equal type “a, b or c” (where these are Tanzanian soil types)
Agriculture will expand where the land is already near a road and near existing areas of agriculture	Distance to road ≤ 20km AND Distance to existing agriculture ≤ 20km
Agriculture will expand mainly in the miombo and coastal habitats; it will not expand into existing plantation forest	Land-cover type ≠ urban, plantation forest or swamp

A second stage of refinement was then undertaken. The spatial masks were graded, with each cell assigned a weight based on accessibility to the main market of Dar es Salaam; accessibility to the nearest navigable road; accessibility to existing agriculture; and climatic suitability for the land-cover class under consideration. Cells with a high weighting were targeted first for land-cover change.

How did the scenarios shape the final results for policy makers?

One outcome of the scenario development was their use as an input for the carbon modeling within the InVEST tool. Researchers compared the total loss of carbon under each scenario, and mapped where carbon gain and loss occurred across the landscape. Using a modest estimate of carbon value (≈ $15 per Mg CO_2), indicative changes in the value of carbon stored and sequestered were calculated under each scenario.

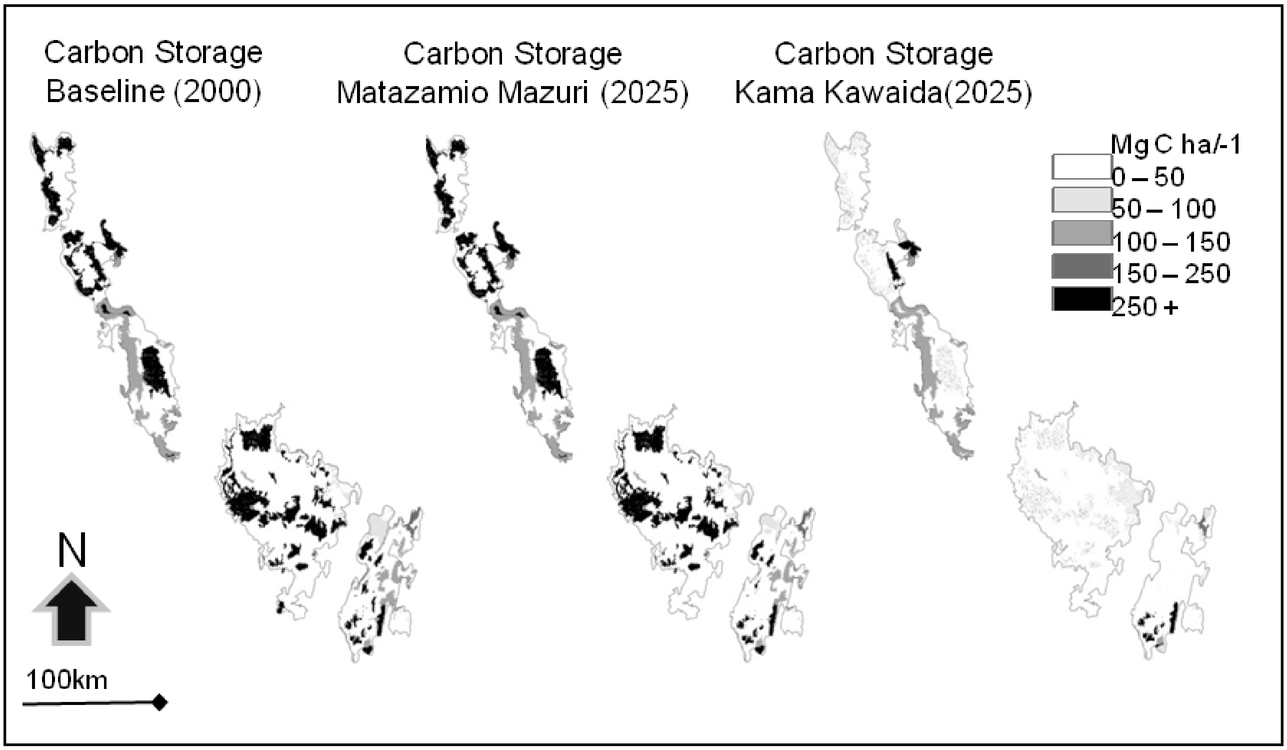
To explore tradeoffs, similar analyses were undertaken using both InVEST and more sophisticated process models for other ecosystem services. Ecosystem services included biodiversity, water yield, firewood, building materials (thatch), food (fruit, tubers, honey, bushmeat), and provision of wood for charcoal. All the terrestrial ecosystem service models used land cover as a major input, so it is through changes in land cover that the scenarios propagated change.

The scenarios showed policy makers what might happen to Tanzanian forests in the future, and the implications for multiple ecosystem services. The difference in the future carbon storage in the Kama Kawaida scenario compared to the Matazamio Mazuri scenario showed the additional carbon “saved.” This identified areas that could be candidates for payment under REDD+ and voluntary carbon projects.

Key assumption

- The scenarios assumed a mid-range climate for Tanzania. The modelers assumed that over the timescale of the scenarios (to 2025), climate would be a less significant driver of land-use change than would socioeconomic forces.

FIGURE 2 Changes in the spatial distribution of carbon storage under scenarios in Tanzania



The four focal mountain blocks of the northeastern Eastern Arc Mountains, showing changes in the spatial distribution of carbon storage by block and overall changes in carbon storage (tonnes). *Figure 5 in Swetnam et al. (2011) Journal of Environmental Management.*

Strengths

- The project used a participatory process that channeled local expert input into the entire process of developing qualitative scenarios, estimating quantitative impacts on land cover for those scenarios, and determining where on the landscape those impacts would occur.
- The final scenarios were selected on the basis of relevance and utility for Tanzanian stakeholders. The scenario process was flexible and iterative, with continued evolution in which scenarios to include, based on feedback from stakeholders. Those scenarios that did not resonate were rejected.
- Scenarios were used as a way to engage policy makers. In presenting the carbon results to policy makers at the Copenhagen Climate Summit, the scenarios generated significant interest.
- The scenarios were based on a comprehensive and integrated set of drivers and interactions, using workshop exercises, but did not require quantitative scenario modeling.
- The comprehensive approach for developing these scenarios enabled learning elsewhere. For example, a simpler version of the approach was developed for a project in the Virungas landscape covering Rwanda, Uganda and Democratic Republic of Congo.

Challenges and areas for future improvement

- The scenarios were highly detailed and parameterized, because they considered a large number of interactions among drivers, sectors, policies and land-cover impacts. This may have made them too complex to be transparent to policy makers.
- The scenarios captured changes in the quantity of each land cover under each scenario, but not changes to the condition of land cover.
- The process required considerable time, capacity and expertise. The total staff time was approximately one year, devoted full-time. This was split between two staff members, who ran the interviews and workshops, and undertook the modeling. Developing the qualitative scenarios required an understanding of macroeconomics and policy, along with facilitation, data collection, literature review and interview skills. Translating the scenarios into land-cover maps demanded a high level of GIS, data management and spatial modeling skills. Funding was needed to cover the costs of workshops.
- Many people seized on the scenario maps as definitive results, and focused on the details of a relatively small area they knew well. Researchers emphasized that the scenarios were depictions of uncertain futures at broad scales—more important in terms of relative gains and losses—and should be interpreted as such.
- The study team initially intended to use downscaled global scenarios based on the Special Report on Emissions Scenarios published by the IPCC, and on the global scenarios developed to assess future trends in ecosystem services published by the Millennium Ecosystem Assessment. However, Tanzanian stakeholders felt these scenarios, and the drivers and policy levers embodied within them, were not relevant to Tanzania. The scenarios were reframed to fit their interests and needs. The new scenarios were not downscaled global scenarios, but based on local information on Tanzanian drivers and policy.
- Data availability was a challenge, with few digital data sources of sufficient quality and scale, and many inconsistencies across sources. The biggest challenges related to information on soils and agricultural capacity. Key datasets, such as settlement and road data, had to be created from disparate sources or digitized afresh. Interviews, grey literature, peer-reviewed literature, and government policies were cross-checked to obtain reliable estimates of key statistics.
- It did not prove feasible to integrate climate change and socioeconomic scenarios in the same modeling approach. As they interact, this presented a complicated modeling and conceptual challenge.

Case Study References

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Valuing the Arc: www.valuingthearc.org

REDD in Tanzania: www.reddtz.org

SNAPSHOT | Tanzania

POLICY CONTEXT

Policy level
Local, sub-national (Eastern Tanzania) and national

Policy questions
- advocate conservation by demonstrating nature's value
- explain why REDD and PWS policies are needed
- suggest where REDD and PWS pilots could be feasible and outline different costs of these approaches

Ecosystem services included
Carbon storage and sequestration, biodiversity, water yield, firewood, building materials (poles and thatch), food (fruit, tubers, honey, bushmeat), provision of wood for charcoal production

SCENARIO PRODUCT AND PROCESS

Scenario format
Qualitative narrative storylines and quantitative impacts on land cover for each scenario

Number of scenarios
2

Time frame for scenarios
Study undertaken in 2010; scenarios envisioned for 2025

Time frame for ES assessments
Carbon assessed for 2025

Spatial extent of scenarios
Eastern Tanzania (340,000 km^2)

Spatial extent of policy recommendations
Eastern Arc Mountains (35,000 km^2)

Stakeholder participation in scenarios
Medium/High

Consideration of exogenous drivers
High

Consideration of endogenous drivers
High

Capacity and time required
High

THIS CASE STUDY WAS DEVELOPED THROUGH THE NATURAL CAPITAL PROJECT, WHICH IS A PARTNERSHIP AMONG

Developing Scenarios to Assess Ecosystem Service Tradeoffs: Guidance and Case Studies for InVEST Users is a resource for practitioners who want to assess the provision of ecosystem services under alternative future scenarios. The guide draws on case experiences where InVEST was used to compare ecosystem service tradeoffs under different scenarios. It can help InVEST users choose appropriate types of scenarios and methods, engage stakeholders, and create scenario maps. The guide highlights key issues and questions for reflection, along with tools, case studies, references and resources for those who want to learn more.

InVEST is a suite of ecosystem service models, developed by the Natural Capital Project, for mapping, quantifying and valuing ecosystem services under different scenarios. InVEST helps decision makers incorporate ecosystem services into policy and planning at different scales in terrestrial, freshwater and marine environments.

Further materials are available on the scenarios page at naturalcapitalproject.org