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The Value of Decision Models

Using Ecologically Based Invasive Plant Management as an Example

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Many professions operate with systems of checklists or decision models that ensure decisions are based on the best current knowledge and are consistent. There are a number of natural human tendencies that cause us all to skip important steps in the decision-making process, and the checklist approach helps overcome this problem. These lists are some of the simplest decision tools we can employ. For a variety of reasons checklists have not been widely adopted in rangeland or natural resource management. Our objectives here are to: 1) provide a brief overview of decision-making theory and the specialty area of judgment and decision making (JDM), 2) discuss how ignoring decision tools can limit our success, 3) describe examples of simple decision models used in other professions, and 4) introduce Ecologically Based Invasive Plant Management (EBIPM) as an example of a decision model in rangeland weed management. We will not go into the specifics of EBIPM; that is the purpose of this special issue of *Rangelands*. The goal of our discussion is to provide the underlying argument for the use of stepwise decision tools such as EBIPM.

How We Think

All the decisions we make are constrained by how we think. Yet we seldom consider how humans make decisions when discussing management of rangelands. Much of the material for this section comes from Daniel Kahneman's book Thinking, Fast and Slow.[1] In his book he describes two very different modes of thinking: System 1, which operates automatically (also described as intuitive, experiential, narrative, and natural[2]—see Table 1) and System 2, which involves more complex mental activities (also described as rational, analytical, deliberative, propositional, and extensional,[2] Table 1). From an evolutionary standpoint, it makes sense that we developed a way to respond quickly to threats: it's hard to negotiate with charging buffalo or packs of wolves; it's better to react quickly and get out of the way. However, solving most math problems, or building a sound bridge can take more than intuition. There is a point of view by some JDM experts that there is a continuum between these two decision strategies, but most agree that some decisions are more automatic and others require more deliberative thought.[3] We are sure many folks understand this concept. The value of System 1 is the quick reaction time—reading a person's mood, catching a basketball, evaluating the environment around us, and forming sentences. But, according to Kahneman, only System 2 can "construct thoughts in an orderly series of steps."

What is the advantage of having two distinct thought strategies? Clearly we need to react quickly in some situations and spend time analyzing in other situations. But we can only spend so much time analyzing a given situation or we would never make decisions. Enter the subject of "heuristics" which is defined as "methods for arriving at satisfactory solutions with modest amounts of computation."[4] Because we do not have unlimited time, we must be as efficient as possible in many of our decisions, what Shah and Oppenheimer[5] call an "effort-reduction framework." The problem is ensuring that we don't attempt to be too efficient and rely on System 1 when we really should be using System 2. To paraphrase Kahneman,[1] System 1 is prone to systematic errors, might answer easier questions than it was asked, and has limited understanding of logic and statistics; in addition, it cannot be turned off. He proposes that people tend to overuse System 1, citing the "law of least effort" which suggests people will "gravitate to the least demanding course of action."

How We Manage

How does fast (System 1) or slow (System 2) thinking relate to management of natural resources or rangelands? In a previous article we discussed the differences between simple and complex problems.[6] Simple problems are those for which a single solution exists, whereas the solution for complex problems varies in time and space. If we allow System 1 to dominate, it is likely that complex problems will be addressed through a simple thought process: for example, grazing issues can be addressed by either cutting stocking rates or applying a grazing system of choice; postfire rehabilitation can involve seeding some preferred mix of species; and weed management can invoke a "see weed → kill weed" response. These are all complex problems, yet many will be handled with automatic or intuitive solutions, rather than the analytical and

deliberative thought process they deserve. We are all prone to making decisions based on intuition rather than a stepwise thought process. Intuition is often based on past experiences or preconceived biases, and the fact that this approach occasionally works only clouds the decision-making process. In many cases we don't really even think about how we make decisions. In his book on business mistakes, Nightingale[7] points out that "most decisions are made unconsciously."

Potential Solutions

The preceding discussion should make it clear that we need to engage System 2 for many of our decisions in natural resource management. System 2 can handle stepwise thinking, compare objects for multiple traits, and uses logic and statistics.[1] Other professions have adopted decision tools to ensure that System 2 is engaged during decision making. Many examples are given in Kahneman's book[1] and in the Checklist Manifesto by Atul Gawande.[8] Decision tools need not be complicated or too detailed to be effective. In his book, Gawande gives many examples in medicine, architecture and construction, food service, and other disciplines that show the value of both simple and complex checklists. In several cases, there are checklists for both actions and for communications. In construction, for example, there are specific tasks that need to be completed (an action checklist) and at critical points other members of the project team must be informed (a communication checklist).[7] In several of his examples from the medical profession, the savings in both lives and dollars are stunning. The most extensive checklist test cited by Gawande[8] was done in cooperation with the World Health Organization (WHO). This effort involved surgical operations at eight hospitals around the world. The hospitals were located in four high-income countries (United States, Canada, England, and New Zealand) and four in low- to middle-income countries (Philippines, Jordan, India, and Tanzania). At each hospital, observers documented actual rates of complications, death, and system failure in surgery over a 3-month period. A "safe surgery checklist" was then developed by Gawande and his cooperators. The list was tested and refined under actual operating room conditions and the final product was a 2-minute, 19-step list. Observers then collected data for another 3 months after checklist implementation. The rate of major complications for surgical patients at the eight hospitals fell by 36% and deaths fell by 47%. Since the results of the WHO study were released, more than a dozen countries and hospital associations in 20 states in the United States have agreed to adopt this approach.

The aircraft industry has adopted the checklist approach extensively. In his book, Gawande[8] outlines the origins of this practice. In 1935, the precursor aircraft to the B-17 (the primary US long-range bomber used in World War II) was given a test flight by the Air Corps' chief of flight testing. The result was tragic; the plane crashed, killing several crew members. The B-17 was a complex plane to fly and the test pilot had forgotten to release a new locking mechanism associated with the flight controls. Instead of requiring more training for pilots of the B-17, a group of test pilots developed a checklist that ensured that critical steps were not missed. As Gawande[8] points out, pilots now have checklists for a wide variety of routine and emergency scenarios. Every time a major issue arises with a commercial airliner in the United States, the National Transportation Safety Board investigates. When the cause of the problem is identified, a determination is made as to whether a change in procedure is needed or if a new checklist is necessary. Obviously not all problems can be addressed in this manner, but many can be. These investigations and subsequent advisories provide a feedback loop to ensure that potential mistakes are not repeated. And the issue might be more related to incorporating new knowledge than to actual errors in judgment. This example points out the value of investigating failures, an action that is lacking in many professions.

Table 1. Two alternative strategies for decision making. Keep in mind that these are simply ways of thinking and are not necessarily associated with specific regions of the brain. The descriptors presented here were taken from the book by Kahneman[1] and paper by Denes-Raj and Epstein[2]

Mode of thinking	Descriptors	Evolutionary position	Characteristics
System 1	• Automatic • Intuitive • Experiential • Narrative	Shared by all higher organisms (but more complex in humans)	• Cannot be turned off • Little or no effort • No sense of voluntary control • Does not incorporate math or statistics
System 2	• Rational • Analytical • Deliberative • Propositional	Relative newcomer, functions via a person's understanding of conventionally established rules of logic and evidence	• Can be partitioned into specific steps • Can incorporate logic, math, and statistics • Requires attention and is disrupted by distractions

One of the stumbling blocks in adopting decision tools, checklists or otherwise, is that professionals feel they are fully capable of making decisions without such aids. However, there is a good deal of information showing the clear benefits of simple decision tools. Airline pilots might have thousands of flights worth of experience, yet they still use preflight checklists prior to each take-off. Hospital emergency room staffs regularly use such lists to great advantage. How would we feel if either of these groups of professionals decided they no longer needed to ensure System 2 was engaged? Poor decision making by either pilots or emergency room personnel could have immediate and severe consequences. We suspect that adoption of decision tools is more likely in situations where feedback is fairly rapid and results are easier to measure. The short duration of time between making a decision and realizing its effects promotes accountability for results. In natural resource or rangeland management, results of decision making can be subtle and unfold over what we perceive as long time horizons, generally at least a year (i.e., a growing season) and sometimes much longer. Both of these factors encourage a reliance on intuitive decisions and a culture of decision making that rewards the fact that action was taken, rather than effectiveness of the action.

We cite these two examples because in both cases the practitioners (surgeons and pilots) are well trained and are dealing with complex systems. We have probably all heard the argument that ecosystems are very complex and thus simple approaches (such as a checklist) would not seem appropriate. Clearly we would not hand a surgical or aviation checklist to an untrained person and expect them to complete the task. Similarly, professional judgment will be critical in making natural resource decisions, regardless of the decision tools employed.

Checklists in Natural Resource Management

The approach outlined for the medical and aviation professions seems to be less routinely used in natural resource management. Many of the potential examples we find are really strategic rather than tactical. There are many versions of the adaptive management circle that usually consist of steps such as: 1) identify problem, 2) plan, 3) implement, 4) evaluate, 5) adjust, and then start the cycle again. In terms of actual operational guides, we know of relatively few cases to cite. The checklist approach was used in the "Western Juniper Field Guide: Asking the Right Questions to Select Appropriate Management Actions."[9] In this example a series of 29 questions are posed under the following categories: setting objectives, identifying ecological site, current state of the site, landscape considerations, and selecting the appropriate management actions and treatments. The guide provides background information intended to help managers answer the questions, but does not provide specific answers to the questions. Several revegetation guides take the approach of either asking a series of questions[10] or presenting a checklist of actions.[11] A series of checklists for wildland fire fighting are provided in the "Incident Response Pocket Guide."[12] In this case the lists tend to be very specific.

We think it is useful to break checklists into two categories: 1) instructional lists that can be very specific because they deal with fairly uniform systems, and 2) decision frameworks that provide a structured thought process rather than specific instructions. In the examples we have provided, the aviation and firefighting lists fall in the first category, and the surgery, juniper management, and revegetation lists fall in the second category. In general, variable systems such as ecosystems require a list that helps us think through our decisions. In other words, what are the most important considerations and in what order should they be addressed. This approach generally will not provide an answer to the question being asked, but will identify steps in the decision process. When dealing with engineered systems the lists can be pretty specific (there isn't such variation in the control system of a Boeing 737, for example).

EBIPM as a Decision Tool

Managing weeds on rangelands is a complex action that will benefit from decision tools and ensuring that we engage System 2 in decision making. We need a framework to help ensure that steps are not missed, and that scientific principles and management experiences are used to guide decisions. EBIPM is an approach to rangeland weed management which applies scientific principles and management experiences in a stepwise sequence. We could develop checklists for each of the five steps outlined in Figure 1. One value of the framework outlined in Figure 1 is that the steps require engagement of System 2. There is that natural tendency for System 1 to take over, causing us to jump to step 5 and develop the plan, ignoring steps 1–4.

We believe there is a pressing need to develop simple, easy-to-measure parameters for assessing step 1, and in step 5, for assessing progress toward success. In the medical profession, four to five vital signs are measured on every patient who enters a hospital or clinic. The vital signs are used to help assess the "current situation" of the patient. Our research group has conducted a series of studies that suggest that native bunchgrass density could be one vital sign for northern Great Basin rangelands (as discussed in Davies et al.[13]), especially in terms of resistance to annual grass invasion. Bunchgrass density could be viewed as a critical parameter for assessing the current situation, even if weeds are not yet a problem. Such vital statistics are of elevated importance in rangeland management because they can allow managers to preemptively identify and address management concerns (e.g., downward trend in perennial grasses) as opposed to reactively dealing with the resulting fully developed problems (e.g., annual grass infestation). Other variables linked to research or documented management results could be used in subsequent EBIPM steps (Fig. 1).

We have briefly cited some examples from other professions in which engaging our more logical System 2 thought processes using simple decision tools can yield big dividends. For more detail we recommend the books by Kahneman[1]

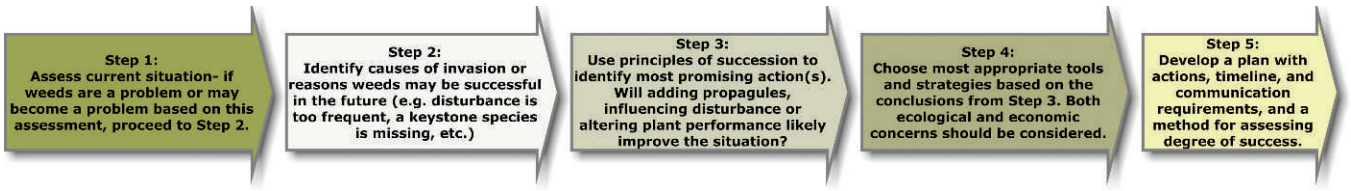

Figure 1. Steps in applying the EBIPM (Ecologically Based Invasive Plant Management) Model.

and Gawande.[8] One issue we have not mentioned is that this approach will also help us explain decisions to others—a neighbor, a judge, or the interested public. Additionally, the steps we might choose for coming to a management decision can be tied to research results and monitoring data, and a relatively uniform approach will make it easier for managers to communicate and share experiences, because the experiences will be couched in a similar framework.

The rest of this special volume will provide more detail on the thought process and science used to develop the EBIPM approach. This framework represents an ecologically based game plan for bridging the gap between current and desired conditions, can easily incorporate simple decision tools into the 5-step process (Fig. 1), and can be adjusted as new information becomes available. Although EBIPM was developed specifically to address weed management problems, we believe that the structured thought process embodied by this framework has application to a wide variety of complex problems currently faced by rangeland managers.

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–Brenda S. Smith, Guest Editor