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Building scenarios for ecosystem services tools: Developing a methodology for efficient engagement with expert stakeholders

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ABSTRACT

The ecosystem services framework provides a holistic perspective for planning on local, national, and global scales. Often, scenarios are utilized to quantify and contrast the potential impacts of anthropocentric or climatic drivers of change on ecosystem services. One freely available modeling suite, Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), from the Natural Capital Project, aims to aid in decision making and planning processes by quantifying ecosystem services in spatially explicit context. Several of their modeling tools require land cover data layers, and the user can generate future land cover data layers through the scenario generator tool, released in 2014. The tool's associated literature emphasizes the integration of stakeholders into the scenario generating process to help create plausible and relevant scenarios, often through workshops. Our study reviews the tool and presents an alternative methodology for engaging expert stakeholders in the scenario generation process through a less time intensive format than the recommended workshops—a detailed questionnaire. We find that there is a need for systematic decision making analysis of stakeholder input before scenarios can be created, and we used cumulative percent frequency analysis of questionnaire responses to dictate scenario generation transition tables, when appropriate. We conclude that using a questionnaire to elicit input from expert stakeholders to develop land cover scenarios may be a time and cost effective alternative that still provides realistic and usable inputs when compared to workshops.

1. Introduction

Ecosystem services (ES) provides a framework and language to represent the goods and services provided by the natural environment to human communities (Jacobs, Dendoncker, & Keune, 2013). Essentially, ecosystem services represent positive benefits that an environment provides to people (National Wildlife Federation, 2015). A purely anthropocentric concept, ecosystem services are typically divided into four categories: regulating (climate control, water purification, etc.); provisioning (water and food resources, timber); supporting (photosynthesis, nutrient cycling) and cultural (recreation, spiritual or historical aspects of the environment). We are experiencing an explosion in research on ecosystem services, and

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there has been a major push in the ES field to spatially quantify the goods and services rendered by the environment around the World (e.g., Millennium Ecosystem Assessment, 2003). The drive for ES quantification is paralleled by the growing demand, specifically within governmental organizations, to incorporate ES into policy and management decisions (President's Council of Advisors on Science and Technology, 2011; PR&G, 2013; Donovan, Goldfuss, & Holdren, 2015). There are now an array of ES tools and models available, and most of them either incorporate or suggest analysis of future scenarios that represent storylines of various natural resource management decisions. Here, we focus on one new tool for scenario generation that serves a suite of models.

Stanford Woods Institute for the Environment, University of Minnesota's Institute on the Environment, The Nature Conservancy, and the World Wildlife Fund run the Natural Capital Project (NatCap) (Sharp et al., 2014). NatCap aims to incorporate ES into decision making on a global scale through a suite of modeling tools, including the Integrated Valuation of Environmental Services and Tradeoffs (InVEST), aimed at mitigating development, optimizing resource investment, and quantifying ES (Kareiva, Tallis, Ricketts, Daily, & Polasky, 2011). InVEST is most useful when modelers can show how alternative future actions may impact ES flow, but the earliest versions did not include a way to generate future scenarios (McKenzie et al., 2014; Ruckelshaus et al., 2013).

Since its release, InVEST users have created and used a variety of methods to model their own future scenarios. For example, changing values on input data like precipitation to reflect scenarios for climatic futures (Guerry et al., 2012). Also, the NatCap team used a variety of other models and Geographic Information Systems (GIS) to create scenario maps in Hawaii, Borneo, Belize, and other areas (Goldstein et al., 2012; Rosenthal et al., 2014). In order to make InVEST more user-friendly, NatCap needed to create a supplemental tool that would make spatial scenario generation more accessible. Recognizing the gap in their toolbox, Natcap premiered the first fully functioning scenario generator tool in InVEST version 3.1.0 in 2014. This tool allows stakeholders and policy makers using InVEST to make more informed decisions regarding land cover management by creating visual representations of different future land cover scenarios (Baral, 2013; Kareiva et al., 2011). Regarding scenario generation, the NatCap team recently suggested "that more interdisciplinary studies, with a greater range of social science expertise, could help the ES science community to better understand complex human well-being outcomes and synthesize lessons from practice" (Rosenthal et al., 2014). Our work is one such study.

1.1. Scenario background

Scenario generation is complex and requires a broad knowledge base. The best scenarios are based on plausible, relatable and internally consistent narratives that are translated and then mapped (Hulse & Gregory, 2001). There are a variety of methods to build scenarios: trend extrapolation, forecasting, cross-impact analysis, workshops, Delphi-type expert-based estimates, role playing, future state visioning, and even wild speculation (Henrichs et al., 2010). Regardless of the methodology employed, there are uncertain choices that must be made regarding important developments within communities. Although difficult, good scenarios reflect these key decisions.

Scenario development literature does not agree on how best to accomplish this goal. To make the wealth of previous scenario literature more digestible, NatCap created a document that explains scenario development and details several InVEST case studies that successfully relied upon future scenarios of land cover change (McKenzie et al., 2012). NatCap recommends four iterative steps to scenario building based on previous work: "literature and data review to establish historical and current conditions for the area of interest; review of existing and proposed policies and strategies; key informant interviews with selected stakeholders who have local knowledge about resource use and extraction and governance conditions; and consultative stakeholder workshops to review scenarios and improve them" (Rosenthal et al., 2014). They also recommend that scenario generation be iterative to add or remove scenarios in order to build the most relevant set of three or more options because "experience has shown that two scenarios often represent polarized extremes . . . and fail to consider moderate action or balanced compromises" (McKenzie et al., 2012; pp. 35, 113). Outside literature recommends that to show the uncertainty of the future, scenarios should represent two to four plausible perspectives (Heijden van der, 1996). Readers will recall that InVEST stands for Integrated Valuation of Ecosystem Service and Tradeoffs. This geographic information systems (GIS) based tool combines ecosystem processing models with economic data on various ecosystem services provided by different land cover types. Land cover is thus a proxy for ecosystem varieties, and InVEST compares the amount and value of certain ecosystem services (such as nutrient retention and water purification) under varying land cover futures so that decision makers can evaluate tradeoffs amongst development and conservation choices (Kareiva et al., 2011). Scenarios of different futures are key to driving the output of InVEST and, ultimately, the decision amongst tradeoffs.

Essentially, the InVEST scenario generator tool aims to enable users to look at the landscape with a change-oriented perspective by asking the questions: What could change? What would it change into? Thus, users must think through possibilities and what could be driving those possibilities. These changes should be based upon political, social, and economic community-specific factors. These factors or "drivers of change" are defined and discussed in length by the Millennium Ecosystem Assessment (2003). Ideally, scenarios would be based on perfect comprehension of drivers of change in a specific region. Bhagabati et al. (2014) used two scenarios, one based on government plans and the other based upon a spatial planning forum, but they are quick to acknowledge the inherent assumptions of scenarios created based on imperfect understanding of drivers of change. Regardless of which parameter is changing, someone must decide what the future should look like to create representative input data for the model.

Based on the need to identify drivers of change, NatCap emphasizes that scenario development is best when rooted in community opinions (McKenzie et al., 2012). Scenario literature agrees. For instance, Van der Heijden (1996, p. 183) prefers scenarios planned after “a series of in-depth open-ended interviews.” When creating future scenarios, stakeholders contribute knowledge of planning policies, climate change, demographic projections, technological limitations, and economic stipulations (McKenzie et al., 2012). Although the recommended InVEST methodology includes scenario planning workshops to review scenarios, Rosenthal et al. (2014) admit that both the scenario planning and technical workshops require specialized facilitation and can isolate stakeholders.

Previous InVEST users had modelers participate in rule-developing workshops with stakeholders to ensure that participants were guided towards feasible modeling parameters (Swetnam et al., 2011). Even with modeling experts in house, Swetnam et al. (2011) indicated that there were some issues that required the opinions of specialized stakeholders or local experts. Thus, previous InVEST users relied on expert stakeholders to provide insight and feedback on realistic scenarios. One published study that incorporated technical expert groups into InVEST scenario planning used “sporadic meetings, conference calls and emails with specific questions” (Hulse, Branscomb, Enright, & Bolte, 2009).

Ultimately, InVEST users need to create spatially explicit scenarios, and this need drives some of the differences between previous literature on scenario generation (Malczewski, 1999). The model requires matrices, spatial layers, and various other formats that are not easily translatable from stakeholder input. Apart from specific formatting, the required inputs must show what the likelihood is for land to change to a different cover type. One challenge for those following the user manual is to take qualitative stakeholder data and turn it into a quantitative format (Swetnam et al., 2011). To be clear, NatCap provides insight on how to develop scenarios that are driven by stakeholders and has been doing this through case studies in the United States and internationally. This guidance has been in the form of a background primer and series of case studies (http://www.naturalcapitalproject.org/decisions/scenarios.html). Recently, developers at NatCap created a scenario generator tool that is meant to interface directly with InVEST, circumventing the need for communities to use alternative future building software. Due to the nature of working with new tools, we were highly dependent upon personal contact with NatCap staff to send “nightly builds” or unreleased updates to the tool upon which to base our research development. The beta version scenario generator tool was available upon request to outside researchers like us, and the fully functioning iteration was publically released in the InVEST 3.1.0 suite. Thankfully, we were able to wait to create and run our scenarios until InVEST 3.1.0 was released, thus using the publically-available tool.

As Van der Heijden (1996, p. 184) discusses, those attempting to create future projections must be comfortable tolerating ambiguity, as each person’s observations and judgments of those observations are distinct. This raises some of the issues with querying an array of opinions and attempting to meld them into two to four scenarios. How are the varying opinions weighted? Stakeholders provide differing opinions from one another, and there is perhaps too much ambiguity about how stakeholder input is incorporated into the current InVEST recommended methodology. We wanted to rely on a more structured decision making analysis of stakeholder input for the InVEST scenario generator tool.

1.2. Case study background

The watershed located in New Hampshire and Southern Maine contributes nonpoint source nutrients to the Great Bay Estuary (GBE), a gem of the New Hampshire shoreline that is suffering from nitrogen driven eutrophication (Lee, Short, & Burdick, 2004). Tightening permit regulations are driving several nutrient management opportunities on the town and regional levels (Kessler, 2010; Piscataqua Region Estuaries Partnership, 2013). We focused on this region due to the financial and ecological problems associated with nutrient over-enrichment, the importance of the GBE, and the decision making opportunity faced by local communities. The watershed that we studied, the Piscataqua Salmon-Falls Watershed, is also a good case study of a coastal watershed, as it is hydrologically separate from the larger riverine systems of New England. We selected InVEST because of its potential utility for incorporating stakeholders and providing insight into various solutions.

The InVEST Nutrient Retention model focuses on the contributive and retentive properties of land cover using data on land use and land cover (LULC), nonpoint sources, precipitation, soil types, and slopes (Kareiva et al., 2011). The model calculates the ES of nutrient retention for phosphorus or nitrogen. Based on user inputs, different LULC provide varying N contributive capacity and retention rates. The model is built to be sensitive to the LULC data parameter. Thus, users who create new visions of LULC can see how potential futures impact the nitrogen loading and retention rates. Because stakeholders in our study area desire to understand future changes in nitrogen sources to the GBE, this region is an excellent case study location to utilize the scenario generator tool. For our modeling efforts to be most helpful for decision makers, we needed to be able to project changes in land cover.

LULC varies over time according to the needs or desires of the populous. For instance, almost all the forest cover in New Hampshire was harvested between 1800 and 1900, with much of it transitioning into open fields or cultivated crops (Goodale & Aber, 2001). This history provides an example of the inherent difficulty in making decisions about likely LULC changes. In our study area, increased population density and land use has contributed to the poor water quality (USEPA, 2012). The Piscataqua-Salmon Falls watershed is also listed as the most at risk area in the United States for water quality deterioration due to land development (Stein et al., 2009). Several N modeling studies have concluded that the current course of land management will proceed to increase N loads due to population growth alone but failed to quantify the parameters of potential increases based upon land practices (Kinney and Valiela, 2011).

In our study area, lands in conservation are also growing. In 2008, 11.3% of the GBW was "permanently protected from development, and 280 acres of salt marsh had been restored" (PREP 2010, p. 5). According to PREP (2013), 20% of watershed land area is on track to be in conservation by 2020. Previous collaborative stakeholder work in this region defined Conservation Focus Areas (CFAs) of 75 NH and 15 ME land parcels (Zankel, 2006). Although the CFAs were useful, seven years have passed since they were outlined. Some of them had already been conserved when we began our work. As of December 2011, 88,747 acres (or 13.5%) were conserved in our study watershed (Piscataqua Region Estuaries Partnership, 2013). We wanted to look at the potential for further conservation efforts by relying on stakeholder input and the scenario generator tool.

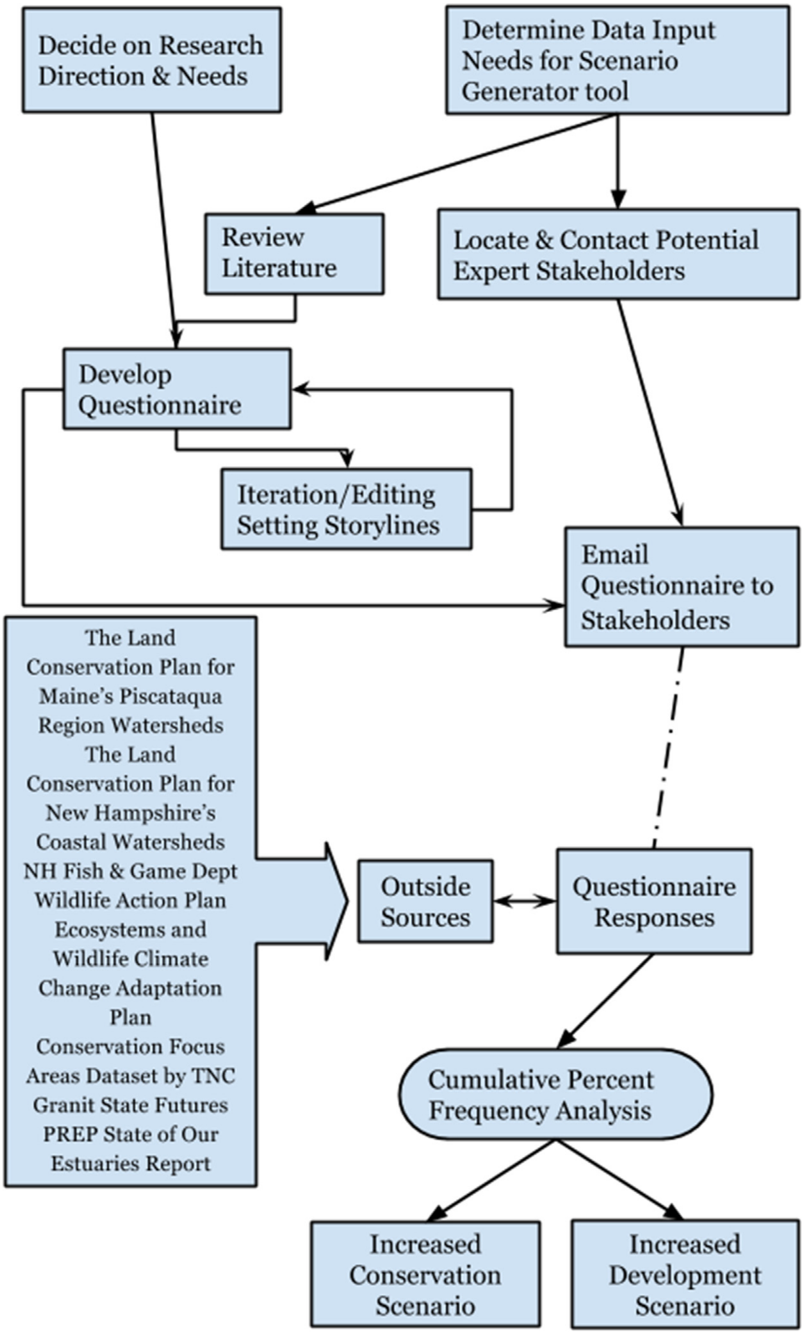

Fig. 1. Flow diagram of the methodology employed to create scenarios of land cover change in our study area.

2. Methods

2.1. Gathering data

We reviewed the NatCap published guidance and user manual for the scenario generator as well as outside literature on scenario generation. Unlike most situations published about InVEST scenario generation, our situation only focused on one model within the InVEST platform instead of a suite of models for different ES. Also, this study had very specific research objectives related to decision making about nitrogen levels. Due to differences in project needs, we did not follow the four NatCap recommended steps (Rosenthal et al., 2014). Thus, instead of querying stakeholders to decide storylines for potential scenarios, we chose the scenario storylines before reaching out to stakeholders (Fig. 1). We outlined scenarios to represent contrasting end points on the spectrum of plausible change so that the scenarios represented the range of impacts from conservation and development futures. This focus enabled us to create storylines of future change that best fit our study needs.

Thus, our interdisciplinary team of researchers created and edited storylines in iteration. By bookending the change, we focused on scenarios that would help us quantify the achievable reduction in N input to the GBE possible from land conservation. These scenarios were defined as two alternative futures for the GBW- increased conservation and increased development.

We also located and processed land cover data as recommended. We used the 2011 National Land Cover Database at a 30 meter resolution (Homer et al. 2015). Using Esri® ArcMap™ 10.2.0.3348, we manipulated the data using the follow process: (1) project raster using the normal setting of nearest resampling technique to match other layers in the NAD_1983_NSRS2007_Maine_2000_West_Zone coordinate system and the Transverse Mercator projection using meters; (2) extract by mask using a shapefile of the watersheds of interest; (3) reclassify and aggregate the initial land cover categories to reduce them to 8 more manageable land cover classes as recommended by NatCap (McKenzie et al., 2012). Resulting scenarios were compared against Conservation Focus Areas to ensure compatibility.

Based upon the data needs of the scenario generator tool (Table 1), we identified stakeholders in our study region who had the ability to provide this knowledge and the willingness to participate. Although all stakeholders have a sense of direction for the future, the scenario generator requires specific analysis of land cover transitions. Thus, we reached out to community members and leaders with specialized knowledge in various conservation and development sectors, also known as expert stakeholders (Henrichs et al., 2010). In order to reduce bias, we identified experts who represented both private and public interests with ranging perspectives from state level to the municipal level. Our stakeholders represented planning organizations, towns, consulting firms, academic institutions, state departments, leadership boards, and conservation non-profits. Stakeholders were approached via personal contact, and additional stakeholders were identified through the snowball sample methodology (Goodman, 1961) until a broad array of opinions was represented. We presented our stakeholders with detailed information about our research questions, study area, and needs. Those who were willing to participate agreed to dedicate a small amount of personal time to complete a questionnaire. The expert stakeholders provided us with insight and feedback on realistic scenario generation for our study area.

Simultaneously, we developed a questionnaire around the two scenario storylines. We designed the questionnaire to bridge the divide between the technical requirements of the modeling software and human perspectives. The full questionnaire is provided as a supplemental document.

The questionnaire introduction included several full page maps to emphasize the spatially explicit nature of our work and the scale of our inquiry. The maps provided background information about current land cover, previous land cover, and the

Table 1
Scenario generator data needs and corresponding resources we utilized.

Minimum User Data Required for Use	Resources & Methods Used to Obtain Data		
Land cover file	2011 National Land Cover Database (30m resolution) aggregated to 8 classes		
Transition Matrix:	Within the questionnaire:		
	Qualitative Questions	Quantitative Questions	Spatial Questions
Proximity Analysis	✓	✓	✓
Percent Change	✓	✓	
Priority	✓		
Ranked Likelihood of Change between land cover types	✓		✓

rates of change between the two. The goal of the introduction was to equip our participants with any information they may need as well as to align their mindsets to the work at hand.

The later questionnaire sections focused on the storylines. For each storyline (Table 2), expert stakeholders answered a series of questions to describe the most realistic site-specific change potential using a mixture of quantitative, qualitative, and spatial questions. For example, the questionnaire provided a current percentage of land cover in development and inquired about potential for future development levels.

> *The current land in conservation shown in Figure 8 represents 13.5% of the study area. In the next 10 years, how do you expect this total percentage to change? What is a realistic increase of the total percent area in conservation under this scenario? (ie: conservation areas will increase from 13.5% to ________% of the study area)*

A follow-up question helped reveal underlying reasoning:

> *Land can be transitioned into conservation for many reasons. For the Great Bay Watershed, what could be driving the increased conservation?*

In accordance with previous studies, stakeholders ranked land cover change (McKenzie et al., 2012).

> *Please rank the following land cover types in order of most likely to increase (1) to least likely to increase (4).*
> *Urban _______*
> *Suburban _______*
> *Cultivated Crops _______*
> *Open Fields _______*

Expert stakeholders received the questionnaire via email with the request to return it within a three-week time frame.

2.2. Data analysis

We compiled the responses and obtained all the policies and outside sources that respondents referenced. At times, it was difficult to incorporate all of the stakeholder responses, as they often disagreed on key concepts or drivers of change. Respondents voiced concern regarding specific questions, and one refused to answer the questions that were heavily opinion oriented. To aggregate the responses in a comprehensive and justifiable manner, we looked at them through cumulative percent frequency analysis when appropriate. For most queries, we followed trends with 50% or greater expert support. For instance, one expert indicated that wetlands would increase under both scenarios of the future, but we did not implement that opinion because it was not shared by the majority.

Table 2
Scenarios are storylines of potential futures, and they can be created in visual forms. Experts were asked to answer questions using the two storylines we created to show bookends of potential change in our study area. The following text boxes are examples from the actual questionnaire sent to expert stakeholders. Any reference to figures or sources in the boxes refer to the full questionnaire, which is available in the supplementary materials.

Increased Development Scenario 2025	Increased Conservation Scenario 2025
From 2015-2025, the United States does not see a repeat of the economic recession of 2007-2009. Rather, the economy sees a burst of activity—taking the Piscataqua-Salmon Falls region beyond a business as usual state into a robust economic development. New businesses are created, and this region attracts a growing population.	*From 2015-2025, the United States economy remains on the current trends. Population, development, and agriculture increase or decrease according to the business as usual dynamics. The Piscataqua-Salmon Falls region sees a burst in conservation activity. New areas are put into conservation easements, deed restrictions, protective easements for water supply areas, or changed to more natural areas.*

Also, we took into consideration the amount of documented rationales included by some respondents. For example, we deviated from the analysis framework for two questions pertaining to land cover change based upon the very detailed responses of one respondent. Since the respondent relied upon a credible source and included the detailed calculations for projecting rates of change into the future for this numeric parameter, we overruled our previously decided decision framework and did not score the other stakeholders' responses.

3. Results

Our sixteen expert stakeholders, some of which worked in pairs, provided a wide range of responses. For the Increased Development Scenario, the majority of our experts predicted that cultivated crops, suburban, and urban land covers would increase. When asked to rank urban, suburban, cultivated crops, and open fields, the majority of our experts chose suburban areas as most likely to increase (Fig. 2). The ranking analysis confirmed that development in the study area would increase land cover in (1) Suburban, (2) Urban, and (3) Cultivated Crops.

Our experts also thought that some land covers will increase in proximity to the same type of land cover. 83 percent indicated that urban lands will increase in proximity to existing urban lands. Suburban lands were unanimously predicted to increase within a certain distance of other suburban areas, and 67 percent of experts thought cultivated crops would also follow the proximity rule. Once translated into modeling tables, our experts' insights provided the following results in the scenario generator tool (Figs. 3 and 4).

For the Increased Conservation scenario, our expert stakeholders indicated that development would still occur but at 3% of total area. They also noted that conservation efforts have the potential to increase by 15 percent of the watershed area over the next ten years, which would total to 28.5 percent of the watershed area being in conservation. Although this amount of land conservation would be substantial, the experts noted that conservation priorities would lean heavily towards more pristine land parcels and less towards remediation efforts. Translating this into land cover changes, conservation will mostly protect existing forests and wetlands while creating potentially 1% more forest (Fig. 5). Keeping in mind that as with all tools that look at percent change, a small percent of a large area can represent large tracts of land. For instance, the seemingly dramatic decrease in open fields is relative to the original amount of open field (Fig. 5). The scenario generator created a visual representation of our experts' insight (Fig. 6).

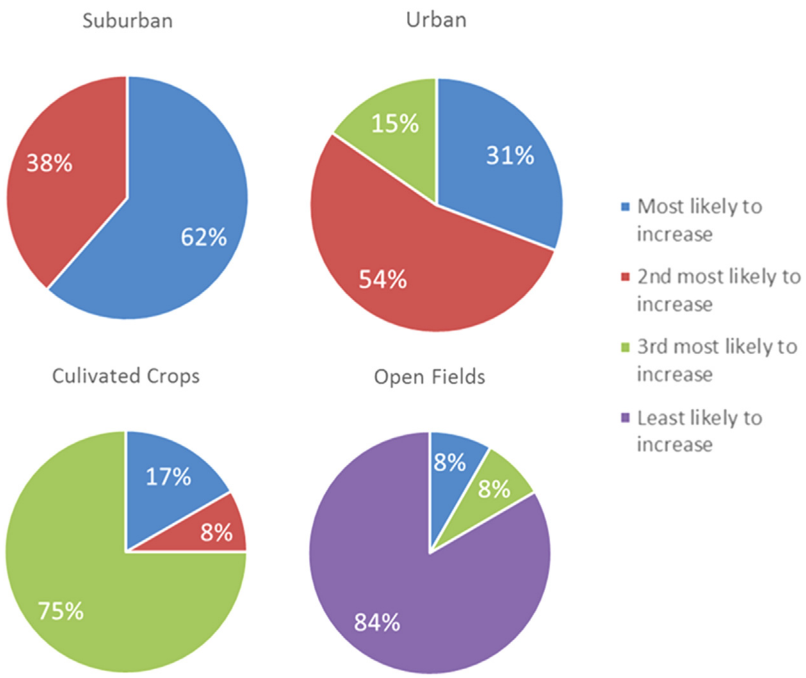

Fig. 2. Visual representation of our expert stakeholders' advice regarding land cover likelihood of increase under an increased development scenario ($n = 13$).

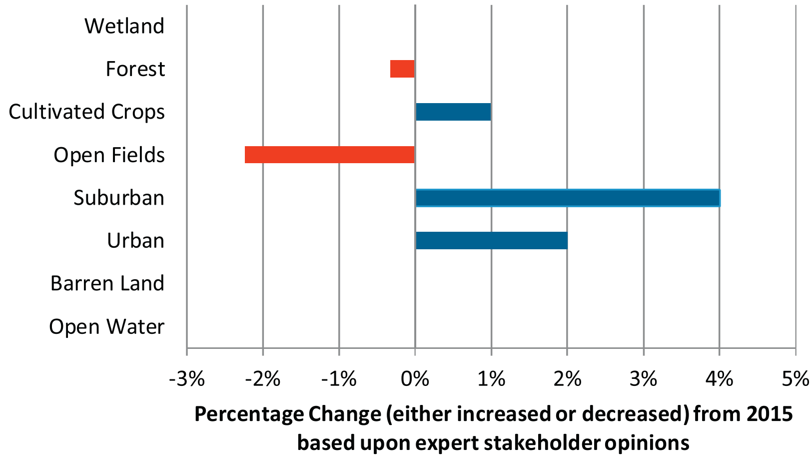

Fig. 3. Depiction of which land covers changed and by what percentages under the Increased Development 2025 Scenario, as indicated by expert stakeholder advice. This figure is similar to the html output created by the tool.

4. Discussion

4.1. Stakeholders

We find that many of the NatCap recommendations for this tool must be adjusted based on user goals. For instance, the focus on iterative stakeholder workshops requires stakeholders to invest large amounts of personal time and effort. By creating a questionnaire, we provided stakeholders with a more flexible, comfortable, and less time and resource intensive route to provide input. Another benefit of the questionnaire is that every voice has the opportunity to be heard and incorporated. Under workshop conditions, louder voices or personalities can dominate the conversation causing some opinions to be weighted more than more quiet individuals. Furthermore, participants can read and process the questionnaire, access outside resources, and take the designated amount of time to think about or calculate their responses.

Our method also provides an alternative to the expensive issue of collecting expertise (Rosenthal et al., 2014) by asking less of individual experts' time and energy. The focus on allowing stakeholders to provide input on their own time solves some of the budget challenges of small, place based and community studies like participant support and other costs associated with in person workshops (space, food, facilitators, etc.). Furthermore, a broader cross section of stakeholders can participate through the questionnaire, not just those who have more flexibility in their schedules or reside closer to the workshop location. Workshops requiring days off work and away from home would hinder some experts from contributing to the discussion, potentially biasing the scenarios.

We would be remiss not to mention that workshops have benefits. Guerry et al. (2012) discuss the unique ability of the scenario generation process to start with conflict or diverse stakeholders and end with unified "vision, values, and goals." Supposedly, this happens because those in charge keep reminding everyone of the goals of the workshop and to think bigger picture . . . "broadening planning discussions from single-sector perspectives to more comprehensive ones that explore cumulative impacts and benefits and are explicit about tradeoffs and win-wins." Additionally, based on our own experience conducting and participating in stakeholder workshops, reaching consensus is a much more reasonable goal for workshops compared with the questionnaire process. The group can openly discuss differences of opinion in real time and often decide which direction to take after the discussion. Instead, with a questionnaire, the researchers must sometimes decide amongst the varying opinions and perspectives. As already mentioned, we needed to do this with two land cover questions and likely would not have had to exercise this judgment had we conducted a workshop(s). We acknowledge these benefits, but we also suggest that the unification of stakeholders may not be as it seems, as some stakeholders may stay quiet for various reasons, with their opinions going unrepresented.

4.2. Questionnaire development

A large body of academic work exists regarding general scenario development types, tools, and techniques—we appreciate the user guidance provided by McKenzie et al. (2012) which incorporates much of the academic literature. We found this resource to be helpful as a starting point for our own work. Still, we encountered language barriers when creating questions to ask stakeholders that would also provide needed Table parameters. These issues seem inherent to scenario generation when incorporating modeling parameters, stakeholder mental models of historical and future trends, and predictions about the future. The language barrier adds another layer of complexity and uncertainty to scenario generation results (Hulse et al., 2009).

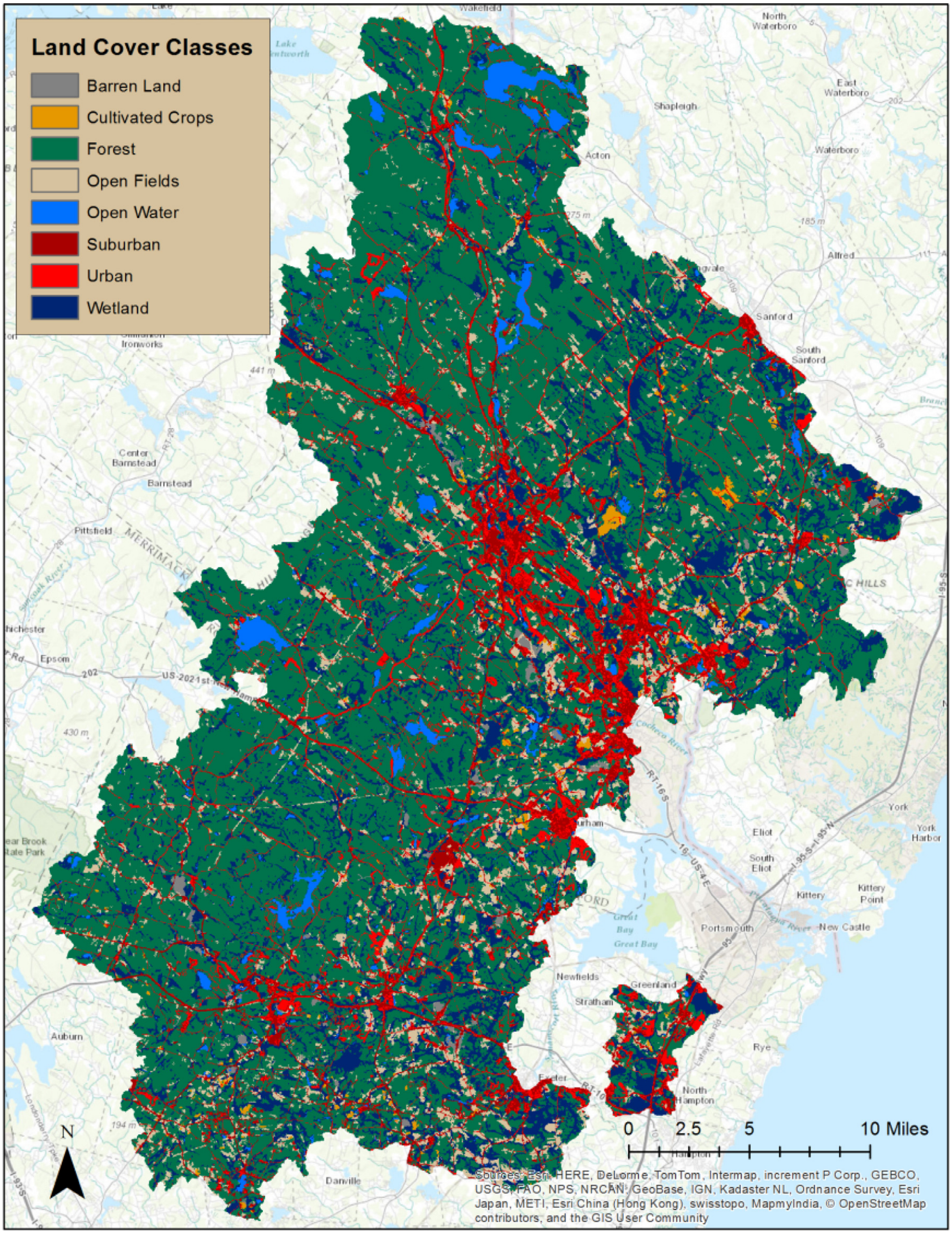

Fig. 4. Increased Development 2025 land cover map made using InVEST's Scenario Generator tool based upon expert stakeholder advice about potential change over the next 10 years.

We also struggled with choosing an appropriate time frame for the scenarios because of uncertainty. There are several issues to consider when selecting a scenario time frame. In this case, we considered the Clean Water Act's National Pollution Discharge Elimination System Permitting timelines for publicly owned treatment works (POTWs) compliance under the

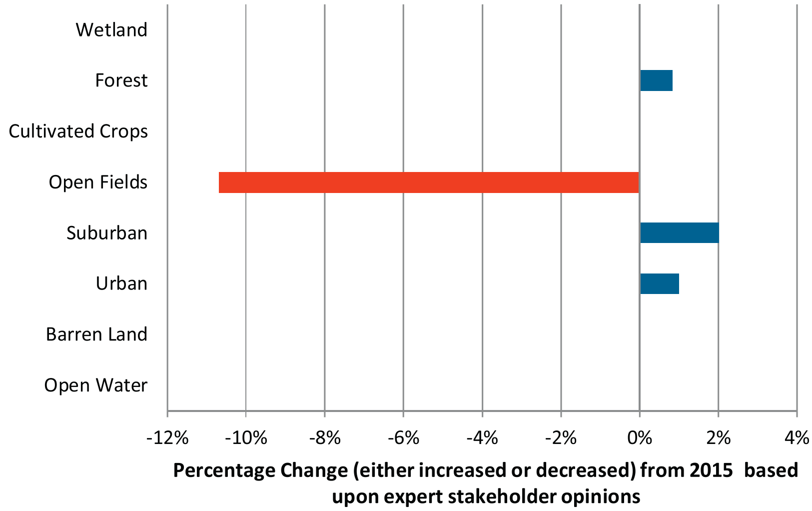

Fig. 5. Depiction of which land covers changed and by what percentages under the Increased Conservation 2025 Scenario, as indicated by expert stakeholder advice. This figure is similar to the html output created by the tool.

Environmental Protection Agency (EPA) and stakeholder limitations. Although the element of uncertainty is inherent with future scenarios, the level of uncertainty increases with longer time frames (McKenzie et al., 2012). Projecting into the future gets much harder as time increments are extended. We anticipated that although POTWs can get extensions, the EPA will look for compliance within 10 years. We also felt comfortable asking stakeholders about 10 years into the future because typical transportation planning time horizons for local regional planning commissions generally have 10 year spans.

4.3. Scenario generator tool

Although NatCap's InVEST suite provides very useful tools, these tools generally require future scenarios. How these scenarios are generated greatly impacts the final results. The scenario generator tool begins the journey to transparency, but there is great need for improvement and systematic analysis of stakeholder input for scenario generation within the tool. How did previous users decide which perspective to follow and which to ignore? In our experience, stakeholders have different visions of the future. In theory, we could generate a scenario of each individual stakeholder's responses, but we did not see the utility of gaining so many potential futures. Having multiple output maps for each scenario would be too complex to be useful. Thus, we had to decide how to combine expert perspectives. We looked back to previous InVEST studies to see if there was any specified decision analysis tool or methodology employed. This, we find, is a major gap in the InVEST suite of tools.

Although we settled on cumulative percent frequency analysis to follow trends with 50 percent or greater support, there are several other methodologies that could be applied to this area. Castella, Trung, and Boissau (2005) used an innovative approach by having stakeholders indicate drivers of change through a role-playing game, but we did not foresee experts volunteering multiple days for role-playing games in our study area. The Delphi Method is a popular option that uses facilitated iterative written discussion cycles among experts until the group has reached consensus (Landeta, 2006). In hindsight, this would have been an interesting methodology to employ with our experts, but it would have been more time intensive. If future users planned to query a small representative group of expert stakeholders to decide future scenario parameters and had ample time to reach stakeholder consensus, we recommend trying the Dephi method instead of cumulative percent frequency analysis.

Inherent in the InVEST scenario generator tool is the need for translating all stakeholder input into a "land suitability factor matrix, landcover transition table, change override layer, and constraints layer" (Sharp et al., 2014). Although we designed questions to make this translation as direct as possible, this aspect was still challenging. There is potential for an online assessment tool that would enable stakeholders to provide perspective and have input translated by NatCap into necessary tables. This online feature would eliminate the required translation between opinion and tables, which is currently an inherent obstacle to use.

Also, we were challenged by the set-up of the scenario generator in relation to the other NatCap model that we ran for our study. Ideally, we could just use the scenario generator output directly in our models. We asked the stakeholders very specific questions about our study area, which was delineated to the watershed limits. However, the nutrient retention model requests that the LULC input extend beyond the study area, which creates an inherent disconnect. We recommend that future users inquire about changes beyond the border of their study area.

Still, his tool was incredibly useful to our research goals. Without it, InVEST users would have to rely upon outside tools to alter land cover layers to create scenarios. Another positive aspect of the scenario generator tool is the instant generation of a

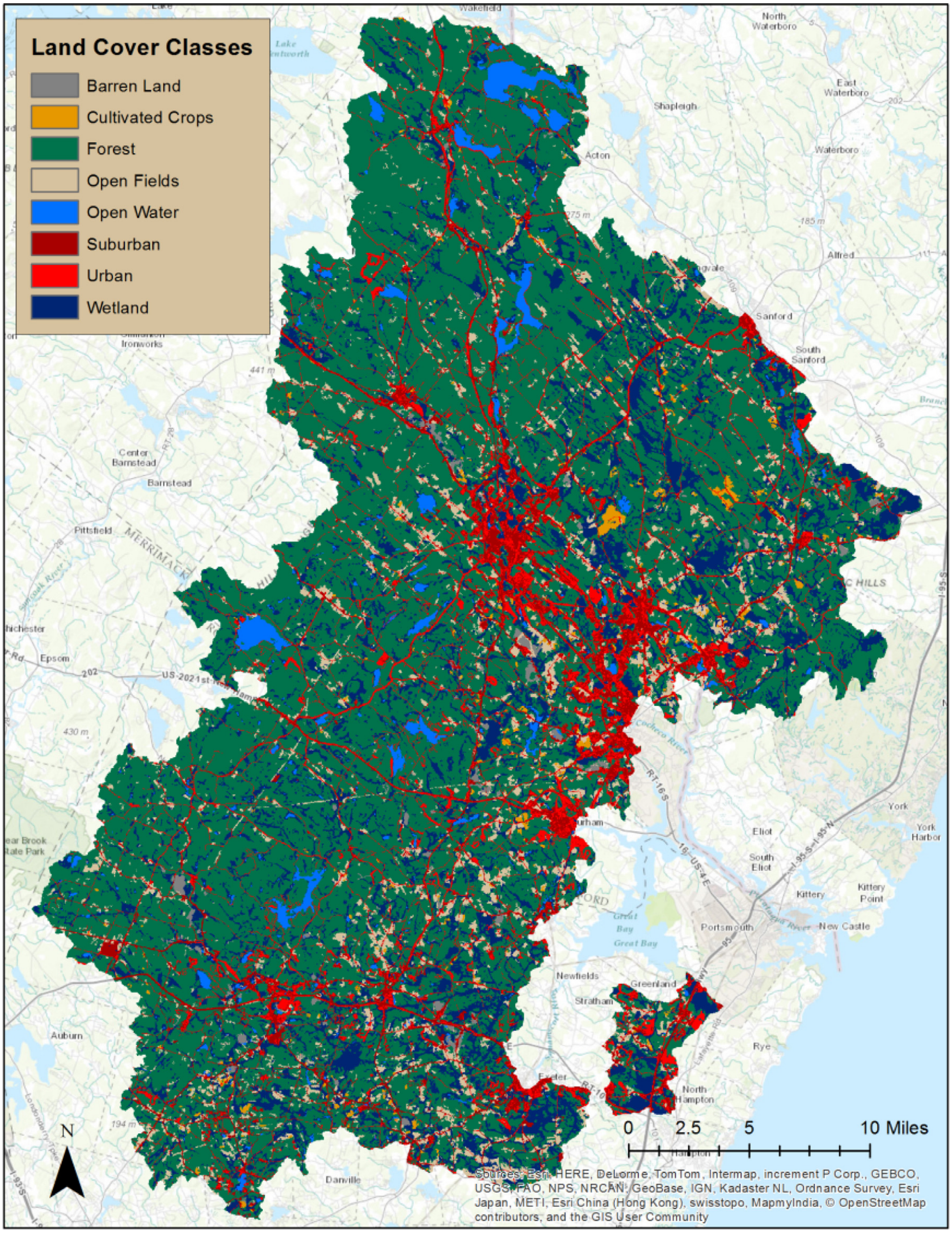

Fig. 6. Increased Conservation 2025 land cover map made using InVEST's Scenario Generator tool based upon expert stakeholder advice about potential change over the next 10 years.

report in HTML format. Although we do not present any of these figures, we did model Figs. 4 and 6 after the graphs and tables generated by InVEST that explain in percentages the land cover shifts for the proposed scenario. This output was very useful in visualizing changes and is presumably easy to share with stakeholders and the public on a website. Furthermore, as new versions of the tool are developed, we expect it to become more reliable and easier to use.

5. Conclusion & recommendations for future work

We recommend the questionnaire methodology as a valid alternative to the in-person multi-day workshops currently recommended by InVEST for scenario generation. In regards to the need for decision making science, we suggest that the Delphi Method may be useful allow for unity of definitions, percentages, and other aspects of the scenario generator needs amongst a small group of expert stakeholders. The Delphi Method has been used in a variety of circumstances, but we suggest that its utility in future InVEST work should be explored (Tsaur et al., 2006).

One recommendation to all users, regardless of stakeholder methodology, is to ask stakeholders to evaluate land cover change beyond the watershed boundary of the study area. If the tool's output is to be used in other InVEST models, the land cover data layers should extend beyond the watersheds of interest (Sharp et al., 2014).

We also recommend that that presentation of scenarios to stakeholders such as planners, decision makers, and other stakeholders may benefit from Multi-Criteria Decision Analysis (MCDA) as a framework for comparing preferences and integrating stakeholder input into environmental decision making (Rogers, Seager, & Gardner, 2004). The MCDA process generally involves identifying stakeholder interests, building a decision framework, rating alternatives, ranking alternatives, and discussing how the alternatives score with stakeholders (Malczewski, 1999), which we feel would be most beneficial to the goals of the NatCap team and other InVEST users.

Overall, we found the questionnaire method provided us with realistic and timely responses to generate plausible scenarios using InVEST's scenario generator tool. As communities continue to be faced with complex decision making opportunities, the exercise of building futures and modeling the impacts of those futures will become more standardized. InVEST and other ES modeling tools will provide decision makers with much needed information about the impacts their decisions will have on their surroundings. In our preliminary sharing of the final model runs, we've received positive feedback from several stakeholders about the plausibility and utility of the information generated from InVEST. Ultimately, the utility of modeled information was dependent upon the creation of stakeholder-driven scenarios, and the questionnaire tool proved extremely useful in generating plausible spatial scenarios.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.futures.2015.10.014.

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