InVEST Scenarios Case Study:
Hawaii, USA

Josh Goldstein, Giorgio Caldarone, Gretchen Daily, Ka'eo Duarte,
Neil Hannahs, Emily McKenzie

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

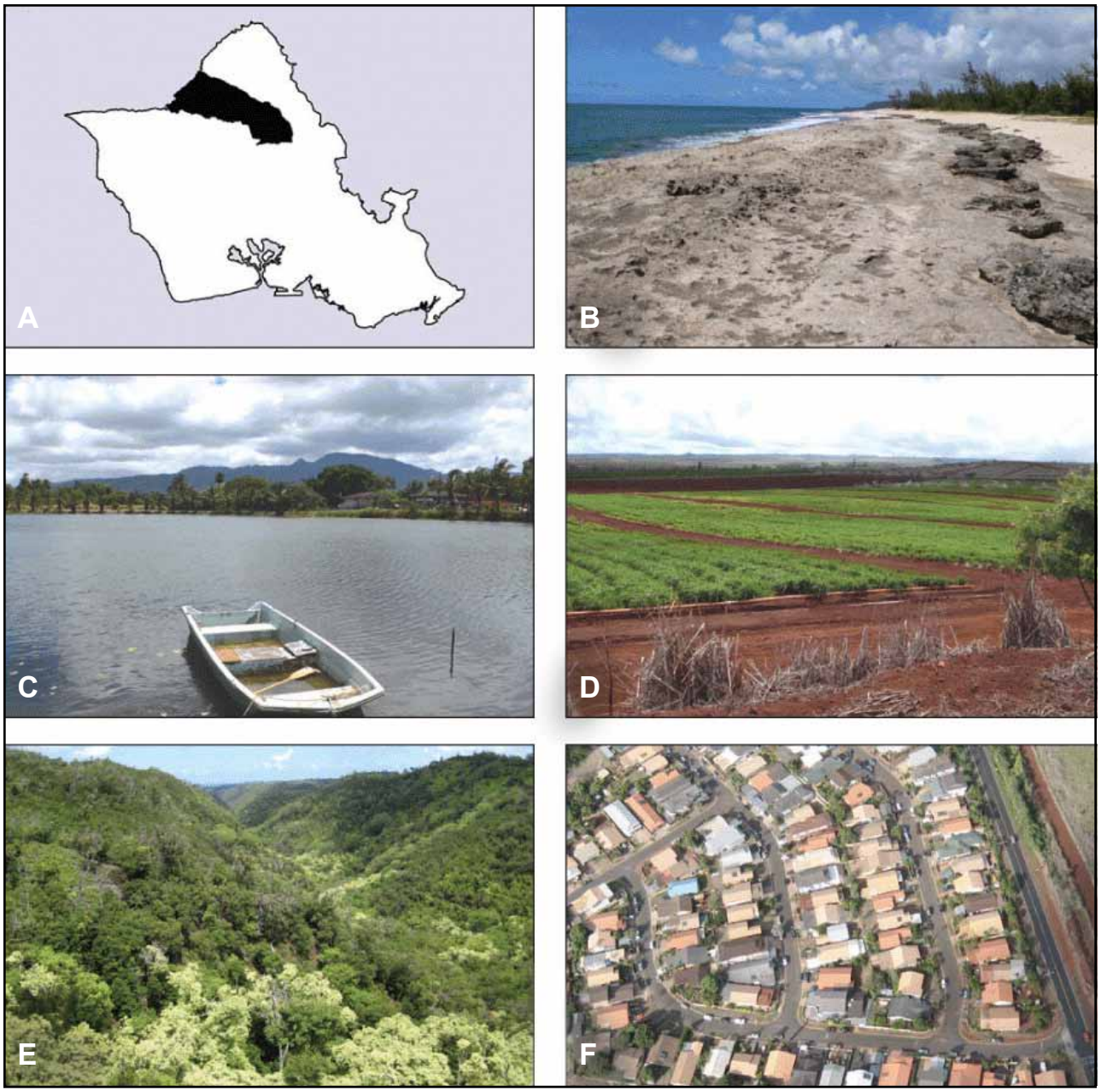
Mirroring global trends, Hawaii is facing unprecedented pressures on its land base as a growing population intensifies demand for residential and commercial development. Concurrently, there are rising concerns related to food security, fossil fuel reliance, climate change mitigation and adaptation, and other factors integral to the well-being of the state's residents and visitors. Recognizing these challenges, landowners, communities, and leaders are pursuing new strategies to incorporate the values of natural capital into land-use and policy decisions.

One such leader, Kamehameha Schools (KS), is an educational trust serving people of Hawaiian ancestry and is also the state's largest private landowner, owning approximately 8 percent of Hawaii's land base. In 2000, KS adopted an innovative approach to land management that seeks to "derive an overall balance of economic, educational, cultural, environmental, and community returns" (Kamehameha Schools 2000).

From 2006 to 2008, KS undertook an extensive land-use planning process in partnership with local communities for one of its major land holdings on the North Shore region of the island of Oahu. KS lands in this region (approximately 10,600 hectares) have a rich legacy of use for agricultural production, aquaculture cultivation, and habitat for biodiversity (see Figure 1, p. 2). The agricultural lands (approximately 2,200 hectares) were in continuous sugarcane production for over 100 years, but in 1996 the Waialua Sugar Company surrendered its lease of lands and infrastructure that showed the effects of years of deferred maintenance. Since then, agricultural use has been restored on only one-third of the former sugarcane plantation lands. The remainder is no longer in production and is being overtaken by the rapid advance of invasive plants.

A key challenge for KS and the communities was to determine what should be done with the remaining agricultural lands to meet KS' and the communities' mission to balance environmental, economic, cultural, educational, and community values, and to contribute to statewide policy initiatives for sustainable development. Stakeholders were concerned about how uses of the agricultural fields would affect waterways, economic opportunities for the community, tourism, the rural character of life, and cultural heritage.

FIGURE 1 Different land uses in Kawailoa, Oahu, Hawaii



Using InVEST to help assess management options for (A) a land-holding of Kamehameha Schools (Kawailoa, Oahu). This 26,000-acre (10,500 hectares) parcel has (B) prime undeveloped coastline, (C) an ancient fishpond and other important cultural assets, (D) a highly productive agricultural belt with water resources, (E) biodiverse native upland forest, and (F) commercial and residential areas. *Figure 4 in Daily et al. (2009), Frontiers in Ecology and the Environment.*

Through a community land-use planning process, KS worked collaboratively with stakeholders to determine desirable futures that addressed the needs of KS (as a private landowner and educational trust), community groups, and county and state policy goals. KS has tenure and property rights in the planning region, with the exception of a few small parcels of land. KS also has legal decision-making authority over which land uses are implemented.

What policy questions did the analysis set out to address?

The aim of the InVEST application in Hawaii was to help design a land-use plan for the North Shore region of Oahu that would achieve a balance of environmental, economic, cultural, educational, and community goals, and contribute to statewide policy initiatives (Goldstein et al. In press). The analysis focused particularly on the agricultural portion of the study region and addressed two guiding questions: (1) what is the best use of the largely abandoned agricultural lands to meet the needs of the local community and those of the broader public (related particularly to policy initiatives for climate, food, and energy security), while also generating positive financial return for KS? (2) do alternative land uses result in win-win outcomes or tradeoffs for ecosystem services and financial return relative to a business-as-usual scenario? In summary, the InVEST analysis had to provide an objective, scientific framework for exploring how alternative land uses would affect ecosystem service tradeoffs—and hence KS's goals—in different ways.

What scenarios were selected?

The Hawaii study assessed the impacts on ecosystem services that would arise from a set of scenarios that represented plausible future land-use options for KS and the region. InVEST was used in the context of contrasting scenarios to demonstrate the tradeoffs of pursuing different plans and policies. Drawing on local community input to the existing land-use planning process, KS and the InVEST research team developed seven spatially explicit and contrasting scenarios. These scenarios included one future projection scenario representing the status quo, five intervention scenarios representing actual planning options, and one exploratory scenario representing an unlikely but possible future that has occurred elsewhere across the state. The scenarios were set within the context of a critical management decision facing KS regarding whether or not to allocate funds to improve the region's aging irrigation system to sustain and enhance agricultural production or instead to pursue other options. In this context, KS had three overarching decision alternatives within which the seven scenarios were situated (see Figure 2, p. 4):

No improvements to the irrigation system

1. "Status Quo": maintain current land uses into the future
2. "Pasture": convert all fields to cattle-grazing pasture

Make improvements to the irrigation system

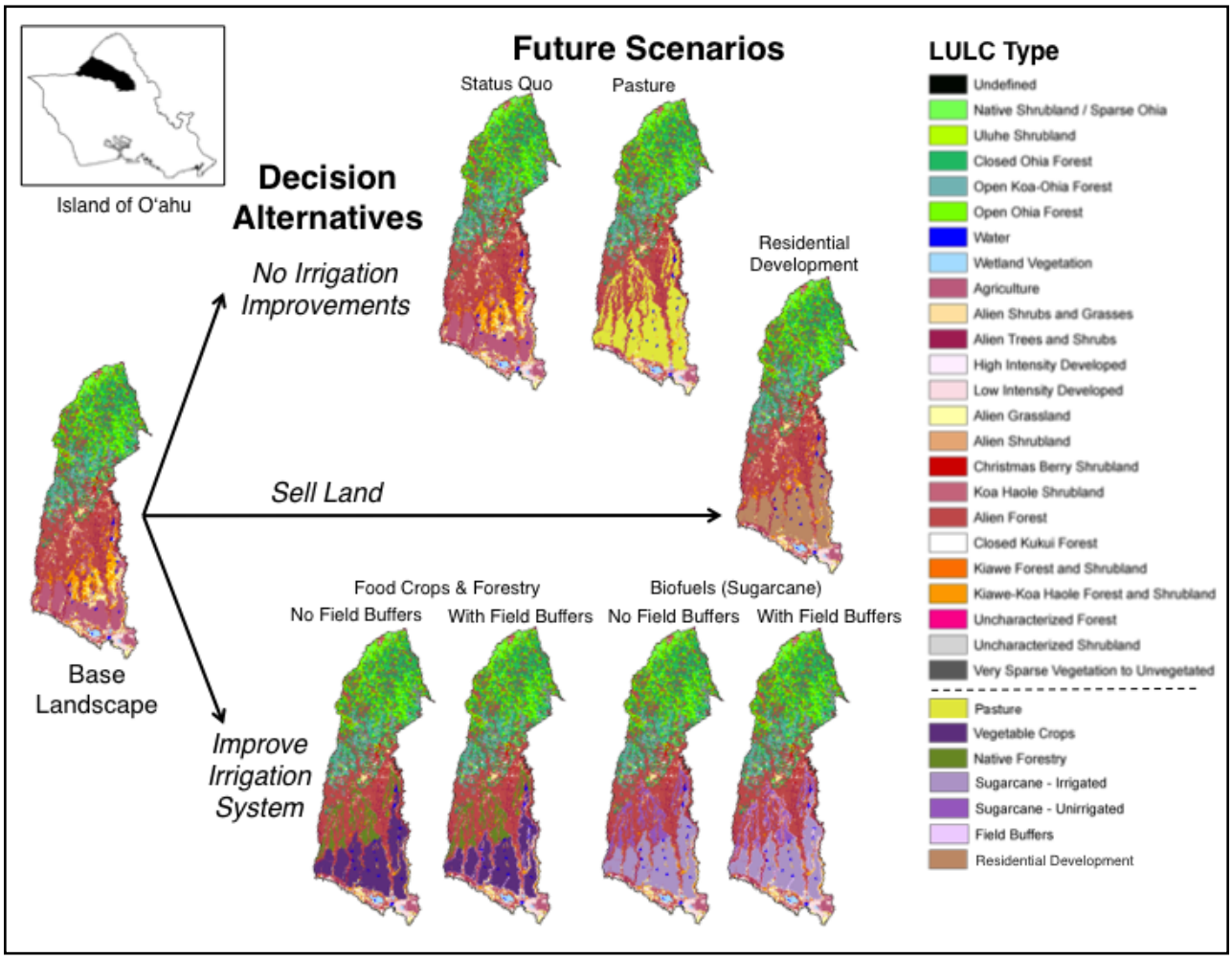
3. Food Crops & Forestry: use the lower irrigated fields for diversified food crops with forestry plantings on the upper fields
4. Biofuels: return the agricultural lands to sugarcane to produce an energy feedstock

5. Food Crops & Forestry with Field Buffers: add vegetation buffers to scenario #3 to reduce nutrient and sediment runoff on fields adjacent to streams
6. Biofuels with Field Buffers: add vegetation buffers to scenario #4 to reduce nutrient and sediment runoff on fields adjacent to streams

Sell land

7. Residential Development: sell the agricultural lands for a housing development. While neither KS nor the community was disposed to pursue this last option, it represented a development pattern that has occurred repeatedly on former agricultural lands across the state, which motivated its inclusion in the analysis.

FIGURE 2 Spatially defined alternative scenarios in Hawaii



Land-use scenarios for the North Shore of Oahu, Hawaii, planning region. *Figure in Goldstein et al. (In press) Proceedings of the National Academy of Sciences.*

How were scenarios developed?

KS engaged extensively with stakeholders to develop the North Shore strategic plan. Beginning in July 2006, representatives of Kamehameha Schools conducted a series of discussions with the North Shore community regarding their future desires for the lands. The community visioning and input was incorporated into the guiding vision for the plan. Stakeholder concerns and issues were considered in the development of the specific projects.

The scenarios used for the InVEST analysis were based on real opportunities and priorities for using the agricultural lands, as identified by KS and local communities through this participatory visioning and planning process. The InVEST modelers worked closely with KS to develop the scenarios based on the issues identified by stakeholders. KS picked a few options that characterized real choices in terms of how to manage the agricultural lands: biofuel feedstock (sugarcane), diversified agriculture and forestry, and grazing pasture. A residential build-out option was also considered, given that elsewhere in the state this land conversion from agriculture to residential has occurred, even though it was not supported in this planning process. The scenario developers depicted these options spatially, in close consultation with KS, to determine what each option implied in terms of land use for the agricultural region covering ~2,200 ha of the larger 10,600 ha planning region.

The scenarios were developed iteratively. An initial set of scenarios that considered a wider set of possible options was developed and presented with model outputs to KS. Feedback was used to eliminate scenarios that were deemed not useful or plausible, and also to identify scenarios for which additional options and a finer level of detail should be considered. Initially, changes across the entire 10,600 ha planning region were included in the scenarios, with a decision to focus specifically on the agricultural portion for the refined scenarios arising from discussions between KS and the InVEST modeling team. This decision was driven by the sense that InVEST was best positioned to analyze changes in this region, and also that this level of detail would be most helpful to KS.

The time frame for the scenarios was not explicitly defined, but was considered to be roughly 5 years, which was the approximate transition time required for the improvements to the irrigation system and related land-use transitions in the scenarios.

How were scenarios translated into land-cover maps?

Maps were made for each scenario by changing the land-use type for each agricultural field on the basis of KS's views about what could occur. For example, KS gave feedback to the scenario developers that under the biofuel scenario, a set of agricultural fields planted with sugarcane would receive irrigation water while others would be dependent upon precipitation. These choices were made within the bounds of what was practical and of possible interest to KS and the community.

A GIS expert helped to translate the paper map scenarios into digital GIS maps. Two GIS layers were essential in this process: first, a land-cover map from the Hawaii Gap Analysis Project that provided current land-cover types from the early 2000s, and second, a polygon shapefile provided by KS delineating

Project members look at a map of the North Shore region during a field trip to discuss scenario development in October 2007. *Photo: Josh Goldstein*

the boundaries of each agricultural field. To code the scenarios, the agricultural fields were divided into three groups with each group being assigned a designated land use: (1) low elevation fields currently receiving irrigation water, (2) mid-elevation fields that could receive irrigation water if infrastructure improvements were made, and (3) upper-elevation fields that would remain dependent upon precipitation.

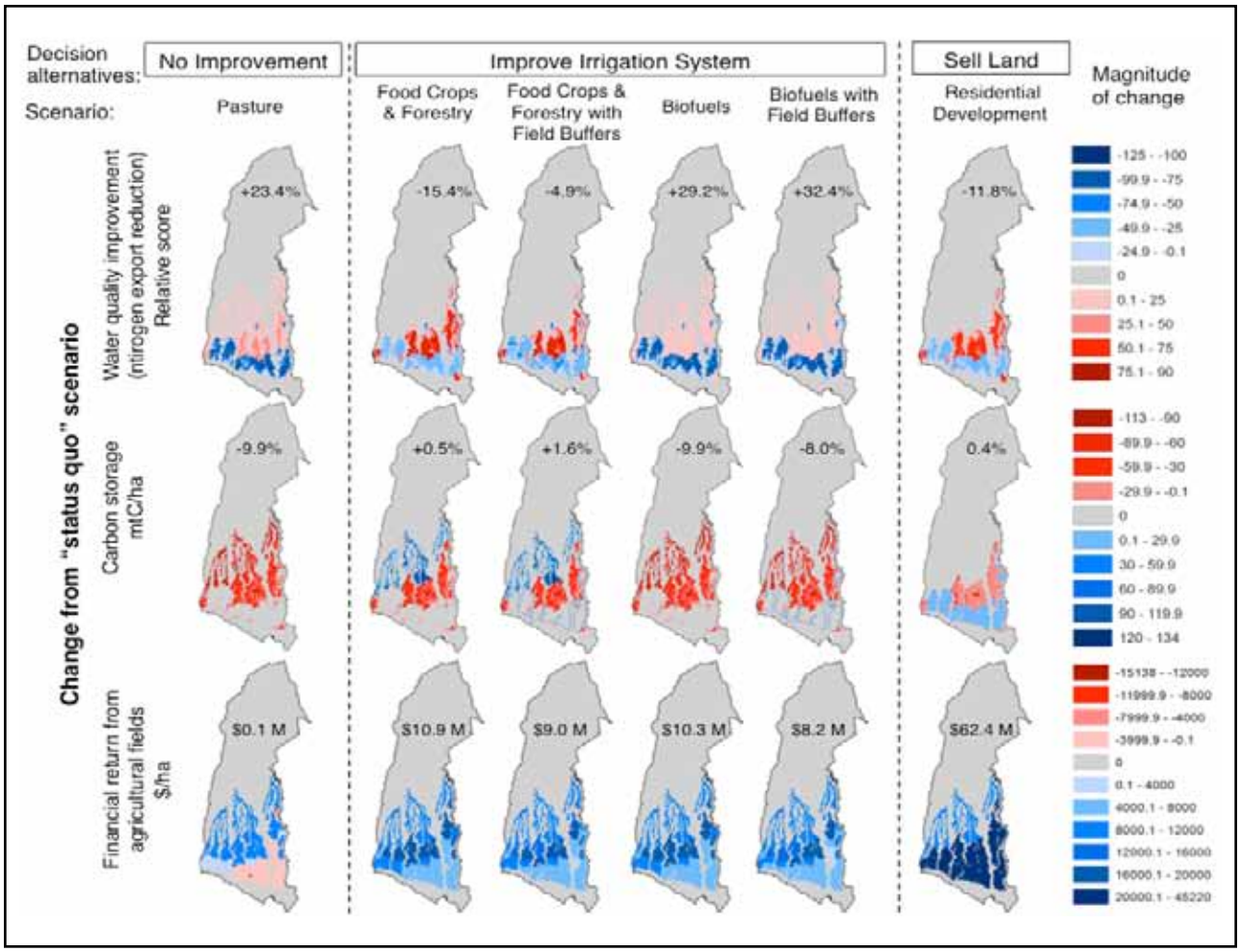
The scenario team worked with KS to determine what land-cover type would realistically occur in each area under each scenario they wanted to explore. This occurred through conversations between KS and the technical team, who were both developing the scenarios and running InVEST models. For example, for the biofuels scenario, the team took the current LULC layer, overlaid the three agricultural field group boundaries in GIS, and then assigned each field type a new land-cover classification (e.g., irrigated sugarcane, non-irrigated sugarcane) that reflected likely changes if biofuels were introduced as a significant part of the North Shore strategic plan. These changes were based on expert input from KS staff.

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

KS used InVEST to evaluate the impacts of each scenario for the agricultural lands on carbon sequestration and storage (to mitigate climate change), water quality (to meet current and future needs of the community), and financial return (to support KS's educational activities).

All scenarios were projected to generate positive income streams for the agricultural lands that exceeded the returns that would result from the Status Quo scenario (see Figure 3). However, persistent tradeoffs existed between carbon storage and water quality, with no scenarios presenting lose-lose or win-win outcomes relative to the Status Quo scenario. Tradeoffs were also seen between environmental improvement and financial return.

FIGURE 3 Ecosystem service tradeoffs under alternative scenarios in Hawaii



Maps shows field-level changes between the land-use planning scenarios and the base landscape for water quality improvement (nitrogen export reduction), carbon storage, and financial return from the agricultural fields. Blue colors show areas with enhanced ecosystem services and financial return; red colors show areas with reductions; gray color shows no change. The number associated with each map shows the net scenario change. The cost of improving the irrigation system is not factored into relevant scenarios at the field level for display on the financial return maps. *Figure in Goldstein et al. (In Press) Proceedings of the National Academy of Sciences.*

An examination of the tradeoffs among the scenario alternatives prioritized a land-use plan involving diversified agriculture and forestry. This plan generates positive financial return ($10.9 million) and improved carbon storage (0.5% increase relative to status quo), but with negative relative impacts to water quality

(15.4% increase in potential nitrogen export relative to status quo). Water quality impacts could be partially mitigated (reduced to 4.9% increase in potential nitrogen export) by establishing vegetation buffers on agricultural fields.

Informed by the strengths and drawbacks of each alternative, KS is working with the communities to implement a mixed land-use plan to deliver the desired balance of ecosystem services, while also having potential to contribute to statewide policy initiatives for climate change mitigation, food security, and diversifying rural economic opportunities. In this context, biofuel feedstock may be incorporated along with diversified agriculture and forestry, and possibly other compatible uses. KS and the communities will be aware of the benefits and tradeoffs inherent in their decision, enabling them to mitigate negative impacts where necessary.

Strengths

- Scenarios were selected on the basis of their relevance to the interests of KS and local communities and to the impending decisions facing KS.
- The original set of scenarios included some extreme possibilities. For example, one scenario considered what would happen if all the upland forest was cut down and converted to grassland. Although this was subsequently removed from the scenario set as unrealistic, it sparked interesting discussions as a thought experiment.
- The relative simplicity of the scenarios meant they were transparent and easily understandable in terms of what was being explored and contrasted.
- The process of discussing which scenarios and ecosystem services to consider helped KS to clarify what they were trying to achieve in the planning region with their new approach to managing land assets for economic, environmental, cultural, community and educational values.
- The scenario development was not too demanding in terms of capacity, time and resources.
- Stakeholders were broadly and deeply engaged in KS's land-use planning process, which enabled them to feed their goals and visions for the future into the scenarios. KS worked closely with the InVEST modeling team to develop plausible and relevant scenarios.

Challenges and areas for future improvement

- The scenarios represented static and discrete changes, with no temporal dynamics. It would have been valuable to consider the timing of decisions and implementation of changes to the agricultural fields explicitly, to represent how things would unfold over time in a sequence. However, this did not seem necessary for understanding the questions facing stakeholders.
- The scenarios did not consider external drivers explicitly, such as market demand and prices for sugarcane ethanol. This may have made the scenarios unrealistic or inconsistent.
- The scenarios did not have a transparent methodology for how land-uses were allocated across the landscape as a function of drivers and rules.

SNAPSHOT | Hawaii

POLICY CONTEXT

Policy level
Local (private land holding)

Policy questions
- design and select land-use plan that balances goals
- understand more explicitly the tradeoffs and highlight the needs for mitigation of negative impacts

Ecosystem services included
Carbon sequestration and storage, water quality, financial return to KS from different uses of agricultural fields

SCENARIO PRODUCT AND PROCESS

Scenario format
Qualitative scenarios, converted to maps that defined a land use for each pixel on the landscape

Number of scenarios
7 (status quo + 6 alternative futures)

Time frame for scenarios
Roughly 5 years in future (not explicitly defined)

Time frame for ES assessments
50 years to account for changes in carbon stocks and calculating net present value for financial return

Spatial extent of scenarios
KS lands in North Shore of Oahu (10,600 hectares)

Spatial extent of policy recommendations
KS lands in North Shore of Oahu (10,600 hectares)

Stakeholder participation in scenarios
Medium

Consideration of exogenous drivers
Low

Consideration of endogenous drivers
Medium

Capacity and time required
Medium

Case Study References

Goldstein, J., G. Caldarone, C. Colvin, T. Ka`eo Duarte, Driss Ennaanay, K. Fronda, N. Hannahs, Emily McKenzie, G. Mendoza, K. Smith, Stacie Wolny, and G. C. Daily. 2010. Integrating ecosystem services into land-use planning in Hawai`i, USA. The Economics of Ecosystems and Biodiversity (TEEB).

Goldstein, J., G. Caldarone, T.K. Duarte, Driss Ennaanay, N. Hannahs, G. Mendoza, S. Polasky, Stacie Wolny, and G. Daily. In press. "Integrating ecosystem services into land-use planning." *Proceedings of the National Academy of Sciences of the United States of America*.

Kamehameha Schools. 2000. Kamehameha Schools Strategic Plan: 2000–2015. Honolulu: Kamehameha Schools.

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