UF IFAS Extension
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UF/IFAS PEER REVIEWED

FOR394

https://doi.org/10.32473/edis-FR465-2023

Scenario Planning for Managing Ecosystem Services and Natural Resources[1]

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Introduction

Global environmental changes (e.g., climate change, biodiversity loss) are challenging the sustainability of ecosystem services (benefits people obtain from nature such as food and timber production, clean water and climate stabilization). Recent comprehensive reports (MEA 2005a; IPBES 2019) provided compelling evidence of ecosystem service degradation worldwide over the past 50 years. Decline of regulating services (i.e., services from regulation of ecological processes such as maintaining the quality of air and soil) is of special concern because it often takes a much longer time (e.g., decades) to perceive changes and may influence the long-term resilience of social-ecological systems (Carpenter et al. 2009). In the face of these challenges, it is thus critical to understand how global changes may reshape the future provision of ecosystem services to inform sustainable management and development.

Anticipating trajectories of future environmental changes and consequences for ecosystem services is remarkably challenging and requires long-term thinking (Alcamo 2008; Carpenter et al. 2015). The future entails a high degree of uncertainty because: (1) historical changes may not repeat themselves; and (2) complex dynamics in social-ecological systems (e.g., abrupt change or collapse) can be highly difficult to anticipate (Folke et al. 2004; Polasky et al. 2011). In other words, current trends of human society development could lead to divergent and even unpredictable future outcomes.

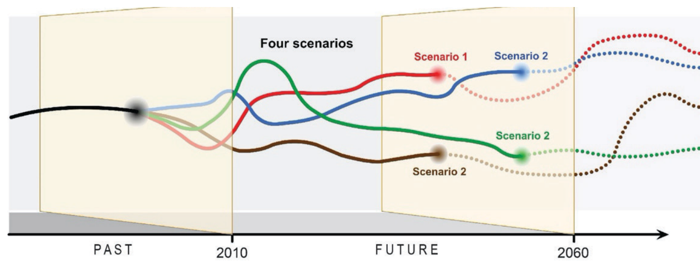

Figure 1. Schematics on the concept of scenarios that emerge from past and current conditions into a series of contrasting but plausible future pathways.
Credits: Adapted from Carpenter et al. (2006)

Scenarios emerged as an effective approach to envisioning how the future of complex social-ecological systems might unfold from existing patterns, drivers, and alternative human decisions and actions (Peterson et al. 2003; Raskin 2005). Rather than using model predictions, scenarios consist of a series of plausible and often contrasting storylines (i.e., "narratives"). These narratives depict the future in ways that incorporate relevant science, societal expectations, and assumptions about drivers, relationships, and constraints (Figure 1) (Alcamo 2008; Thompson et al. 2012). Scenarios can also integrate with computational models to explore a range of plausible changes and quantify the likely outcomes for ecosystem services (Booth et al. 2016; Qiu et al. 2018). Results from scenarios can then be used for planning, policy, and decisions-making.

1. This document is FOR394, one of a series of the School of Forest, Fisheries, and Geomatics Sciences. Original publication date March 2023. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

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The purpose of this publication is to introduce the concept of scenarios and the use of scenario planning in Extension practices to inform individual and public decisions on agriculture and natural resource management under uncertain future environmental changes. The intended audiences include: Extension agents, land managers, natural resource managers, resilience planners, policy makers, and nonprofit organizations. This publication will provide an overview of: (1) what scenarios and scenario planning are; (2) when scenario planning can be useful; (3) main steps to develop scenarios; (4) human dimensional factors that could affect scenario planning; and (5) real-world examples of how scenarios can be effective in Extension programs.

Decision-Making under Uncertainty and Scenario Planning

The future is always unclear, but combined with global changes and human actions, it becomes highly uncertain. Without reliable and accurate information about how current actions are likely to influence the trajectory of global change, and how global change is likely to affect the wellbeing of future generations, it is difficult to provide sensible advice to decision-makers (Polasky et al. 2011). Nevertheless, decisions still must be made despite these inevitable uncertainties. The questions then become to how to best inform and guide decision-making without full knowledge and complete scientific information.

Several key terms are used to understand future changes and uncertainties (Peterson et al. 2003): **Prediction** is the best possible estimate of future conditions. While scientists often interpret predictions as probabilities under certain conditions, non-scientists often understand them as things that will happen no matter what they do (Sarewitz et al. 2000); **Forecast** is the best estimate from a particular method, model, or individual (e.g., expert). It is generally perceived by the public and decision-makers that a forecast may or may not be true (e.g., weather forecast) (MacCracken 2001); **Projection** is an estimate of a future situation depending on assumptions. Projection may have unknown or imprecise probabilities (MacCracken 2001) (e.g., climate projections). All these terms reflect different perspectives on how best to embrace uncertainty. In standard decision theory and optimal decision making, uncertainty is often assigned numeric probabilities for different possible outcomes, which are then used by decision makers to determine the action that maximizes benefits and minimizes risks (e.g., measured in monetary terms, resource savings, etc.).

Unfortunately, as stated above, under many situations of natural resource management and global changes, the uncertainty is substantial and impossible to measure, limiting the application of decision theory. Scenario planning has emerged as an alternative method for thinking creatively about complex and uncertain futures. The pivotal idea of scenario planning is to consider a wide range of futures that are all plausible (Figure 1). Scenarios embrace important uncertainties rather than aiming to reduce uncertainty and improve accurate predictions of a single outcome (Peterson et al. 2003; Alcamo 2008, Carpenter et al. 2015). In other words, scenarios can be understood as "what if, then that" statements to describe how the future *could* be rather than how the future *will* be. In essence, scenarios are alternative stories that capture key elements of uncertainty about the future of a focal system (i.e., system of interest, such as urban systems or forest ecosystems). In the context of Extension, scenarios can be used to assess and convey potential future consequences of individual actions or public decisions.

Scenario planning: Process and stakeholder engagement

Scenario planning is similar to adaptive management, but can be more effective when there is a high level of uncertainty about the system of interest (Peterson et al. 2003). Given the inherently subjective and value-laden nature of scenarios, it is thus crucial to involve a wide range of perspectives, including local and scientific knowledge (Berkhout et al. 2002) into scenario planning and development process. There are six steps to develop scenarios (Figure 2).

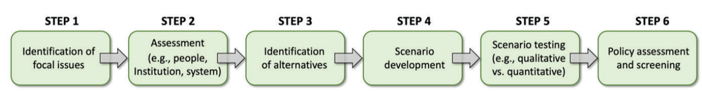


Figure 2. Major steps in scenario planning.

Step 1 involves the identification of a focal issue (e.g., improving coastal resilience, developing climate-resilient cities, maintaining a functional forest landscape), which can emerge from discussions among participants (e.g., policymakers, impacted stakeholder groups) in the initial planning process. This can be done through a formal questionnaire, focus group, or interview with selected participants. Investigating the future in light of a specific issue or question can separate the relevant aspects that are controllable or can be influenced by different human actions or policy responses. In this step, it is vital to involve a diverse group of stakeholders so that the problem under discussion is defined broadly and holistically.

Step 2 is to conduct an assessment of the focal issue identified. One of the main goals in the assessment is to identify which uncertainties will have a large impact on the focal issue. Assessment includes but is not limited to the people, institutions, ecosystems, and connections among them that define a system, as well as the external global environmental changes (e.g., climate, human migration, spread of invasive species). Assessment can be conducted using expert knowledge, literature review, or formal integrated assessment. Assessment can be qualitative or quantitative with specific indicators (e.g., demographics, climate, hydrology, natural resources). It is important to ensure that assessment aligns with the scope and complexity of the focal issue.

Step 3 is to identify the alternative ways that the system could evolve over time and under global changes. These alternative scenarios should be plausible and should pertain to the original focal issue. It is key to define a set of alternative futures that aligns with the uncertain or uncontrollable drivers of change. For example, if precipitation is an important uncertain factor (e.g., as in south Florida), then this factor could be used to structure alternatives such as increasing vs. decreasing precipitation and no changes in precipitation. Note that the uncertainties chosen to define alternatives should be related to the defining issue in the first step. Approaches such as facilitated workshops, focus groups, and round-table discourse (Renn 2006) are all powerful tools to engage stakeholders effectively to identify alternative pathways towards the future (Reed et al. 2013).

Step 4 is to use understanding accumulated during previous steps of assessment and alternative future identification to distill a small number of scenarios that are defined by the key uncertainties. The appropriate number of scenarios is generally considered to be three or four, because two scenarios usually do not sufficiently expand thinking and possibilities, whereas more than four can often confuse users and limit their ability to explore uncertainty (Peterson et al. 2003). These sets of scenarios should turn into narratives or storylines that emerge from historical and present events to hypothetical future events (Figure 1). Ideally, the scenarios need to contrast with each other and capture the maximal range of plausible futures and their underlying drivers of changes and consequences. Effective approaches to assemble stories include the use of tables to show major uncertainties (Schoemaker 1991), a search of the literature for archetypes of change (i.e., typical examples or modes of change) (Wardropper et al. 2020), and integration of local stakeholder perspectives with archetypes to improve the credibility and relevance of the scenarios. It is important to give each scenario a name as well as to use graphical design and illustration to help communicate and discuss scenarios.

Step 5 is to test developed scenarios for consistency. The main goal in this step is to ensure that the scenarios would not be implausible. Implausibility is a major obstacle to the functionality of scenarios for developing effective policies. There are two main ways to test scenarios: (1) qualitative, which typically takes the form of testing stakeholder behaviors (e.g., through stakeholder engagement workshops, interviews, expert opinions or comparing with other scenarios); and (2) quantitative, which often integrates with computational models to test and simulate the dynamics of scenarios and their outcomes (Reed et al. 2013).

Step 6 is to analyze and create policies based on developed scenarios. Examples of such applications include: assessing how existing policies would play out under different future scenarios of environmental changes; identifying aspects of policies that will perform better than other aspects under certain or all future scenarios; and exploring proactive or novel management strategies or policy interventions that will improve the system resilience to future environmental changes (i.e., the capacity of a social-ecological system to maintain its structure and functions). A range of visualization and computer simulation techniques such as interactive computer graphics, 3D visualization, virtual reality, and facilitated discourse have proven effective to develop policy options based on scenario planning and to communicate corresponding outcomes for ecosystem services and natural resources.

Stakeholder engagement. Because scenario planning processes are often oriented toward influencing decision-making, they can potentially exert a wide range of implications for different stakeholders (Oteros-Rozas et al. 2015). Hence, scenario planning in environmental research and management of natural resources has become increasingly participatory. Stakeholders are engaged in a collaborative process with researchers and develop a leadership role within some or all stages of a scenario development process to investigate alternative futures. In other words, stakeholder engagement is a key component in successful scenario planning so that diverse stakeholders can be involved to reflect more broadly and creatively about future challenges and what actions may be needed to move the system towards a more desirable future. Involving diverse stakeholders with influence and interest in the focal social-ecological systems, including those stakeholders who are potentially most affected, could promote social learning and collective action to achieve desired societal goals and foster support of policy options derived from scenario planning (Kok et al. 2007).

Nevertheless, there are important human dimensional factors to consider while engaging stakeholders in scenario planning. These factors could have profound impacts on the processes and outcomes of scenario planning. First, planners must identify and select diverse and relevant stakeholders, ensuring broad demographic representation of age, gender, socioeconomic status, education, industrial representation and so on to ensure all possible interested demographic sectors are included. Second, planners must consider power relations and dynamics among members of stakeholder groups, because power inequalities have been shown to be key barriers to meaningful engagement. Further, processes and procedures need to be in place to address questions about which perspectives are relevant to the focal issue, how to establish mutual trust and consensus, and who will be the "winners" and "losers" from each specific scenario. Last but not least, scenario planners should communicate frequently with stakeholders and work to ensure their continued access to and participation in the scenario planning process. Failure to maintain continuity of stakeholder involvement can limit the success of participatory scenario planning.

Scenario Planning: Examples and Application to Extension

In this section, we briefly present two case studies of scenario planning at regional and global scales and further elaborate on how scenario planning can be applied to Extension programming, using Florida as an example.

Millennium Ecosystem Assessment

In the Millennium Ecosystem Assessment (MEA 2005b), scenarios were used in global assessments of biodiversity and ecosystem services, their various future trajectories, and their potential impacts on human wellbeing. Through interviews with stakeholders and a literature review of major ecological dilemmas, focal questions, key uncertainties, and assumptions were identified and explored in detail to develop four plausible alternative futures (MEA 2005b). The four scenarios are summarized below and shown in Figure 3.

1. ***Global Orchestration*** depicts a worldwide connected society where global markets are well developed. Supranational institutions are well placed to deal with global environmental problems such as climate change.

2. ***Order from Strength*** represents a regionalized and fragmented world concerned with security and protection. It emphasizes regional markets with little attention to the common good and an individualistic attitude toward ecosystem management.

3. ***Adapting Mosaic*** depicts a world fragmented due to discredited global institutions. It sees the rise of local management strategies and the strengthening of local institutions. Investments are geared toward improving knowledge about ecosystem management, resulting in a better understanding of the importance of resilience, fragility, and local flexibility of ecosystems.

4. ***Techno Garden*** depicts a globally connected world relying on technology and highly managed/engineered ecosystems to deliver goods and services. Overall, eco-efficiency improves, but it is shadowed by risks inherent in large-scale,human-made solutions (e.g., resilience and adaptability).

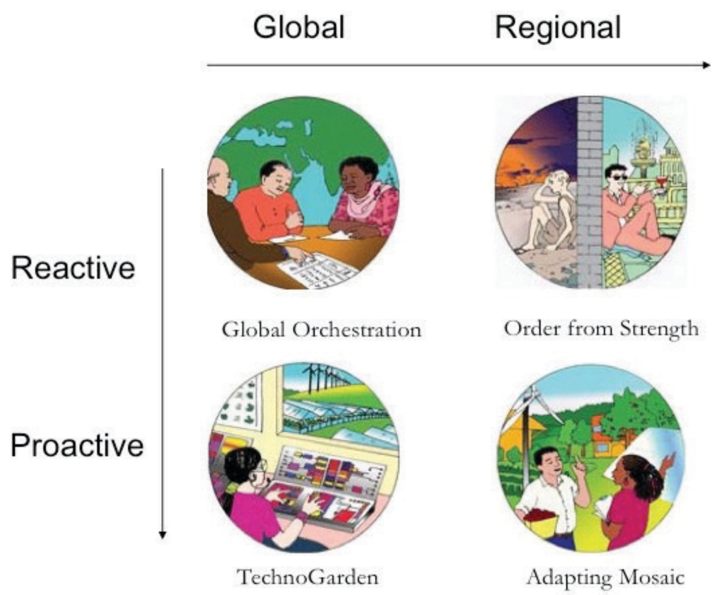


Figure 3. Illustrations of four future global scenarios from the Millennium Ecosystem Assessment.
Credits: Adapted from MEA (2005b)

All four scenarios align along two axes of contrasting transitions of society that are the main sources of uncertainty: one is from increasingly globalized to regionalized, and another is from reactive management of ecosystems to more proactive (Figure 3). Scenario narratives were further integrated with quantitative models to evaluate how ecosystem services and biodiversity would change under various policy initiatives to explore benefits and pitfalls of different policy responses. It was revealed that elements of policies that could improve the condition of ecosystem services and human wellbeing involved major investments in the public good and poverty reduction together with elimination of harmful trade barriers and subsidies; widespread use of actively adaptive ecosystem management and investment in education; and significant investments in technologies to use ecosystem services more efficiently, along with widespread inclusion of ecosystem services in markets (MEA 2005b).

Regional Watershed of Southern Wisconsin

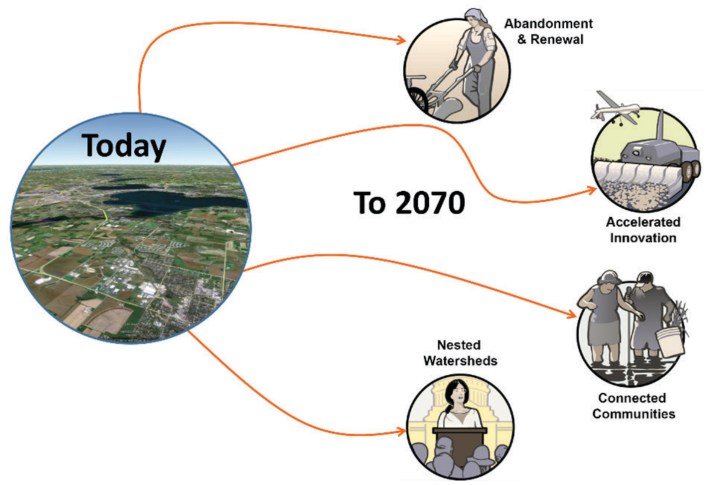
Scenarios were used to explore alternative futures for the Yahara Watershed in southern Wisconsin, USA (Carpenter et al. 2015). Major steps of scenario development included: extracting drivers of change from the global scenario literature; eliciting local stakeholders' perspectives on the future of the watershed through interviews and workshops; and assembling participants' views into four alternative future scenarios. Synopses of the scenarios are (Figure 5) (Booth et al. 2016):

1. ***Accelerated Innovation.*** Extensive technological development is the major driver and the primary tool to address issues related to climate change and decreasing resources. Precision agriculture becomes the norm to increase productivity and nutrient-use efficiency. Cultured meat and vegan cheese are developed and popularized in the watershed to avoid problems with excessive manure disposal.

2. ***Abandonment and Renewal.*** The main theme is societal inaction (i.e., instances where policymakers "do nothing" about societal issues) leading to disasters. Urban growth continues and agricultural production intensifies to boost food production in light of a national food crisis driven by climate change. This is followed by a series of devastating events, including an unprecedented flood, a harsh heat wave, and the emergence of an airborne cyanobacterial toxin that reduces the watershed population by over 90% through death and migration. Loss of population leads to farmland abandonment and deterioration of urban areas.

3. ***Connected Communities.*** A shift in social values toward less resource consumption and community-building is pivotal to this scenario. Widespread social unrest and environmental disasters inspire a global youth movement emphasizing low resource consumption, happiness, and community. Diets in the region and most developed countries have shifted away from meat and dairy after recognition of their environmental impacts.

4. ***Nested Watersheds.*** Federal water policy and governance is the primary theme of this scenario. Severe climate disasters push citizens for a complete overhaul of the nation's water and food policies. Jurisdiction for the governance of land and water is re-drawn to match natural watershed boundaries. Tax disincentives for intensive cropping systems completely transform the agricultural landscape. Environmental monitoring is extensive to evaluate compliance with rules and regulations. Full narratives of the scenarios can be found in YAHARA 2070 at https://wsc.limnology.wisc.edu/yahara2070.



Name:	Nested Watersheds	Abandonment & Renewal	Accelerated Innovation	Connected Communities
Dynamics:	Adaptation	Transformation	Adaptation	Transformation
Key Factor in Change:	Government	Inaction	Technology	Values
Nutshell:	Government intervention maintains nature's benefits	Disaster decreases population, leads to reorganization	Massive growth in technology businesses, including green tech	Global shift in values toward sustainability

Figure 4. Illustration of four future scenarios developed for the Yahara watershed in southern Wisconsin.
Credits: Adapted from Qiu et al. (2018)

The qualitative scenarios were then translated into a series of quantitative drivers, which were further input into computational modeling to simulate the long-term dynamics of ecosystem services (Qiu et al. 2018). Scenario planning was communicated with decision-makers of this watershed to demonstrate policy responses to mitigate tradeoffs between food production and water quality, identify future environmental changes that likely will intensify tradeoffs among ecosystem services, and highlight the importance of adaptive strategies for managing ecosystem services in a changing and uncertain future. All these insights provide scientific basis to develop watershed management and conservation policies for sustaining valuable long-term provision of ecosystem services.

Integrating scenario planning into Extension. A critical role of Extension is to assist clienteles to plan, prepare for, and adapt to changing but uncertain futures. Hence, scenario planning can be applied to Extension to assess, understand, and communicate potential future consequences of individual actions or public decisions. Given the inherent nature of Extension programming and activities of Extension agents and faculty who closely interact with and maintain a long-term trusted relationships with a wide range of stakeholder groups, scenario planning thus has substantial potentials that yet remain under-utilized. Integration of long-term thinking from scenarios and approaches of scenario planning into existing Extension programs could facilitate informed decision-making under uncertainties. It can also help achieve the goals of Extension to promote knowledge and behavioral changes, and positive societal outcomes.

In such applications, Extension agents can play important roles in multiple steps of scenario planning (Figure 2). For example, Extension agents could serve as facilitators to bring together scientists and knowledge experts (e.g., state specialists), decision-makers, and relevant diverse stakeholders into productive discourse and explorations of alternative futures. Extension agents can help identify major issues that are grounded upon clientele/societal needs and would benefit from scenario planning. Agents can assist in the system assessment based on their local expert knowledge. Further, they can help organize workshops, focus groups, interviews, and surveys to develop and test scenarios. Finally, Extension agents can and serve as effective communicators about the outcomes derived from scenario planning. In the context of Florida Extension, scenario planning can be an effective approach to foster individual and collective actions for achieving initiatives such as enhancing resilient agriculture and food systems (i.e., Initiative 1), and protecting water, environment, and other natural resources (Initiative 2 and 3), all of which are susceptible to profound but uncertain future environmental changes.

Conclusions

Understanding how to feed a growing population while sustaining land, water, and climate in a rapidly changing and uncertain future remains challenging but critical for research and policy communities. This publication presents an overview of scenario planning, essential steps for scenario development along with case studies at regional and global scales, and practical applications of scenario planning to Extension. Scenarios can be a highly valuable approach but have so far not been much used in Extension (Kim et al. 2017). Scenarios can be integrated into existing Extension programs and help develop more robust and resilient solutions to future agricultural and natural resource management challenges in Florida, such as climate change, sea level rise, and urbanization. The knowledge and lessons gleaned from scenario planning will be relevant for informing individual decisions, developing public policies to cope with future uncertainties, and, ultimately, sustaining agriculture, ecosystem services, and natural resources to ensure human wellbeing in the future.

Glossary

Adaptive management: A structured and iterative approach to natural resource management and environmental decision-making in the face of uncertainty. Its aim is to learn from the outcomes of management and improve management strategies through system monitoring.

Collective action: An action performed by a group of people. Collective action is governed by self-interest, and aimed at achieving a common vision.

Decision theory: Applied probability theory concerned with optimal decision-making based on probabilities assigned to different actions and numerical consequences assigned to the possible outcomes of actions.

Ecosystem services: Benefits people obtain from nature, such as food and fiber products, air and water purification, disease regulation, flood mitigation, erosion control, climate stabilization, and cultural benefits.

Forecast: The best estimate from a particular method, model or individual. Most people understand that a forecast may or may not be true (e.g., weather forecast).

Precision agriculture: The application of modern information technologies to provide, process and analyze multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production.

Prediction: The best possible estimate of future conditions.

Projection: An estimate of a future situation that depends on assumptions about drivers. Projections may have unknown or imprecise probabilities (e.g., climate projections).

Resilience: The capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system maintains its structure and functions.

Social-ecological systems: Complex, adaptive, and integrated systems in which humans are part of nature. They explicitly encompass natural and social systems and their interactions and feedback mechanisms.

Social learning: A behavioral theory that posits that new behaviors can be learned by observing and imitating others.

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