

HOW DO LAND MANAGERS ADOPT SCIENTIFIC KNOWLEDGE AND TECHNOLOGY? CONTRIBUTIONS OF THE *DIFFUSION OF INNOVATIONS* THEORY

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SUMMARY

Both researchers and managers cite barriers to incorporating the best available science into land management. This paper outlines a tool that can be used strategically to obtain broad application of new scientific knowledge and technology. The overarching premise of the *Diffusion of Innovations* theory is that it takes time for individuals, and society as a whole, to incorporate innovative concepts and techniques into established approaches and practices. The amount of time depends on characteristics of the innovation and individuals who might adopt the innovation, as well as established social norms and communication networks. Management communities in different organizations function as social systems with interrelated units, communication networks and established social norms. Individuals in these communities have different levels of comfort with uncertainty that affect how they obtain their information and how quickly they adopt new approaches. Once they are introduced to a new idea, individuals go through the “innovation-decision” process, which includes awareness and understanding, evaluation of advantages and disadvantages, decision, implementation and decision confirmation. Understanding the various components of this theory will help reduce the amount of time it takes to get diffusion through management community. Specifically, researchers can reduce barriers to the use of scientific innovations by targeting each stage in the adoption process and working to understand management audiences. This paper provides an introduction to the *Diffusion of Innovations* theory for researchers and upper-level managers who are working to improve research application, but who are not yet familiar with this theory.

1. INTRODUCTION

For ecosystem management to be effective, the gap between scientific knowledge and existing management practices must be narrowed (1). In addition to the need for ecological and social knowledge to inform decisions, the use of science adds credibility to management decisions, provides conceptual approaches for complex problems, and contributes to new techniques for accomplishing management objectives. Efforts to inform managers about scientifically derived knowledge and conceptual approaches are often applied ad hoc, with most scientific information provided in the form of publications and presentations. Local interactions among individual scientists and managers who work to ensure that research results are effectively applied result in local successes; however, broad application is often absent or takes much longer to occur. Unfortunately, although broad management audiences are exposed to scientific information through a variety of avenues, awareness of new approaches and techniques does not necessarily transfer to active use of new management practices.

A strategic approach may be more efficient for obtaining broad application of scientific knowledge and technology. By understanding the processes of adoption and diffusion, as well as the effects of innovation characteristics (e.g., complexity and observability) on adoption rates, scientists can reduce the amount of time these processes take. Additionally, by realizing

that adoption and diffusion of new ideas and techniques takes time, scientists can be realistic about the timeframes within which they expect managers to use innovations. This paper describes the facets of the *Diffusion of Innovations* theory, as described by Rogers (2) that are relevant to incorporating science into management. This theory is useful both to scientists who provide science to support management and to upper-level managers who strategically work to improve the ability of their staff to use the best available scientific information.

Diffusion of Innovations theory has been applied by a variety of disciplines, including anthropology, sociology, geography, agriculture, public health, communication, and marketing. The fields of ecosystem science and management are comprised of a large number of ecologists and a few social scientists. Most ecologists have not studied the *Diffusion of Innovations* theory and the social scientists involved in ecosystem management who may be familiar with it are often occupied by investigating human values and improving conflict resolution. This overview is targeted at scientists and upper-level managers who are not yet familiar with the *Diffusion of Innovations* theory. While the paper is focused on the science-management interface, it is also applicable to the interface between science and members of the public who are interested in ecosystem management.

2. THEORY OVERVIEW

An *innovation* is “an idea, practice, or object that is perceived as new” (2). Examples of innovations include: a) conceptual approaches, such as ecosystem management (1) and natural range of variability (3); b) monitoring (4,5) and restoration (6) techniques; and c) planning tools, such as the Limits of Acceptable Change process (7), adaptive management (8), fire models (9), and a framework for addressing scientific activities in wilderness (10). According to this theory, *change agents* (members of the research community) introduce innovations to *potential adopters* (members of the management community) who then go through a multi-stage adoption process. While *adoption* is the “mental process through which an individual passes from first hearing about an innovation to final adoption,” *diffusion* is the “process by which an innovation is communicated... over time among members of a social system” (2) (Figure 1). If enough managers adopt an innovation, its use diffuses through the management community. Members of the research community can facilitate this process by understanding and influencing factors that affect both adoption and diffusion (11,12).

Although the classic theory is linear and implies a one-way information flow from change agents to potential adopters, its use has evolved into a convergent model where the potential adopter and the change agent work together to develop an innovation that solves a problem described by the potential adopter. Scientists working on land management issues work according to both linear and convergent models. They either develop innovative approaches in response to needs directly communicated by managers or use their own knowledge and insight to anticipate and address future management needs. Whether the development and communication are linear or convergent, managers ultimately decide whether the proposed new approach is superior or inferior to current practices.

3. STAGES OF ADOPTION

Researchers frequently disseminate information about new conceptual approaches and research results through publications and presentations. The *Diffusion of Innovations* theory describes what happens once a manager becomes aware of new ideas presented by the scientific community (Figure 2). If a manager’s interest is piqued by exposure to the innovation, the individual begins the “innovation-decision” process by gathering information. Initially, an individual works toward understanding how the innovation works. Next, the individual gathers information to weigh the potential advantages and disadvantages of using the innovation and develops either a favorable or unfavorable attitude toward it.

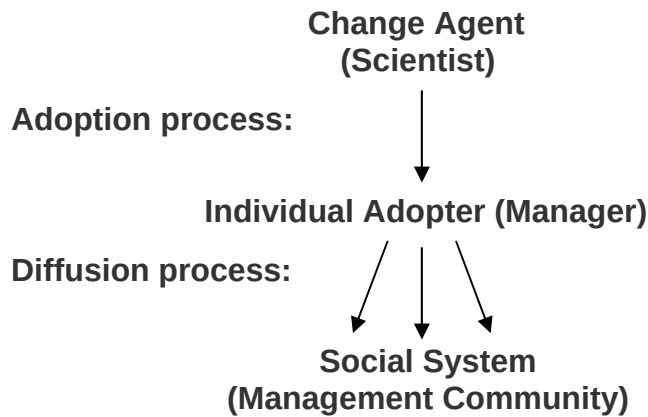


Figure 1. Relationship between the adoption and diffusion processes. The arrows represent information flow about an innovation. They are not meant to imply successful adoption or diffusion.

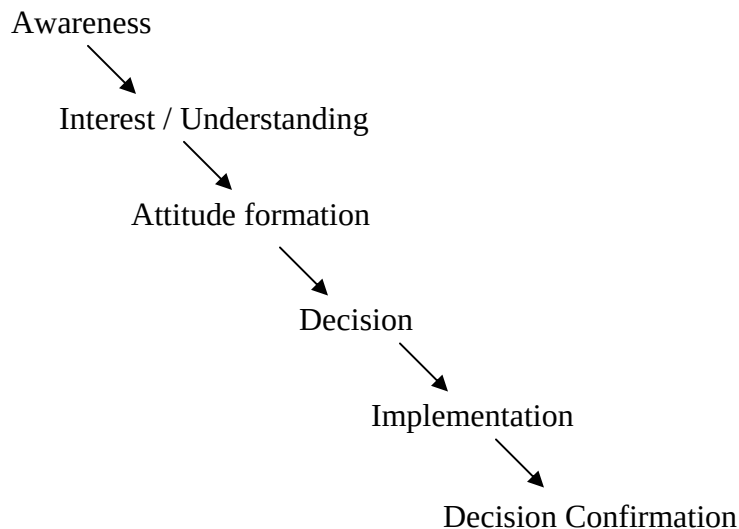


Figure 2. Stages an individual passes through from awareness of an innovation to adoption.

If uncertainty is reduced to a tolerable level, and a manager develops a favorable attitude and decides to adopt an innovation, the innovation is tested. Upon implementation, the manager often adapts the innovation to fit within existing practices. During this stage, which is sometimes referred to as “re-invention” (2) or “fitting” (13), the scientist no longer has control of how the innovation is applied. Following a trial period, where anticipated and unanticipated consequences of applying the innovation are evaluated, a manager either confirms the decision to use the new approach or rejects the innovation and again uses previous practices to meet objectives. The innovation-decision process also occurs at the organizational level, where a few individuals with power, status, or technical expertise go through the process and charge other managers with implementing an innovation. This is the fastest way for diffusion to occur unless either the authoritative group is not innovative or the implementers disagree and circumvent the adoption decision.

Barriers to adoption occur at any stage during the innovation-decision process. Barriers can include a lack of awareness, lack of interest, or lack of adequate information to either understand or develop a positive attitude toward an innovation, as well as difficulties during implementation. For effective application, the research community needs to focus on reducing barriers at each of these stages. For example, conference/seminar presentations and newsletters target awareness, whereas summary publications, specialized training, or handbooks may be necessary to increase understanding to the point that the innovation can be evaluated and implemented (12).

4. RATE OF ADOPTION

Each individual takes time to work through the stages of adoption. Diffusion through a management community, where many individuals undergo the adoption process, takes more time. The amount of time diffusion takes to occur (i.e., the *rate of adoption*) is described on a graph showing the cumulative number of adopters over time (Figure 3). The more individuals that adopt an innovation within a given time, the steeper the slope and the sooner diffusion occurs. The standard s-shaped *adoption curve* represented on this graph begins with a slow rate of adoption that increases only after a critical mass of individuals within a community (10-25%) adopts an innovation, thereby activating interpersonal communication networks (2). Following this critical mass, a faster rate of adoption continues until it levels at an asymptote representing the time when most of the community has adopted the innovation.

In addition to describing the adoption curve, the *Diffusion of Innovations* theory addresses the characteristics of innovations, individuals, social systems, and communication channels that affect the rate of adoption. Increased familiarity with the characteristics of innovations as well as those of target management audiences will enable the research community to decrease the time it takes for individuals to adopt innovations. For example, Watson et al. (14) found that “localized” communication, where centralized management offices circulated information about an innovation, increased awareness and the rate of adoption. The shape of the s-curve can be changed by reducing the time it takes to reach the critical mass and by increasing the subsequent rate of adoption (Figure 3). Such efforts might even facilitate the adoption of innovations that otherwise might not be adopted.

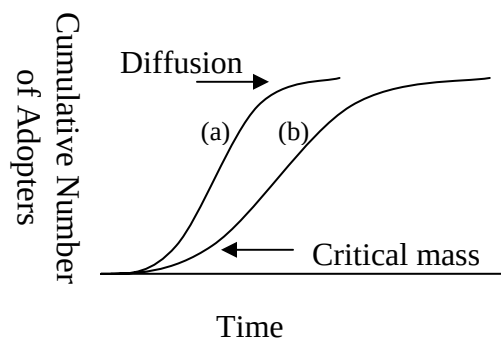


Figure 3. S-shaped adoption curve, showing an increased rate of adoption (cumulative number of adopters/time) between reaching critical mass and complete diffusion. Graph (a) takes less time to reach the critical mass, has a faster rate of adoption, and takes less time to achieve diffusion than graph (b).

4.1 Innovation Characteristics

According to diffusion research, the time taken to adopt an innovation varies most with characteristics of the innovation including its complexity, compatibility, trialability, and observability. For example, complex innovations take more effort to understand and therefore take longer to adopt. This is especially true when new skills or knowledge are needed to understand the technical aspects of an innovation. Similarly, innovations take longer to adopt when they are incompatible with existing values, beliefs, or management needs. In fact, incompatible innovations may not be adopted unless they are preceded by the adoption of a new value system. Regardless of whether innovations are complex or compatible, those that are easier to try and implement are adopted more quickly than those that are difficult. Similarly, innovations that produce visible results (e.g., on-the-ground campsite restoration techniques) will stimulate interest and be adopted more quickly than those that are difficult to observe (e.g., conceptual approaches). Some innovations can be designed to be less complex, more compatible, easier to implement, or easier to observe. However, for other innovations, the research community needs to recognize these characteristics and spend more effort presenting them to the management community in a way that makes them easier to adopt. Change agents sometimes do this by developing trainings workshops or handbooks for innovations that are complex or difficult to implement. Scientists may also want to address how innovations relate to other successful and unsuccessful innovations that are presented within the same timeframe, because attitudes toward innovations are influenced by prior experience with other innovations. Notably, the perception of these characteristics is a more important driver of the adoption rate than the actual characteristics (2).

4.2 Audience Characteristics

4.2.1. Individuals

Each new approach or technique presented by scientists is associated with some uncertainty. Managers who are comfortable with a high degree of uncertainty will adopt innovations faster than those who are uncomfortable with uncertainty. The *Diffusion of Innovations* theory separates individuals within a community according to their relative comfort with uncertainty and how quickly they adopt new ideas into the following groups: *innovators*, *early adopters*, *early majority*, *late majority*, and *laggards*. In reality, these groups occur along a continuum; however, the terms are useful for describing differences along the continuum. *Innovators* are comfortable with relatively high levels of risk and uncertainty and actively seek innovations from outside their local networks. *Early adopters* are also comfortable with adopting new ideas. Unlike the innovators, early adopters are more focused within local networks, often use established methods to accomplish objectives, and are more cautious when deciding to use innovations. Members of the *early majority* deliberately adopt innovations once their peers have evaluated and accepted them. Alternatively, members of the *late majority* have a less favorable attitude toward science and are cautious and skeptical; they usually adopt new approaches only when pressured to do so. Lastly, the *laggards* are extremely cautious and wait long enough to be sure their use of an innovation will not fail before adopting it. These are the last members of the social system to adopt innovations.

Based on these descriptions, one might conclude that introducing innovations to *innovators* is more effective than introducing them to the latter groups. However, Rogers (2) suggests that *early adopters* are the most effective group to interact with because they are the most respected among their peers. Some research scientists pride themselves on their frequent interactions with land managers. However, without information about which group these managers most closely fit into, it is difficult to gauge the effectiveness of these interactions.

Many managers who are drawn to scientists may be innovators. Scientists who spend energy introducing their ideas to innovators may not be as effective at facilitating adoption as those who seek early adopters because innovators are deemed less influential within their peer groups.

These categories recognize that people have different levels of comfort with uncertainty. To facilitate adoption, upper-level managers might encourage subordinates to be innovators and early adopters who are curious and receptive to new approaches (8). However, since they may not be able to change subordinates' comfort with uncertainty, they also need to intentionally hire some managers who are already comfortable with uncertainty and willing to explore new ideas.

4.2.2. Social Systems

While adoption refers to the process undertaken by an individual, the process of diffusion occurs within a social system. A social system, "a set of interrelated units engaged in cooperative problem solving to accomplish a common goal," is bound by common goals and objectives (2). The management community of a given organization (e.g., government agency, or private or non-profit organization) functions as a social system, with a) managers of different disciplines such as fire, wildlife, botany, and recreation, or b) different levels of management responsibility such as decision makers, staff resource specialists, and field implementers, comprising the interrelated units. Few studies have investigated the way relationships within or between units of a community social structure affect the diffusion process; however, diffusion theorists recognize that social structure is likely to be influential. Understanding the structure of these units can help the scientific community identify communication networks both within and among units.

4.3 Communication within Social Systems

Information about innovations is more likely to diffuse through a management community when communication techniques are based on a clear understanding of the communication channels both between research and management and within the management community. Change agents need to understand the function of different types of communication, the role of opinion leaders, and differences in communication between *homophilous* versus *heterophilous* individuals.

4.3.1. Communication Channels

Communication channels, whether paper, verbal, or electronic, are a key part of the diffusion process. Communication about innovations occurs through a variety of channels ranging from the mass media to interpersonal communication. While mass media provides information to more people at once and is more likely to introduce innovators and early adopters to innovations, interpersonal communication is more likely to influence the attitudes of early majority, late adopters, and laggards when it comes from respected peers. For all audiences, interpersonal communication is thought to be more important during the evaluation and implementation stages of the adoption process than for initial awareness. It is important to consider which combination of techniques will be most effective for a given innovation, a given stage in the adoption process, and a given audience.

4.3.2. Opinion Leaders

Identifying opinion leaders, who are most likely to influence the attitudes and behaviors of others in the community, is a key to successful diffusion. Opinion leaders earn and maintain leadership within the social community through technical competence, social accessibility, and conformity to the system's established beliefs, values, and behaviors (i.e., system norms).

Innovators are not usually opinion leaders because they frequently deviate from system norms. Instead, early adopters are often the opinion leaders in the group; they function as a social model whose behavior is imitated by other members of the system. As a result of conforming to system norms, opinion leaders are innovative only when change is seen as acceptable in the social system. When system norms value tradition, the opinion leaders tend to be late adopters.

Diffusion of new scientific approaches is most effective when change agents interact with opinion leaders, who can lead the adoption of innovations throughout the management community. Rather than identifying leaders for the entire community, it is important to identify opinion leaders within different units of the management community. For example, there are different opinion leaders at different levels in a management hierarchy. Opinion leaders can be identified by asking a) members of the community who they seek information from, b) those who provide information to the network to who they provide it to, or c) members of the community whether other people come to them for information.

4.3.3. *Communication Among Similar (Homophilous) Individuals*

An unstructured communication network, where each individual communicates with all other individuals in the community with equal probability, is unlikely. Rather, individuals are most likely to interact with others who hold similar personal and social characteristics, such as beliefs, education, work experience, and social status. Communication among such individuals, described as *homophilous*, is more comfortable and more effective because these individuals share common meanings and subcultural language. In contrast, *heterophilous* individuals differ in these social characteristics.

Successful diffusion depends on communication between individuals (change agents) who are familiar with innovations and those (potential adopters) who are unfamiliar with them. Change agents, representing the research community, often seek the adoption of innovations and influence the decisions of potential adopters by disseminating information about innovations. However, research scientists and managers tend to be heterophilous. In addition to increased technical understanding of an innovation, scientists often have different levels of education and are motivated by different priorities than most managers who are responsible for adopting and implementing innovations. The two groups work within different cultural environments (15). Communication among heterophilous individuals can be a problem when it causes cognitive dissonance, or internal conflict, for managers who find messages to be inconsistent with the beliefs or the environments in which they are used to operating. These differences can also lead to mistaken understandings, and therefore a lack of adoption (2).

Ideally, aside from differences in technical understanding, individuals who introduce innovations would be perceived as homophilous, or similar, with opinion leaders. Technology transfer or research application specialists are often more homophilous with managers than research scientists and so can help bridge this gap. If they share similar beliefs, education, work experience, and social status, these specialists are more likely to understand social norms and subcultural language with the management community. If they are not homophilous with managers, these specialists are more likely to seek to communicate using the norms and language of management communities. Of course, it is imperative that technology transfer and research application specialists also work closely with research scientists to increase their technical understanding of innovations.

5. THEORY LIMITATIONS

Land managers experience technical, emotional, and political barriers to using scientific information. Technical and emotional barriers include a lack of adequate synthesis, lack of

access to timely information, lack of time or skills to find, understand, and implement research, lack of trust in science, and cultural barriers between researchers and managers (15,16,17). In addition, some barriers are driven by politics and human values. Such controversial and intractable problems, sometimes termed “wicked” problems (18, 19), can occur due to vague or conflicting laws or policies, political strategies, spiritual values, or mistrust (20). These types of decisions are not entirely solved by the adoption of scientific information. Thus, the value of the *Diffusion of Innovations* theory will be most valuable when applied to situations where science plays a major role, such as developing new techniques, assessing social and ecological trends, predicting the consequences of alternative management options, and providing conceptual approaches to complex management issues.

The *Diffusion of Innovations* theory was developed early in the twentieth Century to explain a process through which social change occurs. As of 1995, over 4000 publications addressed applications of this theory in a variety of disciplines throughout the world. This paper serves as a reminder that the theory also provides insight into how wildland managers begin using scientific innovations. While the theory is mature and robust, it must be viewed within the context of other social science theories that describe how people learn and what motivates them to try new approaches, as well as those that describe the structure and function of management institutions as social systems. Nevertheless, by understanding the adoption and diffusion processes, researchers can strategically prioritize research application and communication efforts. This will ultimately lead to increased use of science and thus improve ecosystem stewardship.

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