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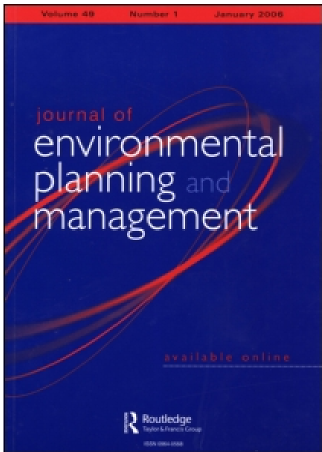
Sadahisa Kato
*University of Massachusetts - Amherst*, skato@larp.umass.edu

Jack f. Ahern
*University of Massachusetts - Amherst*, jfa@larp.umass.edu

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Sadahisa Kato [a]; Jack Ahern [a]
[a] Department of Landscape Architecture and Regional Planning, University of Massachusetts, Amherst, MA, USA

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# 'Learning by doing': adaptive planning as a strategy to address uncertainty in planning

Sadahisa Kato* and Jack Ahern

*Department of Landscape Architecture and Regional Planning, University of Massachusetts, Amherst, MA, USA*

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Adaptive management, an established method in natural resource and ecosystem management, has not been widely applied to landscape planning due to the lack of an operational method that addresses the role of uncertainty and standardized monitoring protocols and methods. A review of adaptive management literature and practices reveals several key concepts and principles for adaptive planning: (1) management actions are best understood and practiced as experiments; (2) several plans/experiments can be implemented simultaneously; (3) monitoring of management actions are key; and (4) adaptive management can be understood as 'learning by doing'. The paper identifies various uncertainties in landscape planning as the major obstacles for the adoption of an adaptive approach. To address the uncertainty in landscape planning, an adaptive planning method is proposed where monitoring plays an integral role to reduce uncertainty. The proposed method is then applied to a conceptual test in water resource planning addressing abiotic-biotic-cultural resources. To operationalize adaptive planning, it is argued that professionals, stakeholders and researchers need to function in a genuinely transdisciplinary mode where all contribute to, and benefit from, decision making and the continuous generation of new knowledge.

**Keywords:** adaptive management; adaptive planning; monitoring; transdisciplinarity; uncertainty; water resource planning

## 1. Introduction

In 1978 Holling presented an adaptive management strategy which had been developed through a series of workshops (Walters and Hilborn 1976, Ludwig and Walters 2002). Simply put, adaptive management is a "management approach to embrace uncertainty and manage adaptively" (Light *et al.* 1995, p. 154). Adaptive management was developed to deal with the uncertainty inherent in complex systems. Holling (1978) described successful applications of adaptive management to the forest management study of the spruce budworm in New Brunswick, Canada. In another application, Pacific salmon harvest was adapted to respond to the changes in recruitment rates of salmon with varying densities of parental spawners.

Since the late 1970s, adaptive management has been widely practiced in natural resource and ecosystem management (Walters and Holling 1990), but has not yet been widely integrated into or applied to landscape planning. For example, in Ndubisi's (2002) comprehensive review of the history of 'ecological landscape planning', adaptive

*Corresponding author. Email: skato@larp.umass.edu

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management is introduced as a strategy for ecosystem management, but adaptive 'planning' is not mentioned.

This paper has drawn examples from issues commonly addressed in landscape planning in order to discuss the need for adaptive planning. Landscape planning is defined as a resource allocation and planning activity, dealing with landscape features, processes and systems for the sustainable use of resources at a broad spatial scale (Cook and van Lier 1994, Ndubisi 1997, Ahern 1999, Marsh 2005). According to Marsh (2005), landscape planning is a subfield of environmental planning. Environmental planning includes all the planning and management activities where the emphasis is on environmental considerations (e.g. clean air and water) rather than other factors (e.g. social, cultural or political) (Forman 1995, Marsh 2005). While environmental planning primarily deals with "things of natural origin" (Marsh 2005, p. 3), human-landscape interactions are central in landscape planning (Cook and van Lier 1994, Forman 1995, Ndubisi 1997). Since this paper primarily deals with and uses examples that relate to landscape issues, we have used the term 'landscape planning' with recognition that its activities are included in environmental planning.

Three questions related to adaptive management are investigated from a planning perspective: (1) what landscape planning issues can an adaptive planning approach address? (2) why has adaptive management not been integrated with, or applied to landscape planning? (3) how can adaptive planning be made operational in landscape planning practice?

## 2. Methods

Three research methods were applied to answer these questions. First, successful applications of adaptive management to natural resource and ecosystem management were reviewed. Following this, key ideas and concepts of adaptive management from the literature were extracted and consolidated (e.g. Holling 1978, Walters 1986, Walters and Holling 1990, Lee 1993, Gunderson *et al*. 1995, Peck 1998, Lee 1999, Lister and Kay 1999, Rutledge and Lepczyk 2002). For example, the process of deciding how much water should be released from a dam to protect an endangered fish that live downstream encompasses adaptive components.

Second, the findings of the literature review were consolidated into an operational adaptive planning method. Next, established landscape planning methods were reviewed for adaptive components (e.g. Steinitz 1990, Steiner 1991, Leitão and Ahern 2002). The findings from the literature review were applied to develop an original adaptive planning method.

Third, the proposed adaptive planning method is discussed in the context of water resource planning. This discussion is intended to identify indicators and indices useful to monitor abiotic, biotic and cultural attributes of water resources in an adaptive planning approach.

## 3. Discussion of adaptive planning issues and questions

### 3.1. *What landscape planning issues can an adaptive planning approach address?*

#### 3.1.1. *Uncertainties in landscape planning*

Each landscape plan and the expected changes it addresses are, by definition, unique: it is for a specific place and for a particular suite of issues and landscape changes. Thus, every landscape plan is subject to the full spectrum of uncertainty relating to that specific place.

For example, a watershed management plan should start with time series data on water quality and hydrologic flow patterns. A landscape plan needs to anticipate the type and magnitude of expected land use change, and to explicitly associate those changes with impacts and consequences on water resources. This is where uncertainty becomes a major obstacle, unless there is an explicit method for addressing all the 'unknowns' that arise in the project. In response, planners tend to rely on standard approaches such as arbitrary buffers or percentage of impervious cover rather than regulations that are based on the specifics of a particular place. This is where an adaptive planning approach has promise.

The issue of uncertainty is considered central to the adaptive planning approach since it involves every step of a planning process. Many landscape researchers have proposed a planning process with explicit steps or stages (e.g. Steinitz 1990, for a six-level framework; Steiner 1991, for 11 interacting steps; and Leitão and Ahern 2002, for five planning phases). In general, these three methods share the following steps or levels: assessment of existing conditions, articulation of goals and objectives, consideration of alternatives, the decision making process, and the development of a plan.

While reducing sources of uncertainty challenges and complicates the planning process, uncertainty also serves as a primary driver of the adaptive approach to planning. The adaptive planning approach seeks to confront and minimize uncertainty by (re)assessing the feasibility and effectiveness of planning decisions and the risks inherent in each stage of the planning process. The following types of uncertainty regularly occur in landscape planning: geographical/spatial, temporal, process, transferability and human input unpredictability. Table 1 summarizes these important types of uncertainty, step(s) of a planning process affected, spatial and temporal scale, strategies to address uncertainty, and some example strategies.

How can an adaptive approach address these multiple uncertainties? Arguably, since landscape planners will never have all the information about the landscapes and systems they work in, uncertainties cannot be fully avoided. Thus, it is argued that it is more intelligent for planners to know as much as they can about uncertainties and develop strategies and methods to address them. First, modeling and monitoring can be used to reduce uncertainty by increasing scientific and professional understanding of a system. Second, under an adaptive planning approach, various uncertainties (determining appropriate systems or populations of study, spatial-temporal scales and geographic extent) can inform adaptive hypotheses, which can then guide planning and monitoring actions and interpretations. Third, interdisciplinary and transdisciplinary approaches help planners understand uncertainty through cooperation and sharing ideas among academics, professionals and stakeholders. Fourth, uncertainties can be explicitly acknowledged to stakeholders who can be involved throughout a planning process. 'Learning by doing' presupposes that something 'uncertain' needs to be learned.

### *3.1.2. Landscape structure and function issues*

Adaptive planning can also answer questions about landscape structure and function. Suppose someone is planning for wildlife movement in a changing suburban landscape. They could articulate a hypothesis that managed native vegetation, species movement corridors could support wildlife movement while adjacent lands are urbanized. Monitoring could address the use of corridors of different configurations by indicator species before and after the plan is implemented. The monitoring could yield valuable information on the effectiveness of various corridor designs and of their respective use by indicator species.

Table 1. Types of uncertainty, relationships with planning, and strategies to address uncertainties.

| Types of uncertainty: | Geographical/spatial | Temporal | Process | Transferability | Human input |
|---|---|---|---|---|---|
| Where in planning process? | Data collection<br>Data analysis<br>Selection of appropriate model/model parameters | Data collection<br>Data analysis<br>Selection of appropriate model/model parameters | Development of model/parameters | Synthesis of data across scales, disciplines | Throughout |
| Scale component | Broad to fine<br>Endemic, local, regional, global | Short-term to long-term<br>Absolute/relative | None | None | None |
| Strategies to address | Replication, Pseudo-replication<br>GAP analysis, remote-sensing, GIS spatial analogues | Replication, pseudo-replication<br>temporal analogues<br>Long-Term Ecological Research | Develop alternative models, test many different parameters | Data analogues, selection of common variables, qualitative generalization | Multiple hypotheses, model simulation, consensus building, adaptive approach |
| Example strategies | Adopt common spatial/time frames and strategies | Cautious use of historical data and temporal analogues along with long-term monitoring | Watershed treatment model to test the effectiveness of various treatment options | Develop a trans-disciplinary framework where agreeable common variables are selected beforehand | Decision analysis to incorporate risk and uncertainty, and calculate the overall value of each option |
| References | Hunsaker *et al.* 2001<br>Yoccoz *et al.* 2001 | Hunsaker *et al.* 2001<br>Schumm 1991 | Beven 2000<br>Bogardi and Kundzewicz 2002<br>Center for Watershed Protection 2007<br>Jackson *et al.* 2004<br>Neal 1993 | Benda *et al.* 2002<br>Hunsaker *et al.* 2001 | Bocking 2002<br>Holling 1978<br>Liska 1975<br>Peck 1998<br>Raiffa 1968<br>Yoccoz *et al.* 2001 |

#### 3.1.3. Abiotic-Biotic-Cultural (ABC) resource model

Ndubisi (2002) recommends the abiotic-biotic-cultural (ABC) resource survey method as a useful way of surveying and assessing resources based on abiotic (e.g. geomorphology, hydrology, physiography), biotic (e.g. flora and fauna), and cultural (e.g. stakeholder values, human use of land and changes in human activity) characteristics classified by their structural and functional attributes. To achieve planning goals and objectives, all the ABC resources need to be addressed in an integrated, holistic manner.

### 3.2. Why has adaptive management not been integrated with, or applied to landscape planning?

#### 3.2.1. Adaptive management examples from natural resource and ecosystem management

Adaptive management has been practiced in natural resource and ecosystem management for several decades, yet it is not yet commonly practiced in landscape planning. Examples of adaptive natural resource management include: managing elk population in Idaho (Meffe *et al*. 2002), waterfowl harvest management (Johnson and Williams 1999), and prairie grouse management (Aldridge *et al*. 2004). Manitoba sharp-tailed grouse populations were in gradual decline due to habitat alteration. A non-profit organization collaborated with researchers to implement an adaptive approach. The management plan tested competing management options, and management treatments were monitored and adjusted annually based on biological and economic performance measures. Preliminary results are positive: desired cover composition for grouse populations has been achieved; landowners are pleased with the results – increased forage use for their cattle and apparent increase in sharp-tailed grouse abundance; and incentive programs are suggested to offset increased farm operation costs (Aldridge *et al*. 2004).

The Ecological Society of America Committee on the Scientific Basis for Ecosystem Management accepted adaptive management as a useful method by which to resolve uncertainty (Christensen *et al*. 1996). Adaptive management addresses the complications of working at the ecosystem scale (spatially broad and temporally short/long with many interacting elements) by acknowledging a lack of understanding of ecosystem processes that are inherently complex and dynamic. Adaptive management has been used to deal with the complexities involved in ecosystem management – complexity of the system itself and of the actors and processes involved. Examples of adaptive ecosystem management in the US include: the impact of flow regulation of the Glen Canyon Dam on the downstream environment (US Department of the Interior 2007), water management in the Everglades (Light *et al*. 1995), and the Columbia River Basin Program (Lee 1993, 1995, Northwest Power and Conservation Council 2003).

The Florida Everglades has a history of mismanagement that resulted from natural disturbances and a water management policy based on artificial drainage and structural flood controls (Walters *et al*. 1992, Light *et al*. 1995, Gunderson 2001, Sklar *et al*. 2005). However, management pressure has always been present and the stakes have been high, relating mostly to human use of water resources (Harwell 1998, Roe and van Eeten 2002). The history of the Everglades water management is a great example of a mandate to act under great uncertainty in a complex social-natural system with significant management consequences for multiple stakeholders (economic growth, flood protection, stormwater management and water quality). The Comprehensive Everglades Restoration Plan (CERP 2007) approved in 2000 embodies a paradigm shift in the management of the

South Florida ecosystem from the pursuit of scientific certainty to an experimental/adaptive approach; the governance has also shifted from "a focus on a hydrologic problem managed by a few specialized institutions to interest groups and public agencies working cooperatively" (Boswell 2005, p. 98). Boswell (2005) believes that the CERP has three characteristics that could potentially advance adaptive governance: holistic approach to problem definition, inclusive and collaborative approach to decision making, and experimental approach to implementation and management (p. 92). The last two principles are the key to adaptive planning, as will be seen below.

### 3.2.2. *Key concepts and principles for an adaptive planning*

The literature and application review identified key concepts and principles of adaptive management: (1) conceiving management actions as experiments; (2) conducting several plans/experiments at once for fast learning; (3) monitoring being the key; and (4) 'learning by doing' (e.g. Holling 1978, Walters 1986, Walters and Holling 1990, Lee 1993, Gunderson *et al*. 1995, Peck 1998, Lee 1999, Lister and Kay 1999, Rutledge and Lepczyk 2002). It is argued that these same concepts and principles can be applied to landscape planning under an adaptive approach.

*3.2.2.1. Management actions as experiments*. Adaptive management conceives management actions as experiments with testable *a priori* hypotheses (Lee 1993, Rutledge and Lepczyk 2002). Traditional or reactive management hesitates to apply new policy decisions until proof of efficacy is obtained through short and long-term empirical studies. Adaptive management is a proactive method, where policy decisions are used as 'experimental probes', enabling the manager or planner to learn by doing (Holling 1978). For example, when a new subdivision is developed, the amount and configuration of impervious surface can be varied to measure its effect on water quality, or wetlands restorations can apply alternative vegetative species compositions and follow with monitoring of species' and hydrological response.

*3.2.2.2. Several plans/experiments at once for fast learning*. Implementing several plans/experiments at once for faster learning is a key strategy in adaptive planning. In adaptive management, rather than implementing one large management action after waiting for data, natural resource managers can learn faster by implementing several small actions/policies simultaneously (Peck 1998). Furthermore, each management action can have several hypotheses, probing different effects of the action.

*3.2.2.3. Monitoring being the key*. Monitoring is a key action to reduce uncertainty by improving understanding of a system over time. Monitoring enables subsequent decisions to be made on more recent and complete data derived from the specific location(s) affected by the plan or management action. Monitoring is also used to gauge the efficacy of a project, plan or policies and management practices (Peck 1998), and the results of monitoring can be used to refine the management action or goals and objectives. Developing and establishing monitoring programs is a challenging activity in many local planning situations where diverse stakeholders may not agree on planning goals and therefore may not support or understand monitoring as part of the process.

*3.2.2.4. 'Learning by doing'*. Finally, the importance of 'learning by doing' cannot be overemphasized. Learning by doing is facilitated by conceiving uncertainties not as obstacles to overcome but opportunities to learn from, and by including feedback loops to ensure that decision makers receive the monitoring results in time to develop appropriate policies, or to alter plans or management practices accordingly.

### *3.2.3. Seven principal reasons for slow adoption of adaptive approach in landscape planning*

It is the nature of planning to face a unique situation every time a new plan is developed. Since any 'real-world' planning project has inherent uniqueness, the likelihood that adequate data exist to support a scientifically-defensible decision is very low. This is the common circumstance that defines planning and that planners must face routinely.

Planning is also a time-sensitive activity. Landscape planners often do not have the luxury to wait for all the scientific data to accumulate to support planning decisions. Landscape planning addresses heterogeneous and dynamic landscapes – a moving target. Therefore, landscape planning tries to place itself ahead of these processes and to 'steer' or influence them in a proactive, anticipatory way. It can be said that landscape planning is inherently prescriptive while science is often more descriptive. The imperative to act challenges planners to develop plans according to short time frames determined by political and other deadlines. However the uncertainty that is inherent in planning arguably requires more time to compile base information and to monitor results of plans that are implemented.

Given the difficulty of addressing real, unique, place-based problems and the imperative for planners to act, it is argued that every landscape plan that is not conducted adaptively represents a missed opportunity to learn valuable information about the landscape, watershed or political jurisdiction. However, in reality, most landscape plans/projects are not conducted adaptively. Seven principal reasons are proposed for the slow adoption of an adaptive approach in landscape planning.

*3.2.3.1. Fear of failure/liability, reluctance to accept uncertainty*. Planners are blamed when projects fail but rarely rewarded when they are successful. Therefore, there is an understandable fear of failing and for being held responsible. To be on the conservative side, planners tend to wait for data to support their actions. Meanwhile, scientists conduct controlled experiments where uncertainties can be controlled. Therefore, it can be said that both planners and scientists are reluctant to take on 'risky' projects – where they cannot control uncertainties, for they are not accustomed to conceiving management actions as experiments and learning from the experience. Planners are responsible for understanding the risks involved in planning actions and should implement strategies (e.g. small-scale experiments, replicates and pilot studies) to do everything reasonable to reduce the risk of failure – yet still be explicitly willing to accept failure. This is perhaps the greatest challenge to implementing adaptive planning.

*3.2.3.2. Unsupportive institutional setting, and complex and competing social values and interests*. Unlike single-objective natural resource management agencies, where the adaptive management approach was conceived, in local planning practice planners are usually not the decision makers. The decision makers are likely to have different social values than advancing the science by incorporating testable hypotheses into plans. The short, elected terms of the decision makers in office shape their values and interests that may not be in alignment with ecologists and normative planners. Additionally, many key stakeholders in local land use planning are unlikely to share the value/interest that implemented plans/projects can yield new knowledge. In sum, adaptive planning is not yet common because either (1) the legal and institutional structure does not support it; (2) stakeholders do not share the values and interests in adaptive learning; and/or (3) the planners in these institutional settings are not the actual decision makers. Therefore, the institutional setting affects the decision of whether or not to adopt adaptive planning as well as its implementation.

*3.2.3.3. Lack of agreement on clearly stated goals*. There is often a lack of agreement among stakeholders on stated goals. For example, in watershed planning, multiple parties may want stream restoration but for different reasons. For example, civil engineers may want the stream to be restored to prevent flooding. A nature conservancy group may want riparian vegetation restored for wildlife habitat. Sport fishermen may want the water cleaner for fishing. If the planning goals are not understood and accepted by diverse stakeholders each with different interests, there could be too many variables to monitor to measure progress.

*3.2.3.4. Lack of data, monitoring expertise, tradition and culture*. Since each planning situation is by definition unique, it takes time for data to accumulate. Monitoring is not often practiced because it is a time-consuming activity and the cost is often not included in a landscape planning project budget. In addition, as discussed above, if there is a lack of agreement among stakeholders on clearly stated goals, arriving at the consensus of what to monitor is difficult. Funding for long-term monitoring is severely limited since planners operate in short time frames and in response to contemporary issues. Furthermore, decision makers (often different from planners) may have completely different values and interests governed by their short terms in office and by the need to respond to a wide range of socio-economic and political issues beyond purely scientific interests. Therefore, the money necessary to monitor the completed plans tends to be spent on other plans/projects with shorter-term results instead.

Given the lack of monitoring tradition and culture, incentives are needed to encourage monitoring. A carrot and stick approach might be useful. A stick might be to make monitoring a requirement of permitting. In return, developers could be rewarded with the 'carrot' of a density bonus or fast-track permitting process.

*3.2.3.5. Lack of scientifically-based guidelines*. In landscape planning, few science-based guidelines exist. For example, if planners want to know how wide a riparian buffer should be, and asked a biologist the question, she or he may say, "give me funding and five years to study, then I'll have an answer for you". Under the imperative to act, landscape planners often do not have time to wait for the establishment of site-specific recommendations based on science.

*3.2.3.6. Lack of successful precedents/models*. The literature review showed no existing method for applying adaptive management to landscape planning. From the literature several reasons were identified for the lack of adaptive planning applications: uncertainty, the difficulty of serving multiple goals of a landscape planning project, the risk of failure, the unfavorable institutional setting and different social values, and the lack of funding/incentive to monitor the project. An operational method is proposed to integrate adaptive management in landscape planning.

*3.2.3.7. Transdisciplinary approach not widely understood or practiced*. It is argued that adaptive planning requires a transdisciplinary approach because landscape planning is an all-encompassing activity that targets constantly changing landscapes with dynamic and interacting natural and social components. Since landscape planning involves human habitats, stakeholders must be involved in the planning process. Furthermore, landscapes are complex heterogeneous entities that need to be represented by scientific disciplines and professional knowledge. The role of planners in making landscape planning decisions necessitates a transdisciplinary approach.

However, a legitimate transdisciplinary approach with non-academic stakeholders involved in a planning process with professionals and academics, is not widely understood or practiced (Tress and Tress 2001, Tress *et al*. 2003, 2005). A full participation of the range of academics, professionals and stakeholders in a plan from the beginning would help communication of uncertainty, to foster trust and to build consensus among the participants (Peck 1998).

### ***3.3. How can adaptive planning be made operational in landscape planning practice?***

#### *3.3.1. Examples of existing landscape planning methods*

Some established landscape planning methods (e.g. Steinitz 1990, Steiner 1991, Leitão and Ahern 2002) include adaptive components. Steiner's ecological planning model (1991) is an example of a comprehensive planning method with adaptive components. For example, public participation (step 8) is encouraged throughout the planning process (see Figure 1.1, p. 10). Also, administration (step 11) includes monitoring and evaluation, the two important components of an adaptive planning.

#### *3.3.2. Proposed adaptive planning method*

Although existing landscape planning methods may contain adaptive components, these components are not at the center of the planning methods. A simplified diagram (Figure 1) of a typical landscape planning method starts with goals and objectives, then plan making and implementation. The plans are sometimes evaluated after their completion.

Using the same simplified steps, an adaptive planning method is proposed (Figure 2). The differences from the established generalized landscape planning method (Figure 1) are

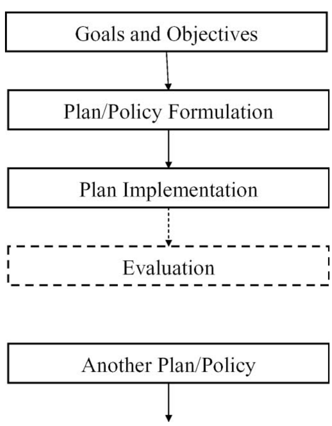


Figure 1. A simplified diagram of a conventional landscape planning method.

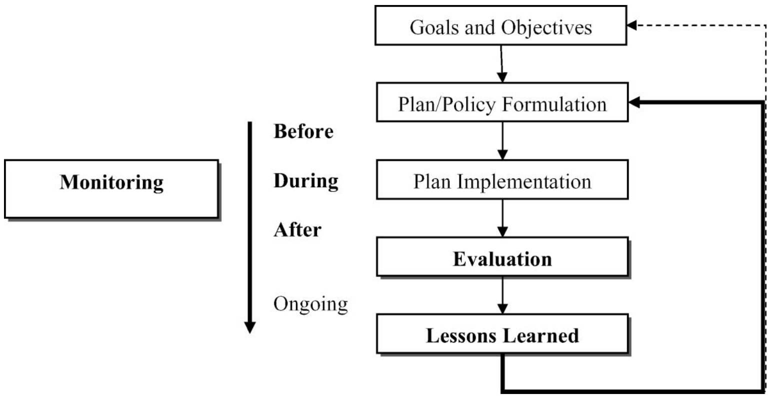


Figure 2. Schematic steps of an adaptive planning method. A characteristic feedback loop is shown: data collected from monitoring are fed back to the process to formulate new policies; landscape plans are adjusted according to the monitoring results.

that the method explicitly includes 'monitoring', 'evaluation', and 'lessons learned' from plans/projects. Monitoring should be conducted 'before', 'during' and 'after' the plan's implementation.

We are mindful of the apparent similarity of the proposed adaptive planning method and the rational planning model, which has been criticized for its information demand, artificial separation of decision-making processes, and requirement for consideration of all possible alternative plans (Kaiser *et al*. 1995). These criticisms and critics from normative process theories are acknowledged, such as strategic planning (Bryson 1995), communicative action theory (Forester 1989), dispute resolution (Susskind and Cruikshank 1987), and "rationality as the legitimation of power" (Flyvbjerg 1998, p. 26). It is argued that although the proposed adaptive planning method may resemble the rational planning model, it does not expect to consider all alternatives, but treats management actions as experiments with *a priori* hypotheses, encourages decision makers to implement several, small plans for faster learning, and actually reduces information demand and uncertainty by employing the key concepts and principles of adaptive management. The proposed method is most similar to Brooks' Feedback Strategy (Brooks 2002).

The systematic integration of monitoring at multiple points in the planning process is the principal innovation in the proposed adaptive planning method. Monitoring is a valuable tool for assessing the effectiveness of a plan to determine whether it has achieved desired effects. This information is then provided to stakeholders, policy makers and planners for refining a plan; this feedback process is emphasized by the thick arrow in Figure 2. Project goals and objectives may be adjusted according to the monitoring results.

When no prior data are available, monitoring can provide valuable baseline information on which future decisions and actions are based. Long-term monitoring can also be conducted to detect changes. Monitoring is particularly useful for assessing the impact of a management action during and after it has occurred, as depicted in Figure 2. After the analysis of the initial management action, the variables can be adjusted to include new variables reflecting the insight gained from the initial assessment (Holling 1978). That is to say, that if the whole model on which the plan was based was invalidated, decision makers and landscape planners are obligated to test an alternative model in search for a better result to the pre-defined plan objective.

As has been discussed, most landscape plans are developed and implemented in a local planning context, which is a vastly different social, economic, legal and political setting from that in which expert-driven state/federal agencies' plans are made. The ways in which monitoring will be established and developed must reflect the setting in which landscape planning occurs. A caveat here is that before monitoring is even attempted, there must be agreement among diverse stakeholders on clearly stated goals. Otherwise, there could be too many variables to be monitored to assess progress towards goals and to evaluate whether or not the plans/projects have achieved the intended goals after their completion.

One way to build a consensus among diverse stakeholders on planning goals might be through an adaptive, transdisciplinary planning process with the early involvement of stakeholders. The consensus-building sessions, built in at the various phases of the planning process, ensure the incorporation of multiple viewpoints of stakeholders through an adaptive approach. Collaborative forums should be held frequently where multiple stakeholders, citizens and experts discuss their values, share information and redefine goals and objectives. In collaboration, the integration of ecological, economic and social values in science is promoted and participants gain a sense of ownership in guiding the planning process that may encourage commitment to the process (Bocking 2002).

The following conceptual test illustrates how the monitoring would be designed as an integral part of an adaptive plan and how the monitoring results could be 'adaptively' fed back into the plan. In a water resource plan, the goals may be to improve water quality and support a greater range of recreational activities. The plan might propose best management practices (BMPs) to be implemented in existing neighborhoods (i.e. rain gardens, infiltrating catch basins and infiltration swales). The plan might also propose riparian buffers in all new developments. The adaptive part could be to define paired neighborhoods, with similar hydrological characteristics and apply different combinations of BMPs in each. Then, monitoring nutrient and pollutant loadings could establish benchmarks and the results could inform future planning/management. Likewise, various riparian buffer widths could be tested to determine the most appropriate width to achieve a specific objective (e.g. to reduce the amount of phosphorus entering a stream by 30%). The cultural resource monitoring, proposed later, could be used to determine which alternative BMPs would produce improvements in recreational activities.

### 3.4. *A conceptual test of the proposed method for water resource planning*

The proposed adaptive planning method has been applied to a conceptual test application in water resource planning. Water quality is selected as the goal of monitoring – to identify the source and nature of disturbance and to measure the consequence, if any, of management and planning decisions on water quality. Scientists, managers and planners use multiple or composite abiotic water quality indicators (e.g. temperature, turbidity, oxygen content and demand) as a means of quantifying changes in water quality.

#### 3.4.1. *Water as integrating resource and key landscape planning issue*

Water is an integrating resource because over time, water forms land, connects terrestrial and aquatic systems, and as a universal solvent, it can serve as a health indicator of the overall system (Forman 1995, Brooks *et al.* 2003). The importance of water is evident in various federal regulations such as the Clean Water Act and the National Pollutant Discharge Elimination System (NPDES) permit program, in efforts to sustain clean water supply (USEPA 2003, 2007).

### 3.4.2. *Non-point source pollution issue*

Non-point source pollution is a landscape issue since it relates directly to most land use and planning decisions, including land conversion, pollution, nutrient translocation and sedimentation. Non-point source pollution is recognized as an important source of pollution since it is difficult to track to a specific polluting source. The problem is exacerbated with the increase in impervious surfaces associated with urban development. Non-point source water pollution problems challenge planners to develop a solution to manage water quality that is holistic and adaptive.

### 3.4.3. *ABC water quality indices as endpoints of monitoring*

It is argued that water quality has measurable attributes of ecological and social well-being. These attributes can be classified by the ABC resource model, as explained earlier. If the ABC resource model is followed, indices are needed to measure. Monitorable indicators of water quality have been identified and developed (Table 2). The indicators also represent an integrated ABC approach to water resource planning, providing a broader and richer assessment of system state.

The recommended abiotic indicators represent the chemical and physical aspects of water quality; the biotic indexes suggest impacts of human activities on aquatic systems; and the cultural indicators represent people's attitudes towards and value of water (Table 2). Since the focus is on water 'quality', the indicators exclude other characteristics of a water resource such as flow regime and flooding frequencies.

### 3.4.4. *Cultural resource monitoring emphasized*

The importance and need for cultural resource monitoring are emphasized since previous water quality monitoring efforts have tended to focus exclusively on abiotic and biotic indicators. 'Culture' is defined as the manifestation of people's beliefs, values and attitudes to a resource as observable behaviors and actions. While much information exists on socio-cultural data taken from the US Census, such as median household income, education and ethnicity, very little data exist on the indicators capturing people's attitudes

Table 2. The Abiotic-Biotic-Cultural indicators (indices) for water quality monitoring.

| Abiotic | Biotic | Cultural |
|---|---|---|
| Dissolved oxygen | Fish index of biological integrity | Use for drinking water supply |
| Total nitrogen | Benthic invertebrate index of biological integrity | Presence and level of water-based recreation |
| Total phosphorus | Aquatic life | Fishing/eating caught fish |
| pH | | Other water uses (e.g. agricultural, industrial) |
| Fecal coliform bacteria | | Level of human access to water |
| Other pollutants | | Behavior of people around the water resource |
| | | Recreational and natural enhancements |
| | | Abstract expression of specific water resource areas in the arts |

toward and value of a resource. The list (Table 2) addresses this issue. It is envisioned that these cultural indicators are understandable by lay people and that their monitoring can be conducted by trained volunteers. Since their effectiveness for water quality monitoring is yet to be tested, an empirical study is necessary before any further recommendation can be made to decide on which cultural indicators are better.

#### 3.4.5. *Integration of the ABC components of water quality critical*

To plan for and protect water resources from a broad range of human impacts, there is a need to integrate the monitoring results of all the abiotic, biotic and cultural resources. Indices that can succinctly capture diverse aspects of a system are preferred over ones that represent a single aspect. For example, fish index of biological integrity (Fish IBI) and benthic invertebrate IBI are preferred to a single biological indicator since they are more inclusive and provide a better representation of broad characteristics of ecological health of a system (Table 2). By understanding how the indices relate to one another, decision rules can be created, such as a ranking system to integrate the indicators so that a working holistic view can be achieved.

## 4. Conclusions

### 4.1. *Proposed operational method for adaptive planning*

An operational method for adaptive planning has been proposed to address abiotic, biotic and cultural resources, and indicators and indices have been identified to monitor in water resource planning.

The adaptive part comes from monitoring the integrated ABC indices before, during and after plan implementation and its evaluation so that both new and existing plans can be adapted to the lessons learned. It is argued that landscape planning needs to respond to the need for action in the face of uncertainty and to apply the concept of 'learning by doing'.

### 4.2. *Willingness to accept 'reasonable' failure*

Planners also need to accept and acknowledge the potential to fail, but that also implies the corollary: the possibility to succeed! In order for the concept that treats management activities as opportunities to learn to be accepted, the culture that encourages experimenting with new approaches and considering new information needs to be embraced by managers (Committee of Scientists 1999) and the risk of 'controlled failures' needs to be accepted as part of the process, not as an indication of incompetence by planners.

A caveat is needed here on professional responsibility. It is not being advocated that it is entirely acceptable to make mistakes as long as we learn something from them. Under a mandate to act, landscape planners and natural resource managers should not refrain from experimenting by acting. However, they should minimize risks and make decisions based on the best available data and knowledge. To limit controlled failures, strategies such as replications and conducting incremental, pilot experiments should be implemented so that management actions will not risk destroying an entire ecosystem. One way to minimize appropriate risks is to engage stakeholders in a transdisciplinary approach throughout the planning process.

### 4.3. *Need scientifically-robust indices of ABC resources*

Planners need to establish scientifically-robust ABC indices such as the indices proposed in Table 2. Indicators are needed that are grounded in science and in explicit socio-economic, behavioral theories, whose usefulness can be tested in empirical studies. A good example of scientifically-robust indices is fish IBI (Karr 1991).

### *4.4. Potentially useful model for applied landscape ecology under a transdisciplinary approach*

It is argued that professionals, stakeholders, decision makers and researchers need to function in a transdisciplinary mode which provides a framework for collaboration and information sharing among different disciplines with explicit roles in the process (Tress and Tress 2001). Scientists can be actively involved in the design and conduct of experimental management and planning programs with inputs from stakeholders from the beginning. Landscape ecology can provide a basis for collaboration among resource managers, landscape planners and stakeholders in the development of landscape plans because of its emphasis on the interaction between landscape structure and function across spatial and temporal scales (Forman and Godron 1986, Turner 1989, Zonneveld and Forman 1990, Turner *et al*. 2001, Ndubisi 2002).

### *4.5. Need for developing pilot adaptive planning applications*

Finally, the paper concludes with the need to develop pilot adaptive planning applications to test the proposed adaptive method to document the issues, approaches and results in the literature, and to contribute to an advancement of an adaptive approach to sustainable planning. Some contemporary issues in landscape planning, where the proposed adaptive approach could be tested in a planning process, include: planning for 'green infrastructure' that can support multiple ecological and social/cultural functions at multiple scales; and planning clustered developments and the New Urbanism-type developments. The NPDES Phase Two applies to smaller political units and communities than Phase One and targets non-point source issues. Uncertainty is more of an issue in Phase Two due to the specifics of more and smaller applications. However, public officials and planners can take advantage of the situation and implement plans with 'testable' hypotheses, as indicators of water quality can be identified and monitored before, during and after implementation. The monitoring results can then be used to select best management practices and decide which plans have achieved the goal of the project. The multiple opportunities to test hypotheses would help establish strong pattern-and-process relationships, and investigate causality among complex interacting elements. Another topic that is important to research concerns residents' perceptions of community to learn how people react to or value alternatives to low-density sprawl development.

Uncertainty is fundamental in landscape planning and needs to be understood in a manner that can inform strategies to address it. We can start developing test applications of these strategies to build empirical experiences for managing water resources and others. Given the uncertainties in natural and social systems, the call for action requires applying the concept of 'learning by doing' through adaptive strategies.


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