Development of Ecologically-Based Invasive Plant Management Curriculum for University Audiences

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DEVELOPMENT OF ECOLOGICALLY-BASED INVASIVE PLANT MANAGEMENT CURRICULUM FOR UNIVERSITY AUDIENCES

by

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A paper submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Human Dimensions of Ecosystem Science and Management

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ABSTRACT

Development of Ecologically-Based Invasive Plant Management Curriculum for University Audiences

by

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The Great Basin is considered one of the most endangered ecoregions in the United States. One threat facing Great Basin rangelands is the invasion of harmful, non-native plants. These invasive weeds outcompete native plants, degrade wildlife habitat, decrease valuable forage for livestock, and cost millions every year in weed control efforts. In order to restore degraded ecosystems of the Great Basin, it is essential that effective weed management programs are integrated in rangeland management strategies. Traditional management approaches have focused on killing invasive weeds with limited regard to the underlying processes that contributed to the invasion.

Ecologically-based invasive plant management, or EBIPM, is an alternative holistic management approach that aims to understand and manipulate the ecological processes influencing weed invasions, and works to prevent further invasions as well as
to treat areas that are already dominated by invasive weeds. EBIPM combines rangeland health assessment, successional theory, ecological principles, tools and strategies, and adaptive management in a 5-step, decision-making framework for a proactive approach to treating and preventing the spread of invasive weeds. The EBIPM method is arranged in a five step framework.

Outreach and education is an important part of a weed management program like EBIPM, as it helps to create awareness and acceptance among managers, policy makers, and the public. EBIPM outreach and education efforts include: a field school that has been held the past 4 years, field tours to demonstrate new techniques and research, manager guidebooks to teach professionals about the EBIPM process, a high school curriculum, and a website.

In order to inform future land managers about EBIPM, a university curriculum has been created to fit into a wide variety of undergraduate courses. This curriculum is compromised of six modules. The first module provides an overview of the EBIPM decision-making framework. The subsequent five modules are aligned with the five steps in the framework. Each module contains a synoptic reading describing the linkages between ecological concepts and management practices, case studies, in-class and field activities, review questions, additional resources, and a Power Point presentation. Each of the modules was reviewed and assessed by a weed ecologist, outreach education specialist, and a media specialist. The curriculum is posted online for access by university students and educators.

(105 pages)
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I also want to thank my family for their support and encouragement throughout this project and my life. They have shown me how important it is to have high goals and to achieve those goals. They have taught me how important education is and how we should always continue to seek out new opportunities to learn and better ourselves.
INTRODUCTION

The Great Basin is considered one of the most endangered ecoregions in the United States (Chambers & Wisdom 2009). One threat facing Great Basin rangelands is the invasion of harmful, non-native plants. There are currently more than 300 rangeland invasive weeds in the United States today (DiTomaso 2000). These invasive weeds outcompete native plants, degrade wildlife habitat, decrease forage for livestock, and cost millions every year in weed control efforts. In order to restore degraded ecosystems of the Great Basin, it is essential that effective weed management programs based on ecological concepts are integrated into rangeland management strategies.

Invasive plant management practices include the use of herbicides, biological control agents, prescribed fire, grazing, mechanical control, and revegetation. These control methods often suppress undesired weed species, but without careful planning and application, they may have minimal influence on ecological processes, fail over the long term, and result in reinvasion. Traditional weed management has focused on killing weeds with these control methods, but with limited regard to the underlying processes that contributed to their invasion (Krueger-Mangold et al. 2006). This shows a lack of ecological understanding on the part of many land managers.

Ecologically-based invasive plant management, or EBIPM, is a holistic management approach that aims to understand and manipulate the ecological processes underlying weed invasions, and works to prevent further invasions as well as to treat areas that are already dominated by invasive weeds. EBIPM combines rangeland health
assessment, successional theory, ecological principles, tools and strategies, and adaptive management into a 5-step, decision making framework for a proactive approach to treating and preventing the spread of invasive weeds.

Outreach and education is an important part of EBIPM (Call et al. 2012). An EBIPM field school has been held 4 consecutive years in different locations at EBIPM research and demonstration sites within the Great Basin. The idea behind the field schools is to take the core ideas behind EBIPM into the field where participants can learn by doing from ecologists, range and weed scientists, and managers. In addition to the annual field school, workshops and field tours were also held. These are essentially mini field schools, packing the information covered in the field school into a 1-day instructional event of classroom style instruction or a day trip to an EBIPM demonstration site. Virtual field tours are also available on the EBIPM website. These feature photographs of field sites accompanied by descriptive text. Eight user guidebooks for resource managers have been produced, describing different components of the EBIPM process. Several technical papers have also been published that describe the results of EBIPM research projects on demonstration sites. EBIPM personnel have also worked in conjunction with educators to develop a modular high school curriculum for use in ecology and agricultural science classes. EBIPM personnel also recognize the importance of exposing future land managers to the EBIPM framework at the university level. Individuals who are exposed to principles that link ecological processes to the relative abundance of desired and undesired species will have a stronger foundation for evaluating the usefulness of tools and strategies when designing a weed management
plan. I developed a modular curriculum for university audiences that can be incorporated into a variety of natural resources, weed science, and rangeland management, and courses. Instructors will be able to use all the modules as a major component of the course or pick and choose which modules are relevant and incorporate them accordingly. Several course design elements were considered during initial curriculum development, including prerequisite knowledge of students, learning outcomes, sequencing and integration of content, materials and activities that would promote student engagement, and an evaluation component (Call et al. 2012).

This university curriculum consists of six modules, (with two more to be added later), which provide an introduction to EBIPM and cover each of the five steps in the decision-making framework. Each module contains a synoptic reading covering the linkages between ecological concepts and management practices, case studies, in-class and field activities, review questions, additional resources, and a Power Point presentation. The modules are available on the EBIPM website at http://www.ebipm.org/ebipm-univeristy-curriculum. Module 2, Assessment of Ecological Conditions and Processes in Need of Repair, has been placed in the Appendix of this report to be referred to as a representative module in the university curriculum.

Goals and Objectives

The overall goal of this project is to increase university students’ knowledge of EBIPM, and to ultimately improve their weed management decisions and plans to treat invasive weeds in the Great Basin and elsewhere.
Objectives:

1. Assess public and private land manager perceptions and knowledge of EBIPM and invasive annual grasses using focus groups and individual phone interviews.

2. Create a modular curriculum based on EBIPM that can be integrated into university weed-related courses.

LITERATURE REVIEW

Invasive Weeds

Executive Order 13112 states that an invasive plant is an alien plant spreading naturally (without the direct assistance of people) in natural or seminatural habitats, which produces a significant change in composition, structure, or ecosystem processes (Executive Order 13112 1999). The changes caused by weed invasion have negative ecological, economic, and social impacts. Ecological impacts include changes in hydrological cycles, fire regimes, erosion and stream sedimentation, energy flow, nutrient cycling, native plant regeneration, and reduction in wildlife habitat quality (DiTomaso 2000, Masters & Sheley 2001). The economic impacts of invasive weeds are more difficult to assess because it is hard to assign an economic value to ecological goods and services. However, several studies have focused on individual plant impacts and one study found that spotted knapweed costs Montana ranchers $11 million annually (Hirsh & Leitch 1996). Invasive weeds can also impact human activities associated with
livestock production, recreation, and aesthetic value of rangelands (DiTomaso 2000). Invasive annual grasses are a difficult problem on western rangelands. Annual grasses, such as cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*) can reduce the production value of grazing land, alter ecosystem processes, and cost producers and resource managers millions of dollars each year (DiTomaso 2000).

**Annual Grasses**

A major invasive weed wreaking havoc in the Great Basin region is cheatgrass (*Bromus tectorum*). Cheatgrass is an annual grass that first appeared in the western United States in 1890 (Mosley et al. 1999). Because of its pre-adaption to the Great Basin environment, early settlers’ abuse of the land through uncontrolled grazing, dryland farming, and recurring drought-like conditions, cheatgrass had reached its current range of distribution by the mid 1930’s (Pellant 1996, Young & Allen 1997). In the 1990’s cheatgrass covered a minimum of 2 million hectares, and it is estimated that over the next 30 years (by 2040) an additional 15 million hectares will be at high risk of invasion (Chambers & Wisdom 2009). Cheatgrass was once considered a valuable forage resource because it grew in early spring, and was deliberately introduced in some areas of the Great Basin (Young & Allen 1997). This was before rangeland managers understood the harm that cheatgrass can do to native rangeland ecosystems.

Cheatgrass dominance has negative ecological, economic, and social impacts. Invasion by *B. tectorum* can alter the natural fire cycle since, because it completes its life cycle and creates a dry, flashy fuel by mid-summer. Historic wildfire return intervals
were 32 to 70 years in sagebrush-steppe ecosystems; in areas heavily infested with cheatgrass the fire interval can be less than 5 years (Pellant 1996). After a disturbance, like wildfire, cheatgrass will become more dominant and expand its range even further. Eventually, many shrub-dominated communities become annual grass-dominated communities. Such a conversion can change biogeochemical cycling, transforming native shrublands from carbon sinks to carbon sources (Bradley et al. 2006). Conversion to an annual grassland can also change an ecosystems’ hydrologic characteristics, i.e., the ability to hold moisture, and can eventually increase the aridity of invaded areas (Chambers & Wisdom 2009). Cheatgrass invasion reduces the quality of wildlife habitat by changing the plants that are available for native animal species to feed on. Herbivores must subsist on cheatgrass in the fall and winter, instead of native species with higher nutrient value (Stewart & Hull 1949). With cheatgrass dominance, the land becomes less productive for livestock forage. The change in forage abundance, quality and availability interferes with traditional grazing practices, increases the cost of managing livestock, and reduces the quality of products from livestock such as, meat, wool, milk, hides. (DiTomaso 2000).

Strategies to control and reduce cheatgrass dominance include: use of chemical control, biological control, targeted grazing, prescribed fire, and revegetation of desired species that can successfully compete with cheatgrass. Careful attention should be paid to the timing and sequence of strategies and tools to coincide with the life cycle of the plant. Successful control of cheatgrass will require resource managers to use multiple tools in conjunction with one another to address the causes of invasion (Masters & Sheley 2001).
Medusahead (*Taeniatherum caput-medusae*) is another aggressive invasive annual grass. Medusahead-dominated rangelands have very low diversity, and low value for wildlife habitat and watershed function (Miller et al. 1999). Medusahead was introduced from Eurasia to southwestern Oregon in the late 19th century. From Oregon, medusahead spread through eastern Oregon, northern California, Idaho and Utah (Young & Evans 1969). Like cheatgrass, medusahead also increases the risk for wildfire by creating a thatch that is very dense and long-lasting, due to its silica content (Miller et al. 1999). Medusahead is almost worthless as forage for livestock. It can only be grazed for a short time in early spring before the seedhead has formed. Current medusahead treatments include: mechanical diskng, prescribed fire, chemical control, biological control, and grazing (Miller et al. 1999).

**Ecologically-Based Invasive Plant Management**

EBIPM is a processed based model for weed managers to implement site specific strategies to address ecological processes (EBIPM website 2010). It combines state and transitional models and successional management models so that the best weed management decisions will be made in areas, whether the areas have been invaded with weeds or are just under the threat of invasion (Figure 1).
Figure 1: The EBIPM decision-making framework.
EBIPM was developed because of the need for ecologically-based land management that addresses the causes of vegetation dynamics. This is due to increasingly severe and frequent disturbance regimes, global climate change, and invasion by non-native plants (Sheley et al. 1996). There is a great need for a unified, mechanistic, ecological framework that improves management’s ability to make decisions, predict changes in vegetation, guide the implementation of restoration, and encourage learning (Sheley et al. 2009a). The theories and models that have been used in the past to predict vegetation dynamics are of three types: 1) based on a general ecological mechanism that does not provide enough detail to guide management, 2) based on a specific process that applies to certain populations but not entire plant communities, or 3) not based on ecological theory, but relies on previous knowledge and observation (Sheley et al. 2009a). In order to effectively combat the invasion of non-indigenous weed species, a weed management program must look at the ecological causes behind the invasion. EBIPM applies ecological theory to develop a framework that managers can use to treat areas infested with invasive weeds and also to prevent the further invasion of invasive weeds.

The first step in the EBIPM model is to conduct a rangeland health assessment (Figure 1). Rangeland health assessment was developed in collaboration by the Bureau of Land Management, U.S. Geological Survey, Natural Resources Conservation Service and Agricultural Research Service. Rangeland health assessment provides a tool for scientists and managers to look at three attributes of rangelands (soil/site stability, hydrological function, and biotic integrity), and assess the ecosystem by examining 17 indicators.
Each indicator of rangeland health is given a rating based on the degree of departure from expected healthy levels, ranging from extreme to none. Examples of indicators include: bare ground, litter amount, the presence of invasive plants, water flow patterns, and observations of erosive forces acting on the soil (Pellant et al. 2005). Rangeland health assessment helps to determine which ecological processes are in need of repair; those processes can be linked to the three causes of succession (site availability, species availability, and species performance) in the second step of the EBIPM model (Figure 1).

The main process related to site availability is disturbance. Disturbance is a discrete event that disrupts ecosystem, community, or population structure and changes the resources, substrate availability, or physical environment (Kruger-Mangold et al. 2006). Traditionally, disturbance has been viewed negatively by land managers because it can contribute to weed invasion. When an area is free from disturbance, those species that tolerate stressful conditions will continue to dominate that community. Therefore, a process called “designed disturbance” can be used to alter successional pathways (Sheley et al. 1996). An area may be disturbed purposely so that there will be a decline in resource use by invasive weeds and, through the process of reseeding, native plants will be able to reestablish in the specified area. Modifying factors of disturbance include size, severity, time, intervals, patchiness, predisturbance history, and treatments such as shallow tillage, and grazing with multiple types of livestock (Kruger-Mangold et al. 2006). These factors can be used to manipulate the type of disturbance and ultimately shift the plant community composition to a more desired state.
Species availability depends on two processes: reproduction and dispersal. Succession greatly relies on a plant’s ability to produce high numbers of seeds and effectively disperse those seeds. Dispersal before and immediately after a disturbance is critical because species that distribute their seeds across the area may remain dominant in that ecosystem. When a site is open for desired species, that site must be occupied with desired species before noxious weeds can establish. Factors that modify dispersal include: landscape features, dispersal vectors, seedbed preparation, and seeding methods (Kruger-Mangold et al. 2006).

A propagule pool is the amount of seeds a species can produce for its seed bank. Invasive species can have very large and long-lived seed banks when compared to native species. Following disturbance, land managers need to assess the composition of the seed bank and determine whether seeding is necessary. If the seed bank is dominated by invasive species, seeding will be necessary. Through the EBIPM program, land managers will manipulate the reproductive capabilities of a plant species with a process called “controlled colonization.” Controlled colonization is the intentional alteration of availability and establishment of various plant species. If native species require more time to establish, less desirable, but not invasive, species can be established to create safe sites for the germination and seedling survival of desired native species (Sheley et al. 1996). These ephemeral species are more like placeholders for the desired species than they are permanent species in the community.

Species performance, the third cause of succession, is influenced by: resource acquisition, response to environment, life history, stress, and interference. In order for
established, desired species to maintain dominance in an ecosystem, they must be supplied with the correct amount of nutrients. Nitrogen is the most important nutrient for plant growth, and taking this away from invasive species by adding carbon to the soil is a potential solution for combating invasive weeds. Land managers also have to be aware of species ecophysiological traits, such as, germination requirements, nutrient uptake rates, growth rates, and even genetic differentiation. In order to control invasive weeds and promote the germination and growth of desired species, land managers must also be knowledgeable about a species’ life history; this includes phenological, physiological, and behavioral traits that a species exhibits as it grows from seed to adulthood. Being familiar with a species’ ecophysiological traits and life history will help land managers to predict which species will dominate the community under different environmental conditions (Kruger-Mangold et al. 2006). Even a factor such as stress can be manipulated to favor desirable species over invasive species. Species rich mixes have a higher chance of surviving stressful environmental conditions, increasing establishment of desirable species. Interference refers to reducing neighboring plants’ fitness through competition, allelopathy, herbivory, resource availability, and predators. Cover crops can be seeded with desired species on weed-infested rangeland to increase competition with invasive weed species. The cover crop is short-lived, but will help the community to retain soil moisture, add organic matter to the soil, and also to prevent soil erosion (Kruger-Mangold et al. 2006). Through “controlled species performance,” land managers can manipulate the growth and reproduction of plant species in an attempt to shift the
community from invasive weed-dominated to indigenous plant-dominated (Sheley et al. 1996).

In the third step of the EBIPM model, principles are linked to ecological processes which affect the causes of succession (Figure 1). Understanding ecological principles when treating invasive weeds allows land managers to choose the best tools and strategies to repair damaged ecological processes. There are different ecological principle that relate back to the processes that influence each cause of succession. For each influential process there are specific principles that will help land managers to understand the underlying causes of weed invasion on rangelands (James et al. 2010).

The tools and strategies section of the EBIPM model, the fourth step, provides rangeland managers with practical methods for treating invasive weeds (Figure 1). In this step, integrated weed management is applied; treatment choices and timing are determined in order to get the best possible response from the treatment for a specific site. Each tool and strategy is linked back to an ecological principle and a process related to a cause of succession. It is assumed that if a land manager understands the ecology of the treatments he or she is applying, they will have more successful outcomes when treating invasive weeds (Sheley et al. 2010).

Adaptive management, the fifth step in the EBIPM model, is a way for managers to operate in the face of uncertainty (Figure 1). Through the use of adaptive management, land managers learn by testing different management alternatives. This expands managers’ and scientists’ knowledge about a system. Adaptive management involves formulating management questions, choosing the best techniques to test these questions,
applying these techniques to the chosen landscape in an experimental context, monitoring the responses to treatments to determine if they work, and making changes based on the findings (Reever Morghan et al. 2006). The process of adaptive management takes time but the end product is a stronger knowledge of the system, and greater confidence in the management strategy. It also provides a management program that is scientifically valid (Sheley et al 2009b). Involving management directly in the scientific process also helps to bring science to the public (Stocker 2004).

Rangeland health assessment, successional theory, ecological principles, tools and strategies, and adaptive management are all important parts that of the EBIPM framework. Understanding each of these components helps those participating in EBIPM to realize the significance of EBIPM as a weed management approach. EBIPM helps rangeland managers understand the underlying causes of weed invasion; understanding the causes can lead to more effective, successful management strategies.

EBIPM has been successfully implemented with perennial invasive forbs, such as spotted knapweed (*Centaurea maculosa*) and sulphur cinquefoil (*Potentilla recta*) in pothole wetlands in Montana. In this study, Sheley and co-workers (2006) demonstrated that using various treatments to modify the factors influencing the causes of succession, in an integrated fashion would favor establishment and abundance of desired species over singularly applied treatments. In essence, various components and processes of the wetland system were repaired and replaced over time. The EBIPM framework has been updated since this and other studies, and is now being applied on rangelands infested with invasive annual grasses.
Curriculum Design

When designing a curriculum, Wiggins and McTighe (2005) recommend using a backward design approach. This is beneficial because it forces designers and educators to think about the specific learnings sought before thinking about what to provide in teaching and learning activities. The objective of backward design is to focus on the output of a curriculum and not just the input. Backward design is accomplished in three stages. In stage one: *identify desired results*, an educator sets goals for students and reviews content standards and curriculum expectations. This is where educators determine what students should know and understand, what content should be presented, and what students need to remember over the long term. It is at this stage where designers prioritize what information should be in a curriculum. In stage two: *determine acceptable evidence*, designers must "think like an assessor" to decide how an educator would determine if students had achieved the desired results. Here educators determine what evidence indicates student understanding and proficiency. In stage three: *plan learning experiences and instruction*, educators must determine what information should be presented to meet the objectives. Designers should decide what enabling knowledge and skills students will need to perform effectively and achieve the desired results set up in stage one. Activities, materials, and resources that will help students learn should be determined at this point (Wiggins & McTighe 2005). Only after desired results and assessments have been identified can educators design an effective curriculum.

There are six entry points and approaches to the design process (Figure 2). The first is to begin with established goals and objectives. When beginning with established
goals/objectives, designers should determine what ideas are embedded in these goals/objectives and what students will learn by accomplishing this. The second entry point is beginning with an important topic or content; here designers must consider why this topic is important and what ideas underlie this topic or emerge from studying it. The third entry point is to start with an important skill or process. When starting here, designers should consider what this skill will enable students to do and what students will need to understand to effectively apply this skill. Entry point number four is to begin with a favorite activity or familiar unit. Starting at this point will bring up questions of what concepts students will understand as a result of this activity or unit and what evidence of understanding is needed. The fifth entry point is to start with a key text or resource. Beginning with a key text or resource asks why students are reading this text or using this specific resources and what they should ultimately understand as a result. The last starting point is a significant test. When beginning the design process here, designers should determine what students will need to understand to perform well on this test and what other evidence of learning is needed. (Wiggins & McTighe 2005) All these points are places to begin the curriculum design process. There is no correct order or beginning point; it is all determined by what resources are available to educators, and what the specific learning outcomes are for the curriculum. The EBIPM university curriculum design process begins at two entry points: the second point, an important topic or content, and the fifth point, a key text or resource, because it is based on the EBIPM decision-making framework and describes each step found in the framework in great detail.
Figure 2: Entry points for the curriculum design process (adapted from Wiggins & McTighe 2005).

According to Erickson (2002) a coherent curriculum is one that holds together, makes sense as a whole, and its parts, whatever they are, are unified and connected by the sense of the whole unity, relevance, and pertinence. A curriculum cannot be coherent if students do not realize the relevance of what they are learning in their everyday lives. In a curriculum based on successional weed management framework, such as EBIPM, it is important to convey to students the importance and practicality of what they are learning.
This is essential because future land managers are the students that will be using this curriculum.

There are many theories about how a person learns. These can be divided into two groups: constructivism and objectivism. Constructivism is founded on the philosophy that we construct our own understanding of the world we live in, based on our experiences. Through our social and physical interactions, we each generate our own framework, which we then use to make sense of our experiences. In objectivism, learning is a biochemical activity in the brain that processes, stores, and recalls information. What we learn is then expressed through critical thinking, remembering, and recalling information (Jonassen 2003).

In developing the EBIPM curriculum, it is important to understand that the curriculum will have to apply to a wide variety of learners. They may have similar backgrounds in ecology, plant science, and land management, and different learning styles. Each learning style is unique and should be accounted for in how the material is presented and what activities will accompany each module.

**PROJECT DESIGN**

The university curriculum is organized in modules that can be easily taught in a wide variety of natural resource, weed science, and range management courses. Although each module can be integrated into individual topic areas, collectively, the modules also provide material for the major portion of a course. There are presently six modules in the
curriculum (Figure 3), with two more to be added in the future. Module 1 provides an introduction to, and overview of, the EBIPM decision-making framework, Module 2 explains how assessment fits into the EBIPM process, Module 3 describes the three causes of succession driving vegetation dynamics, Module 4 describes how ecological principles link the causes of succession with management tools and strategies, Module 5 lists and highlights the various tools and strategies, and Module 6 explains how adaptive can should be used in the context of EBIPM.
<table>
<thead>
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<th>University Curriculum Modules</th>
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| **Module 1: Introduction to Ecologically-Based Invasive Plant Management** | • Traditional vs. ecologically based weed management  
• Overview of EBIPM approach and framework |
| **Module 2: Assessment of Ecological Conditions and Processes in Need of Repair** | • Importance of rangeland health assessment (RHA) in planning process  
• RHA protocol and underlying ecological concepts  
• Integration of RHA and successional weed management |
| **Module 3: Identifying the Underlying Causes of Plant Community Change** | • Overview of causes of succession/ecological processes  
• How causes/processes influence invasion/restoration |
| **Module 4: Ecological Principles for Invasive Plant Management** | • Principles provide a bridge between theory and practice  
• Principles guide selection of tools and strategies |
| **Module 5: Tools and Strategies- Managing Site Availability, Species Availability, and Species Performance** | • Prevention, control, and restoration strategies  
• Biological, chemical, mechanical, and cultural tools  
• Integration of tools and strategies |
| **Module 6: Adaptive Management** | • Managing complex problems in the face of uncertainty  
• Management as an experiment: an eight-step process |

**Figure 3:** Subject matter covered in the 6 modules comprising the EBIPM university curriculum on the decision-making framework.

This modular curriculum was developed in collaboration with scientists who have presented at EBIPM workshops and symposia, and other scientists and managers who are involved with EBIPM. Collaborators include plant ecologists, weed scientists, social scientists, economists, rangeland management specialists, an outreach education...
specialist, and a media development specialist. Each of the modules was developed and then sent to collaborators to review and suggest improvements. Review comments were considered and incorporated into the curriculum. After the revisions were incorporated, a final review process took place, and then the finished product was posted on the EBIPM website.

Sources for developing the curriculum included: EBIPM manager guidebooks, peer-reviewed journal articles, information presented at the EBIPM field schools, technical publications developed by federal land management agencies, proceedings of invasive plant management conferences, and books on invasion ecology, restoration ecology, weed science and rangeland management.

Each module is comprised of a synoptic reading covering the linkages between ecological concepts and management practices, case studies, in-class and field activities, review questions, additional resources, and a Power Point presentation. Each reading begins with a set of learning objectives, followed by an introduction that engages the reader with a question and brief rationales as to why the concepts that will be presented in the module are important to learn. The next section explains where the concepts presented in the reading fit into the EBIPM decision-making framework. The bulk of the reading follows, going into detail and providing examples on ecological concepts that relate to the topic of the module. Each reading includes at least one case study that is based on an actual management scenario or research study, and provides a practical application of the concepts presented in the module. After the case study(ies), the reader is presented with evaluation questions to assess their understanding of what they have
read. These questions strive to reinforce the most important concepts students should learn from each module. If readers wish to read more on their own, additional resources that are hyperlinked to their websites are presented, along with literature citations, at the very of the reading. To ensure uniformity throughout EBIPM outreach and education products, readings were visually designed to resemble the eight manager guidebooks. EBIPM outreach education and media specialists were consulted to determine the visual appeal and ease of readability. The selection of font types and sizes, colors, headings, text boxes, and pictures was carefully determined to ensure the modules would be easy to read and engaging to students. The Power Point summarizes the important points presented in the reading, and provides a tool with which instructors can introduce the modules in the classroom. Activities relevant to the information presented in the module are also included in each module. These are a mix of classroom and field-based activities. Some activities were adapted from activities presented at the EBIPM field school while others were developed for this curriculum.

When completed and assessed by a review team, the modules are posted on the EBIPM website (http://www.ebipm.org/ebipm-univeristy-curriculum) where it can be accessed by university faculty and students. Module 2, Assessment of Ecological Conditions and Processes in Need of Repair, is included in its entirety in the Appendix at the end of this report so the reader can view the components of a module.

Modular Topics and Structure

Module 1: Introduction to Ecologically-Based Invasive Plant Management
This module introduces the EBIPM framework. It explains the origin, basis, and need for EBIPM and outlines each step in the EBIPM framework. The module emphasizes the difference between traditional approaches to weed management and the successional weed management used in EBIPM.

The objectives of this module are:

1) Recognize differences in traditional and ecologically-based approaches to invasive plant management, and why there is a need for an ecologically-based approach.

2) Understand and be able to explain the individual steps in the ecologically-based invasive plant management (EBIPM) framework.

Evaluation questions are presented for students to self-assess or discuss in groups in a classroom setting:

1) What are the three causes of succession and how do they relate to weed invasion?

2) Explain the importance of using a decision-making framework, like EBIPM, to manage invasive weeds.

The activity in this module is to read two articles (provided in the activities folder) and answer questions about each of the articles. One article, Potential for Successional Theory to Guide Restoration of Invasive-Plant-Dominated Rangeland by Sheley et al. (2006), uses an EBIPM approach, while the other article, Long-Term Effects
of Weed Control with Picloram Along a Gradient of Spotted Knapweed Invasion by Ortega and Pearson (2011) does not use EBIPM. The questions students must use to evaluate each article reinforce the difference between traditional weed management and EBIPM. Additional resources provided in this module are all hyperlinked to their websites; these include: the EBIPM website; the management guide Applying Ecologically-Based Invasive Plant Management, and the Implementing EBIPM video.

Module 2: Assessment of Ecological Conditions and Processes in Need of Repair

This module describes how qualitative indicators used to evaluate current rangeland conditions at the ecological site level in the Rangeland Health Assessment protocol (Pellant et al. 2005) are used to help identify ecological processes currently in disrepair at a site. This module is available in its entirety at the end of this report in the Appendix. It covers why assessment is important to have in a weed management plan, how assessment is used in the EBIPM decision-making framework, and rangeland health attributes, and defines terms used when conducting an assessment. This module also describes 17 indicators of rangeland health assessment and provides examples of each indicator. The five steps of rangeland health assessment are also demonstrated with an added sixth step specific to EBIPM.

There are four learning objectives for this module:

1) Understand why assessment is an important part of any weed management plan.
2) Describe the rangeland health assessment protocol and underlying ecological concepts.

3) Explain how the integration of rangeland health assessment and successional weed management creates a more holistic vegetation management framework.

4) Demonstrate how rangeland health assessment can be applied to landscapes of different scale.

The two case studies in this module are both based on research studies that examined the usefulness of rangeland health assessment in real world settings. The study for Grand Staircase-Escalante National Monument by Miller (2008) is an example of a large-scale assessment, while the Duniway et al. (2010) study on road and trail disturbance presents an example of a smaller-scale assessment.

There are four evaluation questions in this module:

1) Why are assessments important for effective weed management plans?

2) Why are the 3 attributes of rangeland health important and how are they related?

3) How does rangeland health assessment relate to the EBIPM framework?

4) How can you apply rangeland health assessment to a site or problem you are familiar with?
In the field-based activity for this module, students will conduct a rangeland health assessment using the instructions and forms in the reading and in the guide Interpreting Indicators of Rangeland Health (Pellant et al. 2005). Detailed descriptions of the activity, a worksheet, and rangeland health worksheets and forms are provided in the activity folder included in this module. Bureau of Land Management rangeland health training videos are hyperlinked throughout this module where a video is relevant to a concept being discussed. Additional resources in this module include: ecological site descriptions, the EBIPM website, the Interpreting Indicators of Rangeland Health technical reference, and three journal articles for further reading.

Module 3: Identifying the Underlying Causes of Plant Community Change

This module examines the three causes of succession (site availability, species availability, and species performance) and the ecological processes associated with these causes. A review of successional management is included and along with how this theory has shaped the development of the EBIPM decision-making framework. Each cause of succession is defined, as are the ecological processes associated with the cause. Examples of each ecological process are presented, along with pictures to visually demonstrate the ecological processes and causes of succession.

There are three learning objectives associated with this module:
1) Understand the causes of succession and how they influence weed invasion and ecosystem restoration.

2) Understand the associated ecological process and explain how they influence the causes of succession.

3) Recognize how assessment procedures in Module 2 help to identify ecological processes that are affecting the causes of succession.

The case study in this module highlights the construction and maintenance of the Ruby Pipeline (a natural gas pipeline from southwestern Wyoming to southwestern Oregon) and how it relates to the process of disturbance. This module also features three species showcases, in-depth examples of an annual grass (*Bromus tectorum*), a perennial forb (*Euphorbia esula*), and a woody species (*Juniper osteosperma*) and how these species are capable of outcompeting most native or desired species on rangelands in the Great Basin.

There are three activities included with this module; all are adapted from activities at the EBIPM field school. The first activity is The Race for a Safe Site. It is a classroom activity in which students drop different ratios of green to white marbles into a board with holes and observe which marbles make it to the "safe sites". This activity demonstrates how the ratio of desired to non-desirable seeds in conjunction with available sites, will determine the composition of the plant community present at a site. The second activity is related to species availability for desired species. In this field-based activity, students create large and small safe sites in the soil surface and broadcast
small and large seeds into that space. This activity helps students recognize the relationship between safe sites and seed density, and safe sites and seed size. The third activity is a seed typing activity in which students broadcast seeds at different depths within a small plot and count how many seeds are recovered at each depth. It is repeated three times, each using a different method of seeding (i.e., broadcast, drill). This activity allows students to observe how a seeding method can deposit seeds at different depths in the seed bank. Directions concerning materials and tools needed for each activity are provided for the instructor.

*Module 4: Ecological Principles for Invasive Plant Management*

Module 4 explains the more abstract concepts of the EBIPM framework: ecological principles and how an understanding of these principles drives land manager decision-making. It introduces the concept that principles provide a bridge between theory and practice, and can guide the selection of tools and strategies.

After completing this module, students will:

1) Understand how conceptual frameworks/models and ecological principles provide a bridge between theory and practice, and facilitate the design and implementation of sustainable invasive plant management programs.

2) Recognize how ecological principles allow managers to identify appropriate tools and strategies to alter ecological
processes and shift plant community dynamics in a desired direction.

3) Demonstrate how ecological principles are linked to other components in the EBIPM framework.

This module defines each ecological process and the principles associated with that process. The case study is based on an article by Sheley et al. (2006), Potential for Successional Theory to Guide Restoration of Invasive-Plant-Dominated Rangeland. The activity is a matrix where students must state the cause of succession, ecological process, and tool or strategy that is related to an ecological principle. This activity reinforces the concept that ecological principles link ecological processes with tools and strategies.

There are three evaluation questions for students to assess their understanding:

1) Why is it important to base a weed management plan on ecological principles?

2) Explain how understanding ecological principles helps managers to better address the underlying causes of invasion.

3) How are ecological processes, ecological principles, and tools and strategies linked within the EBIPM framework?

Additional resources for this module include hyperlinks to the EBIPM website and the Ecological Principles for Invasive Plant Management manager guidebook.
Module 5: Tools and Strategies- Managing Site Availability, Species Availability, and Species Performance

Using ecological principles to link tools and strategies to ecological processes in the previous module provides a basis for individuals to evaluate and compare various treatment options as an invasive plant management plan is further developed in this module. Topics covered in this module include: prevention, control and restoration strategies, and biological, chemical, mechanical, and cultural tools. Tools to use are determined by management strategies and are categorized in this module as such, i.e., no to light infestation, moderate infestation with some desired plants, and monoculture of invasive weeds. Each treatment is presented under the appropriate management strategy. Students also focus on treatment timing and sequencing to get the best possible response, based on the resources available.

There are four learning objectives for this module:

1) Create an awareness of the tools and strategies available to managers.
2) Understand which tools apply to each process and cause of succession.
3) Learn the importance of using integrated weed management strategies.
4) Explain how the selection of tools and strategies fits into the EBIPM framework.
Case studies in this module include: Reducing Cheatgrass Seed Density Through Defoliation (Diamond et al. 2012) and Preventing the Dispersal of Invasive Plants (Davies et al. 2010). Both of these case studies are based on field experiments and demonstrate how researchers addressed the causes of succession to choose an appropriate tool or strategy, based on ecological principles, with the ultimate purpose of developing a weed management plan for an ecological site. Additional resources include hyperlinks to the EBIPM manager guidebooks Establishing a Weed Prevention Area and Revegetation Guidelines for the Great Basin: Considering Invasive Weeds.

Module 6: Adaptive Management

This module describes the process of adaptive management and why it is important for land managers to use adaptive management when developing and implementing an invasive plant program. Emphasis is placed on how to operate in the face of uncertainty and learn by doing.

The learning objectives for this module are:

1) Understand how adaptive management integrates research and management.

2) Recognize how adaptive management provides a feedback mechanism for adjusting management as knowledge is gained.

3) Explain how adaptive management fits within the EBIPM framework.
The module describes the eight steps in the adaptive management process, as outlined by Reever Morghan et al. (2006). It has a case study featuring the Snake River Birds of Prey National Conservation Area and how resource managers have developed an adaptive management plan for an area of critical habitat for raptors which must also meet several other user demands.

There are two evaluation questions for this module:

1) How should adaptive management be used in EBIPM?
Proceed through each step in the framework and identify how it relates to the eight steps of adaptive management.

2) What ways can land managers incorporate adaptive management into their weed management plans?

The activity also relates to the Snake River Birds of Prey National Conservation Area, in which students must develop a management plan for a large area of rangeland and address the concerns of the different stakeholders while following the 8-step adaptive management plan. Additional resources include a hyperlink to the EBIPM guidebook Adaptive Management for Invasive Annual Grasses.

CONCLUSION

Traditional weed management has often been unsuccessful in addressing the causes of succession influencing invasion and restoration. Weed management based on successional theory, such as EBIPM, is an approach that integrates rangeland health assessment, the causes of succession and their associated ecological processes, ecological principle that provide a scientific basis for selecting tools and strategies, and
adaptive management. It is a holistic weed management framework that has shown to be successful when applied to invasive perennial forbs and is now being applied to invasive annual grasses in the Great Basin.

Outreach Education is a major component of a successful EBIPM program. Through the use of the EBIPM website, annual field schools, workshops and field tours, management guidebooks, videos, newsletters, technical journal articles, a high school curriculum, and now a university curriculum- EBIPM is able to reach current and future resource managers, policy makers, and members of the general public across the Great Basin. Making these materials available on the EBIPM website has ensured that they will be available to individuals long after the EBIPM program is completed.

In our globalized society, invasive weeds will always be present. The ability of invasive plants' to transcend geographical borders and establish in new places far from their native habitat ensures that this will remain a major problem into the future. It is hoped that through the use of this curriculum, undergraduate students will gain a greater understanding as to why weeds invade and how as future managers, they can, through the use of Ecologically-Based Invasive Plant Management, more effectively control weed infestations and prevent further spread of harmful invasive plants.
REFERENCES


www.ebpim.org EBIPM website


Module 2

Assessment of Ecological Conditions and Processes in Need of Repair

Learning Objectives

1. Understand why assessment is an important part of any weed management plan.

2. Describe the Rangeland Health Assessment protocol and underlying ecological concepts.

3. Explain how the integration of Rangeland Health Assessment and successional weed management creates a more holistic vegetation management framework.

4. Demonstrate how Rangeland Health Assessment can be applied to landscapes of different scale.
Why are assessments necessary? Qualitative assessments, such as Rangeland Health Assessment (RHA), provide early warnings and help identify areas at risk for natural resource problems (Pellant et al. 2005). Assessments also provide a way for land managers to communicate with each other and with interest groups and the public.

RHA is an assessment of three rangeland ecosystem attributes: soil/site stability, hydrologic function, and biotic integrity. It uses 17 qualitative indicators (plant, soil, and water components) related to these attributes to determine if ecological processes are functioning on a site. To date, RHA has been used for assessing range condition; however, with being integrated into EBIPM, it can now be used to determine what the causes of succession are and if the associated processes are functioning. A brief summary of the RHA protocol and underlying concepts is provided in this document; for a more in-depth description, see Interpreting Indicators of Rangeland Health by Pellant et al. (2005).
How to use Assessment in EBIPM

An understanding of the ecological conditions prior to implementation of invasive plant management programs should help identify the ecological processes in need of repair, the drivers of vegetation change, and the appropriate tools and strategies required to achieve a desired plant community (Sheley et al. 2011). RHA, the first step (Figure 2.1) in the ecologically-based invasive plant management (EBIPM) framework (Figure 2.2), can provide much of this critical information needed for effective successional management.

RHA provides a rapid assessment of rangeland health at the management unit level. However, disturbance regimes, species availability, and factors affecting plant performance can vary considerably within a single management unit. Thus, it is useful to consider RHA, a qualitative assessment, as a relative indication of the drivers of vegetation change. This assessment should be used with other information, such as site history, observations, and land managers’ experience working on the management unit(s). The EBIPM model incorporates this variation and encourages managers to be flexible and adaptive in their decision making.

Although there aren’t any published studies describing the use of RHA in invasive plant management, two case studies provide examples of how RHA has been used in science-based management systems that are similar to EBIPM (see p. 27-30). Before applying RHA in the EBIPM framework, the underlying concepts and instructions for using the protocol are presented on p. 7-24.
Figure 2.1: Rangeland Health Assessment is the initial step in the EBIPM framework.
Figure 2.2: The EBIPM Framework. Rangeland Health Assessment is the first step in the decision-making process.
Module 2

Rangeland Health Assessment: Important Concepts

Attributes
The three rangeland health attributes are soil/site stability, hydrological function, and biotic integrity (Figure 2.3). Collectively, these three attributes define rangeland health, i.e., how ecological processes (water cycling, energy flow, and nutrient cycling) are functioning within a normal range of variation to support specific plant and animal communities. Direct measures of the status of ecological processes are difficult or expensive to measure, so biological and physical components are often used as indicators of their functional status.

To assess the three attributes of rangeland health, an Assessment Sheet is filled out and indicators are ranked according to their degree of departure from expected levels (Table 2.1). Indicators are described later (p. 7-15).

1) soil/site stability
How effectively an area can limit redistribution and loss of soil resources by wind and water erosion.

2) hydrological function
An area’s capacity to capture, store, and safely release water from rainfall, run-on, and snowmelt.

3) biotic integrity
The capacity of a biotic community (plants, animals, and microbes) to support ecological processes within the normal range of variability.

Figure 2.3: Rangeland health assessment determines the quality of three rangeland attributes: soil/site stability, hydrological function, and biotic integrity.

Ecological Sites
RHA classifies landscapes according to the ecological site concept, which describes the potential of the land to produce distinctive kinds, amounts, and proportions of vegetation (Pellant et al. 2005). Ecological sites can be identified in the field using soil, climate, and topographic information.
Spatial variability is present within and among ecological sites. The variability of these microsites is due to slope, aspect, landscape position, and other topographical influences. The relationships between these microsites can influence how the indicators are interpreted.

**Natural Range of Variability**
The biological and physical potential of every rangeland ecosystem is unique in space and time. The sources of spatial variability include soils, climate, natural disturbances, plant communities, and topography. The expected variation of these sources at an ecological site should be documented on the Reference Sheet. Plant communities can also vary naturally through time. For example, drought can increase the amount of bare ground, and litter cover will be lower after a fire. Temporal variation should also be documented in the Reference Sheet.

**Resistance and Resilience**
Resistance is the capacity of an ecosystem to continue to function following a disturbance. Resilience is the ability of an ecosystem to recover after a disturbance has occurred. Both resistance and resilience depend on how the ecological processes of an area are functioning. Communities that are least resistant to disturbances and least resilient after disturbances will most likely transition into an undesirable state.

See the video at the BLM National Training Center website on “Rangeland Health Overview”

<table>
<thead>
<tr>
<th>Soil/Site Stability</th>
<th>Hydrologic Function</th>
<th>Biotic Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme to Total</td>
<td>Moderate to Extreme</td>
<td>Slight to Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td>Slight</td>
<td>None to Slight</td>
</tr>
</tbody>
</table>

Table 2.1: Three attributes of rangeland health and the rating categories for each attribute. From: Interpreting Indicators of Rangeland Health (Pellant et al. 2005).
State and Transition Models

State and transition models are used to evaluate the condition of rangelands, anticipate vegetation change, and plan land management activities (Figure 2.4).

A state is a biological community that occurs on an ecological site. Each site can contain multiple states. States are distinguished by differences between plant functional groups, soil properties, ecosystem processes, vegetation structure, biodiversity, and management requirements. Disturbance can lead to transitions between different states.

Transitions are shifts between states and are caused by mechanisms that alter soil and plant community dynamics. A community’s resilience and resistance to disturbance can determine if that community will transition to an undesired state.

A threshold is a point reached in a particular state when a transition (typically non-reversible) to the different state will occur.

A reference state is a state where soil/site stability, hydrologic function, and biotic integrity perform at a near optimum level. This state includes the historic “climax” plant community.

See the video at the BLM National Training Center website on “State and Transition Models”
**Figure 2.4:** Generic state and transition model for shrub-perennial grass ecological site illustrating vegetation dynamics associated with disturbance and exotic annual grass invasion. Dashed lines between communities within a state are community pathways (relatively reversible), and solid lines between states are transitions (typically non-reversible). State A is the reference state to which other states are compared to. State B is a state in which invasive annual grasses have begun to invade, but native species are still present in reduced numbers. State C is completely dominated by invasive annual grasses; this is the least ideal state for this ecological site.
## Module 2

### Indicators

Indicators are components of an ecosystem whose characteristics are used as an index of an attribute of rangeland health. Different combinations of 17 qualitative indicators are used to assess soil/site stability, hydrologic function, and biotic integrity (Table 2.2). Qualitative indicators are used because it is often too difficult, inconvenient or expensive to directly (quantitatively) measure plant, soil and hydrologic features. When possible, quantitative measurements (Table 2.2) can be used to strengthen the evaluation of qualitative indicators and improve consistency of the assessment process, i.e., when making direct comparisons with other locations or monitoring data are required to determine trend. Pages 7-15 contain images and descriptions of the 17 qualitative indicators.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Qualitative Assessment Indicators</th>
<th>Key Quantitative Assessment Indicators</th>
<th>Selected Measurements and References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil/Site Stability</td>
<td>* Rills</td>
<td>* Bare ground</td>
<td>Line point intercept (2, 3)</td>
</tr>
<tr>
<td></td>
<td>* Water flow patterns</td>
<td>* Proportion of soil surface covered by canopy gaps longer than a defined minimum</td>
<td>Continuous line intercept (2)</td>
</tr>
<tr>
<td></td>
<td>* Pedestals and/or terraces</td>
<td>* Proportion of soil surface covered by basal gaps longer than a defined minimum</td>
<td>Continuous line intercept (3)</td>
</tr>
<tr>
<td></td>
<td>* Bare ground</td>
<td>* Soil macroaggregate stability in water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Gullies</td>
<td>* Soil stability kit (3)</td>
<td></td>
</tr>
<tr>
<td>Hydrologic Function</td>
<td>* Rills</td>
<td>* Bare ground</td>
<td>Line point intercept (2, 3)</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td>* Gullies</td>
<td>* Soil stability kit (3)</td>
<td></td>
</tr>
<tr>
<td>Biotic Integrity</td>
<td>* Soil surface resistance to erosion</td>
<td>* Plant canopy (foliar) cover by functional group</td>
<td>Line point intercept (2, 3)</td>
</tr>
<tr>
<td></td>
<td>* Composition layer</td>
<td>* Plant basal cover by functional group</td>
<td>Line point intercept (7, 9)</td>
</tr>
<tr>
<td></td>
<td>* Functional/structural groups</td>
<td>* Litter cover</td>
<td>Line point intercept (1, 3)</td>
</tr>
<tr>
<td></td>
<td>* Plant mortality/abundance</td>
<td>* Plant production by functional group</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Litter amount</td>
<td>* Harvest</td>
<td>Double sampling (1)</td>
</tr>
<tr>
<td></td>
<td>* Invasion plants</td>
<td>* Invasive plant cover</td>
<td>Line point intercept (1, 3)</td>
</tr>
<tr>
<td></td>
<td>* Reproductive capability of perennial plants</td>
<td>* Invasive plant density</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.2:** Qualitative indicators and associated quantitative indicators used to assess attributes of rangeland health.
**Indicator #1 - Rills**
- Small, erosional, linear channels formed by overland flow.
- Potential for rills increases as the degree of disturbance increases and slope increases.

**Indicator #2 - Water Flow Patterns**
- Paths that accumulated water takes as it moves across the soil surface when infiltration capacity is exceeded.
- Patterns are evidenced by litter, soil redistribution, or pedestalling of vegetation.
- As slope increases and ground cover decreases, flow patterns increase.
Indicator #3 - Pedestals and Terracettes
- Pedestals are rocks or plants that appear elevated because of soil loss by wind or water erosion.
- Terracettes are benches of soil deposited behind obstacles (caused by water movement).

Indicator #4 - Bare Ground
- Exposed mineral or organic soil susceptible to water erosion.
- Its amount and distribution are important contributors to site stability.
- It can vary seasonally and annually, and this must be taken into account when making assessments.
Indicator #5 - Gullies
- Channels cut into the soil by accelerated water flow.
- Can be assessed by observing the numbers of gullies in an area and/or assessing the severity of erosion on individual gullies.

Indicator #6 - Wind-scoured, blowout, and depositional areas
- Accelerated wind erosion increases as surface crust becomes worn by disturbance or abrasion.
- In interspace areas, gravel, rock, or exposed roots are often visible.
- Deposition of soil particles typically associated with vegetation (shrubs, trees).
Module 2

Indicator #7 - Litter movement
- Degree and amount of litter movement is an indicator of the severity of wind or water erosion.
- Site's capacity for litter movement is dependent of its slope and geomorphic stability.
- The greater distance litter is moved and the larger the size or amount of litter moved, the more the site is influenced by erosional processes.

Indicator #8 - Soil surface resistance to erosion
- Soil surfaces may be stabilized by soil organic matter incorporated into aggregates at the soil surface and by biological crusts.
- In areas with low vegetation cover, soil stability is often lower in interspaces, and thus more important than stability under plant canopies.
- Physical crusts, induced by the impact of raindrops on bare soil, can reduce wind erosion but also decrease water infiltration.
- The relative importance of biological crusts (algae, cyanobacteria, mosses, lichens) increases as precipitation and plant cover decreases.
Indicator #9 - Soil surface loss or degradation
- As erosion increases, the potential for loss of soil surface organic matter (and nutrients) increases, resulting in degradation of soil structure.
- Soil organic matter is often reflected in a darker soil color.
- Soil structural degradation is reflected by the loss of clearly defined structural units or aggregates.

Indicator #10 - Plant community composition and distribution relative to infiltration and runoff
- Distribution of amount and type of vegetation is an important factor in controlling variations in infiltration and erosion rates.
- Plant community composition influences the ability of a site to capture and store precipitation.
- Rooting patterns, litter production, decomposition processes, and basal area can all affect infiltration and runoff on a site.
Indicator #11- Compaction layer
- A near surface layer of dense soil caused by repeated impacts or disturbances of the surface soil.
- A structural change usually <6" below the surface soil.
- Physical features indicating a compaction layer include platy or blocky dense soil structure, and horizontal root growth.
- Becomes a problem when it limits plant growth, water infiltration, and/or nutrient cycling.

Indicator #12- Functional/Structural Groups
- Species that are grouped together because of similar shoot or root structure, photosynthetic pathways, nitrogen fixing ability, or life cycle.
- Decrease in number of species in groups may indicate a loss of biotic integrity.
- Presence of groups and number of species in groups have significant effect on ecosystem processes.
Indicator #13 - Plant Mortality/Decadence
- The proportion of dead or dying to young or mature plants in the community is an indicator of the population dynamics of the stand.
- If existing plants are dead/dying and there is no recruitment, invasive plants may increase.
- Only native plants are assessed for mortality, and this may vary depending on natural disturbance events.

Indicator #14 - Litter Amount
- Litter provides a source of soil organic material and nutrients for the site, moderates the soil microclimate, and enhances resistance to erosion.
- Excess litter buildup from exotic annual grasses can increase the fire hazard and decrease the ability of seedlings of desired species to establish.
Module 2

Indicator #15- Annual Production
• Quantity of above ground vascular plant material produced within a year.
• An indicator of the energy captured by plants and its availability to secondary consumers in an ecosystem.
• All plant species (native, seeded, and weeds) are included when evaluating annual production.

Indicator #16- Invasive Plants
• Plants that are not part of (exotic), or are a minor component of (native), the original plant community, and have the potential to dominate if their establishment and growth are not controlled.
• Invasive plants can impact ecosystem structure (type and abundance of species) and function (energy flow and nutrient dynamics).
Indicator #17- Reproductive Capability of Perennial Plants

- For sexually reproducing plants, seed production is assessed by counting the number seedstalks and/or the number of seeds per seedstalk of plants.
- Seed production is related to plant vigor, since healthy plants are better able to produce adequate quantities of seed than are stressed or decadent plants.
- For vegetatively reproducing plants, the number and distribution of tiller or rhizomes is assessed.

Indicator #18- Optional Indicators

- Other indicators and descriptors can be developed to meet local needs.
- The only restriction on developing optional indicators is that the indicators must be ecologically (not management) related, and should significantly increase the quality of the evaluation.
- Examples of optional indicators include biological crusts and vertical vegetation structure.
Instructions for Using Rangeland Health Assessment

Step 1: Determine soil and ecological site at the evaluation area.

Describe evaluation area. The area should be ½ to 1 acre in size. You should become familiar with plant species, soil surface features, and the variability of each ecological site on the evaluation area. Next, describe the topographic position and adjacent features and disturbances (roads, trails, waterpoints, gullies, etc.) that can affect onsite processes. Take photographs of the area and attach them to the evaluation sheet.

Determine the soil and ecological site. Match the evaluation area to the appropriate ecological site description and soils. Dig several shallow soil pits to verify that soil profile characteristics are consistent with those of the soils listed in the ecological site description (ESD). Review the ESD for consistency with the vegetation found on the area.

Actions to take if soil or ecological site information is not available. Use aerial photos, topographic maps, geologic maps, and weather records to decide the most appropriate ESD to use. If an ESD is not available, use other sources for vegetation information, such as habitat-type descriptions, long-term monitoring studies, and other inventory data.

See the video at the BLM National Training Center website on "The Five Step Process"
Step 2: Obtain or develop reference sheet and corresponding evaluation matrix.

Obtain a reference sheet. Reference sheets are being incorporated into ESDs. If an ESD does not exist, additional expertise is required, as it is not possible to properly conduct an evaluation without a reference sheet.

Instructions for reference sheet development. Assemble a diverse group of experts with extensive knowledge of the ecological site. Provide this group with all available sources of information. Define functional/structural groups for the ecological site. Visit one or more ecological reference areas (doesn’t need to be pristine or unused). Describe the status of each indicator in the reference state.

Obtain the evaluation matrix for the ecological site. The evaluation matrix has five descriptors for each indicator that reflect the range of departure from what is expected on site:
- none to slight
- slight to moderate
- moderate
- moderate to extreme
- extreme to total

Add notes to the descriptors to clarify how each descriptor is interpreted for the site.
Step 3: Collect supplementary information.

Spatial and temporal variability. Spatial variability in soils, slope, aspect, and landscape position can greatly affect site potential. Temporal variability can be greater than spatial variability and can include the season, time since the last storm or fire and recent precipitation.

Ecological reference areas. Provide a visual representation of what an expected indicator should look like at the time of evaluation. This should be functioning as well as described in the reference sheet.

Functional/structural groups. The functional/structural groups sheet can be used to compare potential and actual dominance of functional/structural groups; it relies on quantitative data.
Step 4: Rate the 17 indicators on the evaluation sheet.

The rating for each indicator is based on the degree of departure from the reference sheet for the ESD. Rate the degree of departure for each indicator based on the descriptions in the evaluation matrix. The 17 qualitative indicators are listed and described in the previous section.

Step 5: Determine the functional status of the three rangeland health attributes.

The indicator ratings and comments from all of the sheets are summarized into a single degree of departure for each of the three rangeland health attributes (soil/site stability, hydrologic function, and biotic integrity; see Table 2.1). After an evaluation for each attribute is made, managers can decide where more information is required.

Step 6: Use the EBIPM assessment worksheet to determine which of the three causes of succession should be addressed.

The EBIPM assessment worksheet (Table 2.3) allows for land managers to rate the ratings of the indicators with the three causes of succession. The information learned from the assessment should be used to create a holistic management plan using EBIPM.
Table 2.3: The EBPM assessment worksheet categorizes the 17 qualitative indicators within the three causes of succession (site availability, species availability, species performance) and ranks these indicators on a scale from extreme to no (slight) deviation from the standard. The primary causes affecting the indicators are represented by solid boxes and the secondary causes are represented by dashed boxes.
Case Studies

Grand Staircase-Escalante National Monument

In a recent study, Miller (2008) applied the Rangeland Health Assessment (RHA) technique across the entire Grand Staircase-Escalante National Monument in southern Utah, an expansive landscape that is characteristic of public lands in the western United States. RHA provided insight into factors affecting patterns and processes of rangeland degradation, and data to support the development of site-specific management strategies to improve resource conditions.

The Monument covers approximately 760,000 ha. Tremendous geologic and topographic heterogeneity, as well as gradients in elevation (1,164-2,625 m) and precipitation (170-610 mm), were responsible for a diversity of soils (136 distinct soil types) and ecological sites (50 distinct ecological sites) across the Monument. Livestock grazing has been an important land use since the 1870s. Monument lands are divided into 91 grazing allotments. Allotments are divided into two or more fenced pastures (ranging in size from 5,000-54,288 ha) to facilitate livestock management.

Over a 3-year period, assessments were conducted at 507 locations. Specific assessment locations were identified in each pasture by superimposing soil map and ecological site delineations on aerial photos. Field crews used the RHA protocol to evaluate the three ecosystem attributes (soil/site stability, hydrologic function, and biotic integrity) on the basis of 17 qualitative indicators. An 18th indicator, biological soil crust, was added because of its applicability to all three ecosystem attributes. Quantitative data on ground cover, plant community composition, and basal cover by species and plant functional groups were also collected to inform the evaluation of qualitative indicators and improve the consistency of the assessment process.

Because of the large number of assessment locations and ecological sites, data resulting from this effort identified four interacting factors that likely contributed to the patterns in ecosystem condition on the Monument. 1) Production potential and relative use: Upland ecological sites (Upland Loam, Semidesert Loam, and Loamy Bottom) with the greatest production...
potential tended to be the most degraded (greatest departure from reference conditions for all three RHA attributes) due to their disproportionate level of use by livestock, whereas relatively unproductive sites (Semidesert Shallow Loam, Semidesert Sand, and Desert Sandy Loam) receiving low levels of livestock use had higher rangeland health ratings. 2) Plant community composition: On more productive sites containing big sagebrush (*Artemisia tridentata*), selective grazing by livestock increased shrub:grass ratios, reducing biotic integrity, and trampling decreased infiltration, increased erosion, and decreased seedling establishment, affecting all three RHA attributes. 3) Soil texture: big sagebrush sites primarily associated with fine-loamy soils had higher frequencies of assessments with low ratings for all three RHA attributes, whereas sites primarily associated with coarse-loamy or sandy soils had higher ratings. 4) Management: Upland Loam and Semidesert Loam sites, mechanically treated to reduce unpalatable woody vegetation and seeded with non-native forage grasses, had the highest frequencies of low ratings for all three RHA attributes, suggesting that past treatments have not provided long-term ecological benefits compared with untreated areas because allotment management plans typically allowed for higher levels of forage utilization by livestock. These results suggest that ongoing management, restoration treatments, and post-treatment management should be tailored to account for the sensitivity of ecological sites to degradation.

Lessons learned in this study include: 1) Quantitative data exhibited a large degree of variability among assessment locations compared to qualitative ratings, which probably reflects that fact that ratings for the three qualitative attributes were based on suites of multiple indicators. This identifies the need to develop quantitative rating frameworks on an ecological site basis. 2) The RHA technique is effective in broadening many practitioner’s perspectives concerning the number and types of ecological attributes associated with rangeland health, i.e., those who had primarily worked with community composition became attuned to soil and hydrometric processes, and their importance for evaluating the status of rangeland ecosystems. 3) The RHA technique also proved valuable as a tool for facilitating discussions among diverse practitioners and stakeholders about ecological processes influencing rangeland dynamics.

The use of RHA in this study is very similar to the use of RHA in ecologically-based invasive plant management (EBIPM). In both instances, RHA is a key component of an integrated framework designed to support science-based management of rangeland ecosystems. Although exotic plant invasion was not mentioned as a management issue in the Grand Staircase-Escalante National Monument, native unpalatable woody species did increase in dominance because of changes in ecological processes and causes of succession associated with livestock grazing and vegetation treatments.
Module 2
Using Rangeland Health Assessment on Road and Trail Disturbances

Secondary, unsurfaced roads and trails associated with energy development and recreational activities make up the majority of new roads in rural areas of the western United States. Impacts from road and trail development include: soil compaction, loss of soil structure through the degradation of biological crusts and aggregates, increased erosion by wind and water, shifts in plant community composition due to variation in species resilience, and the introduction and increase of exotic species. Duniway et al. (2010) tested the applicability of assessment and monitoring techniques for detecting the impacts of roads, trails, and pipelines in three semiarid regions of the western United States: the Northern High Plains (Wyoming), the Colorado Plateau (Utah), and the Chihuahuan Desert (New Mexico).

Coupled qualitative and quantitative techniques were applied at one ecological site in each region. Interdisciplinary teams tested the sensitivity of the Rangeland Health Assessment (RHA) technique to the impacts of roads, trails, and pipelines on adjacent lands by assessing plots at three distances from these linear disturbances (<5 m away (near), 5-20 m away (far), and >40 m away (control)). The teams evaluated the relative departure of the 17 indicators of rangeland health against a description of the reference range of variation for each indicator, and used this information to determine the status of the three attributes of rangeland health (soil/site stability, hydrologic function, and biotic integrity). Quantitative measures included vegetation cover and composition, basal cover, ground cover, plant height, dead or decadent plants, size of gaps between perennial plants, and depth and width of rill and gully features.

RHA was both sensitive to impacts and correlated to quantitative measures across road-related disturbances in the different ecosystems. In all three study areas, the RHA attribute rating departures were generally greater for soil/site stability and hydrologic function than for biotic integrity. For example, at the Shallow Sandy Loam ecological site in Utah, impacts to biotic integrity were limited to areas immediately adjacent to roads but impacts to soil/site stability and hydrologic function also included areas >5 m from the roads. Analysis of coupled qualitative-quantitative measures indicated that the quantitative techniques captured some of the same information on ecosystem
Assessment

At first glance, it appears that this study has little applicability to ecologically-based invasive plant management (EBIPM). Departures in biotic integrity (i.e. vegetation degradation) were primarily associated with the direct impacts of road construction or vehicle use (i.e. plant damage), and not with invasive weeds. Many of the study sites were in a degraded ecological state due to a variety of factors, including historical grazing, fire suppression, and drought. For example, almost all of the control plots away from roads at the Loamy ecological site in Wyoming were either heavily invaded by cheatgrass (Bromus tectorum), dominated by big sagebrush (Artemisia tridentata) with few perennial grasses, or both. Thus, it was difficult to differentiate the impacts of roads from other stressors. Under other circumstances (i.e. less degradation), exotic weed invasion and expansion along roads, trails, and pipelines may have a greater impact on biotic integrity, as indicated by qualitative and quantitative assessments.

Processes as captured by the RHA technique. For example, the amount of bare ground and the connectivity of bare ground (in gaps > 100 cm) were strongly correlated with both soil/site stability and hydrologic function in all three study areas.

With energy demand and the number of recreationists participating in off-highway vehicle activities increasing, land managers will have to recognize and mitigate the impacts associated with these linear disturbances. Qualitative assessments, such as the RHA technique, are useful because they provide a relatively rapid evaluation of a wide range of ecological processes that are difficult to measure. Line intercept and canopy gap measures can capture information related to six of the 17 qualitative indicators, and should be included if time and resources allow. Using this assessment approach can help land managers develop a comprehensive management plan to address the ecological impacts associated with existing and future roads, trails, and pipelines on rangelands.
What do you think?

1. Why are assessments important for effective weed management plans?

2. Why are the 3 attributes of rangeland health important and how are they related?

3. How does Rangeland Health Assessment relate to the EBIPM framework?

4. How can you apply Rangeland Health Assessment to a site or problem you are familiar with?
Activity: Conducting a Rangeland Health Assessment

In this activity, you will conduct a Rangeland Health Assessment. For detailed help with this assignment, see the “Interpreting Indicators of Rangeland Health” (Pellant et al. 2005) manual and follow the steps 1-5 outlined on pages 21-25 of this module.

1. Select a site nearby that can be easily accessed for an assessment.

2. Find the ecological site description (ESD) for the area. To get an ESD for your area click on the link in the “To Learn More...” section on the following page, select your state, select your major land resource area (MLRA), then click submit. A chart with links to different ESD reference sheets for your MLRA will appear, then you should be able to select the desired ESD.

3. Have students pair up and walk through the site with the reference sheet (from page 72 of “Interpreting Indicators of Rangeland Health”) and evaluate the 17 indicators.

4. Then have students determine which causes of succession need to be addressed (using the causes of succession rangeland health indicators chart in Table 2.3)

5. Lastly, have students think of management goals and treatment options for the site.
To Learn More...

Ecological Site Descriptions

BLM Rangeland Health Training Video

EBIPM website
Literature Cited


For Further Reading...


Written by: Halley Kartchner, Chris Call

The Area-wide project is a USDA-ARS funded program to encourage and support enduring invasive annual grass management throughout the Great Basin.
Assessing Ecological Conditions and Ecological Processes in Need of Repair

Why an Assessment?

• Uses inventory, surveying, and monitoring to identify areas at risk for problems

• Aids in identifying, developing and implementing management strategies, and measuring outcomes

• Provides a path of communication between land managers and the public
Assessment & EBIPM

• Provides necessary information to identify ecological processes in need of repair

• Successional weed management and restoration require initial and periodic assessment

EBIPM decision-making framework
What is Rangeland Health Assessment?

- Assesses three rangeland health attributes: soil/site stability, hydrologic function, and biotic integrity

- Uses 17 qualitative indicators to determine if ecological processes are functioning on a site

Attributes of Rangeland Health

- Soil/Site Stability
- Hydrologic Function
- Biotic Integrity
Soil & Site Stability

The capacity to limit redistribution and loss of soil resources by wind and water.

Hydrologic Function

The capacity of an area to capture, store, and safely release water from rainfall, snowmelt, and run-on.
Biotic Integrity

The capacity of a biotic community (plants, animals, and microbes) to support ecological processes within the normal range of variability for the site.

Concepts

- Ecological Sites
- Range of Variability
- Resistance & Resilience
- State-and-Transition Models
Ecological Sites

- USDA-NRCS developed ecological site descriptions (ESD) to classify landscapes based on potential of the land to produce distinctive kinds, amounts, and proportions of vegetation.

- Site potential is determined by soils, climate, and topography.

Natural Range of Variability

- Biological and physical potential of every site is unique in space and time.

- Sources of spatial variability includes soils, climate, topography, plant communities, and natural disturbances.
State & Transition Models

State:
- one or more biological communities (soil and vegetation) that occur on an ecological site
- distinguished by differences in soil and vegetation properties, ecosystem processes, management requirements, and responses to disturbance
- several communities may be included in a state

Transition:
- trajectory of change from one state to another triggered by natural events and/or management actions
- feedback mechanisms alter soil and plant community dynamics

Threshold:
- Boundary in space and time between states, such that one or more ecological processes has been irreversibly changed

- Active management required before return to previous state is possible

Reference State:
- Soil/site stability, hydrologic function, and biotic integrity perform at a near optimum level under the natural disturbance regime
Resistance: capacity of ecological process to continue to function with minimal change after ecosystem disturbance

Resilience: capacity of ecological processes to recover following ecosystem disturbance

Example of STM

- Dashed lines between communities within a state are community pathways
- Solid lines between states are transitions

- State A is the reference state
- State B is a state in which invasive annual grasses have begun to invade, but native species are still present in reduced numbers
- State C is completely dominated by invasive annual grasses
17 Indicators

Components of a rangeland ecosystem whose characteristics are used as an index of an attribute.

1. Rills

2. Water flow patterns
3. Pedestals and terracettes

4. Bare ground

5. Gullies

6. Wind-scoured, blowout, and depositional areas
7. Litter movement

8. Soil surface resistance to erosion

9. Soil surface loss or degradation

10. Plant community composition and distribution relative to infiltration and runoff
11. Compaction layer

12. Functional/structural groups

13. Plant mortality/decadence

14. Litter amount
15. Annual production

16. Invasive plants

17. Reproductive capability of perennial plants

18. Optional indicators

Other indicators and descriptors can be developed to meet local needs; indicators must be ecologically based.
On the Ground

**Rangeland Health**

- RHA evaluation can be applied to small (pasture) or large (landscape) areas

- Topographic maps, soil surveys, GIS tools, water locations, and local knowledge help managers apply RHA to large areas

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**Instructions for Rangeland Health Assessment**

1. Determine soil and ecological site at the evaluation area
2. Obtain or develop a reference sheet and corresponding evaluation matrix
3. Collect supplementary information
4. Rate the 17 indicators on evaluation sheet
5. Determine the functional status of 3 attributes
6. Use EBIPM assessment worksheet to determine what causes of succession should be addressed
Step 1: Determine soil and ecological site at the evaluation area

• Describe evaluation area

• Determine the soil and ecological site

• If ecological site description (ESD) is not available, use other sources for vegetation information

Step 2: Obtain or develop a reference sheet and corresponding evaluation matrix

• Reference sheet describes status of each indicator in reference state

• Evaluation matrix has five descriptors for each indicator that reflect the range of departure from what is expected on site
Step 3: Collect supplementary information

• Determine spatial (soils, topography) and temporal (season, disturbance timing) variability

• Use ecological reference areas to determine what an expected indicator should look like at the time of evaluation

• Compare potential and actual dominance of functional/structural groups (quantitative data)

Step 4: Rate 17 indicators on evaluation sheet

• The rating for each indicator is based on the degree of departure from the reference sheet for the ESD

<table>
<thead>
<tr>
<th>Soil/Site Stability</th>
<th>Hydrologic Function</th>
<th>Biotic Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme to Total</td>
<td>Moderate to Extreme</td>
<td>Slight to Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td>None to Slight</td>
</tr>
</tbody>
</table>

Attribute ratings reflect the degree of departure from expected levels for each indicator per the Reference Sheet.

• Rate each indicator based on the descriptions in the evaluation matrix
Step 5: Determine the functional status of the three rangeland health attributes.

- Summarize indicator ratings and comments into single degree of departure for each attribute
- After evaluation of each attribute, decide if more information is required

Step 6: Use the EBIPM assessment worksheet to determine which of the three causes of succession should be addressed.

- Assessment worksheet relates ratings of RHA indicators to causes of succession

- Use this information to create a holistic management plan using EBIPM
### EBIPM Evaluation Matrix

<table>
<thead>
<tr>
<th>Rangeland Health Indicators</th>
<th>Causes of Succession</th>
<th>Species Assumptions</th>
<th>Species Performance</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Inte availability</td>
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</tbody>
</table>

- Categorizes 17 indicators within three causes of succession
- Primary causes are solid boxes
- Secondary causes are dashed boxes

### Discussion Questions

1. Why is it important to complete assessments and to reassess?

2. How do the attributes of rangeland health relate to the indicators?

3. What is the role of state-and-transition models in rangeland assessment and management?

4. How can you apply RHA to a site or a problem you are familiar with?
Additional Resources

- Rangeland Health BLM Training Video
- Ecological Site Descriptions

Written by: Halley Kartchner, Chris Call

The Area-wide project is a USDA-ARS funded program to encourage and support enduring invasive annual grass management throughout the Great Basin.
Assessment Activity: Conducting a Rangeland Health Assessment

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4. Then have students determine which causes of succession need to be addressed (using the causes of succession rangeland health indicators chart in Table 2.3)
5. Lastly, have students think of management goals and treatment options for the site.
<table>
<thead>
<tr>
<th>Rangeland Health Indicators</th>
<th>Site Availability</th>
<th>Species Availability</th>
<th>Species Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rills, water flow patterns, pedates, and/or terraces gullies, wind scoured, blowout depositions, litter movement</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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<tr>
<td>Bareground soil surface loss or degradation</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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<tr>
<td>Plant Community Composition</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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<td>Compaction Layer</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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<td>Functional/Structural Groups</td>
<td>Extreme to Moderate</td>
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<td>Sight to Moderate</td>
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<td>Plant mortality/ decadence</td>
<td>Extreme to Moderate</td>
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<td>Sight to Moderate</td>
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<td>Litter Amount</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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<td>Annual production</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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<tr>
<td>Invasive plants</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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<tr>
<td>Reproductive Capacity of Perennial Plants</td>
<td>Extreme to Moderate</td>
<td>Moderate</td>
<td>Sight to Moderate</td>
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</table>
**Evaluation Matrix**

<table>
<thead>
<tr>
<th>Indicator*</th>
<th>Extreme to Total</th>
<th>Moderate to Extreme</th>
<th>Moderate</th>
<th>Slight to Moderate</th>
<th>None to Slight</th>
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<tbody>
<tr>
<td>1. Rills</td>
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<td>2. Water Flow Patterns</td>
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<td>3. Pedestals and/or Terraces</td>
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<td>Reference Sheet:</td>
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</table>

* Descriptions for each indicator should be more specific than those listed in the Generic Descriptors, if possible, and refer to the criteria included in the None to Slight description, which is based on the Reference Sheet (Appendix 1).
<table>
<thead>
<tr>
<th>Indicator*</th>
<th>None to Slight</th>
<th>Slight to Moderate</th>
<th>Moderate</th>
<th>Moderate to Total</th>
<th>Extreme to Total</th>
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<tbody>
<tr>
<td>Bare Ground</td>
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<tr>
<td>Generic Descriptor</td>
<td>Much higher than expected for the site. Bare areas are large and generally connected.</td>
<td>Moderate to much higher than expected for the site. Bare areas are large and occasionally connected.</td>
<td>Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected.</td>
<td>Slightly to moderately higher than expected for the site. Bare areas are small and rarely connected.</td>
<td>Amount and size of bare areas match what is expected for the site.</td>
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<td>Gullies</td>
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<td>Reference Sheet</td>
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**Generic Descriptor**
- Common with indications of active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active.
- Moderate in number to common with indications of active erosion; vegetation is intermittent on slopes and/or bed. Headcuts are active; downcutting is not apparent.
- Moderate in number with indications of active erosion; vegetation is intermittent on slopes and/or bed. Occasional headcuts may be present.
- Uncommon, vegetation is stabilizing the bed and slopes; no signs of active headcuts, nickpoints, or bed erosion.

6. Wind Scoured, Blowout, and/or Depositional Areas

**Generic Descriptor**
- Extensive
- Common
- Occasionally present
- Infrequent and few

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## Departure from Reference Sheet

<table>
<thead>
<tr>
<th>Indicator*</th>
<th>Extreme to Total</th>
<th>Moderate to Extreme</th>
<th>Moderate</th>
<th>Slight to Moderate</th>
<th>None to Slight</th>
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<tr>
<td>7. Litter Movement (wind or water)</td>
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<td>8. Soil Surface Resistance to Erosion</td>
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<td>9. Soil Surface Loss or Degradation</td>
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</tbody>
</table>

### Generic Descriptors

<table>
<thead>
<tr>
<th>Indicator*</th>
<th>Extreme; concentrated around obstructions. Most size classes of litter have been displaced.</th>
<th>Moderate to extreme; loosely concentrated near obstructions. Moderate to small size classes of litter have been displaced.</th>
<th>Moderate movement of smaller size classes in scattered concentrations around obstructions and in depressions.</th>
<th>Slightly to moderately more than expected for the site with only small size classes of litter being displaced.</th>
<th>Matches that expected for the site with a fairly uniform distribution of litter.</th>
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</thead>
<tbody>
<tr>
<td>7. Litter Movement (wind or water)</td>
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<th>Moderate</th>
<th>Slight to Moderate</th>
<th>None to Slight</th>
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</thead>
<tbody>
<tr>
<td>10. Plant Community Composition and Distribution Relative to Infiltration and Runoff</td>
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<tr>
<td>Generic Descriptor</td>
<td>Infiltration is severely decreased due to adverse changes in plant community composition and/or distribution. Adverse plant cover changes have occurred.</td>
<td>Infiltration is greatly decreased due to adverse changes in plant community composition and/or distribution. Deterioral plant cover changes have occurred.</td>
<td>Infiltration is moderately reduced due to adverse changes in plant community composition and/or distribution. Plant cover changes negatively affect infiltration.</td>
<td>Infiltration is slightly to moderately affected by minor changes in plant community composition and/or distribution. Plant cover changes have only a minor effect on infiltration.</td>
<td>Infiltration and runoff are not affected by any changes in plant community composition and distribution. Any changes in infiltration and runoff can be attributed to other factors (e.g., compaction).</td>
</tr>
<tr>
<td>11. Compaction Layer (below soil surface)</td>
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<tr>
<td>Generic Descriptor</td>
<td>Extensive; severely restricts water movement and root penetration.</td>
<td>Widespread; greatly restricts water movement and root penetration.</td>
<td>Moderately widespread, moderately restricts water movement and root penetration.</td>
<td>Rarely present or is thin and weakly restrictive to water movement and root penetration.</td>
<td>Matches that expected for the site; none to minimal, not restrictive to water movement and root penetration.</td>
</tr>
</tbody>
</table>

* Descriptions for each indicator should be more specific than those listed in the Generic Descriptors, if possible, and refer to the criteria included in the None to Slight description, which is based on the Reference Sheet (Appendix 1).
<table>
<thead>
<tr>
<th>Indicator*</th>
<th>Extreme to Total</th>
<th>Moderate to Extreme</th>
<th>Moderate</th>
<th>Slight to Moderate</th>
<th>None to Slight</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Functional/ Structural Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reference Sheet</td>
</tr>
<tr>
<td>[F/S Groups]</td>
<td></td>
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</tr>
<tr>
<td>See Functional/ Structural Groups Worksheet</td>
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</tr>
</tbody>
</table>

**Generic Descriptor**
Number of F/S groups greatly reduced and/or Relative dominance of F/S groups has been dramatically altered and/or Number of species within F/S groups dramatically reduced.

| Number of F/S groups reduced and/or One dominant group and/or one or more subdominate group replaced by F/S groups not expected for the site and/or Number of species within F/S groups significantly reduced. |
| Number of F/S groups moderately reduced and/or One or more subdominate F/S groups replaced by F/S groups not expected for the site and/or Number of species within F/S groups moderately reduced. |
| Number of F/S groups slightly reduced and/or Relative dominance of F/S groups has been modified from that expected for the site and/or Number of species within F/S slightly reduced. |
| F/S groups and number of species in each group closely match that expected for the site. |

<table>
<thead>
<tr>
<th>13. Plant Mortality/ Decadence</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Reference Sheet</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

**Generic Descriptor**
Dead and/or decedent plants are common.

| Dead plants and/or decedent plants are somewhat common. |
| Some dead and/or decedent plants are present. |
| Slight plant mortality and/or decadence. |
| Plant mortality and decadence match that expected for the site. |

<table>
<thead>
<tr>
<th>14. Litter Amount</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Reference Sheet</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>

**Generic Descriptor**
Largely absent or dominant relative to site potential and weather.

| Greatly reduced or increased relative to site potential and weather. |
| Moderately more or less relative to site potential and weather. |
| Slightly more or less relative to site potential and weather. |
| Amount is what is expected for the site |

* Descriptions for each indicator should be more specific than those listed in the Generic Descriptors, if possible, and refer to the criteria included in the None to Slight description, which is based on the Reference Sheet (Appendix 1).
<table>
<thead>
<tr>
<th>Indicator*</th>
<th>Extreme to Total</th>
<th>Moderate to Extreme</th>
<th>Moderate</th>
<th>Slight to Moderate</th>
<th>None to Slight</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Annual Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reference Sheet...</td>
</tr>
<tr>
<td>Generic Descriptor</td>
<td>Less than 20% of potential production for the site based on recent weather.</td>
<td>20-40% of potential production for the site based on recent weather.</td>
<td>40-60% of potential production for the site based on recent weather.</td>
<td>60-80% of potential production for the site based on recent weather.</td>
<td>Exceeds 80% of potential production for the site based on recent weather.</td>
</tr>
<tr>
<td>16. Invasive Plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reference Sheet...</td>
</tr>
<tr>
<td>Generic Descriptor</td>
<td>Dominate the site.</td>
<td>Common throughout the site.</td>
<td>Scattered throughout the site.</td>
<td>Present primarily in disturbed areas within the site.</td>
<td>If present, composition of invasive species, matches that expected for the site.</td>
</tr>
<tr>
<td>17. Reproductive Capability of Perennial Plants (native or seeded)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reference Sheet...</td>
</tr>
<tr>
<td>Generic Descriptor</td>
<td>Capability to produce seed or vegetative tillers is severely reduced relative to recent climatic conditions.</td>
<td>Capability to produce seed or vegetative tillers is greatly reduced relative to recent climatic conditions.</td>
<td>Capability to produce seed or vegetative tillers is moderately reduced relative to recent climatic conditions.</td>
<td>Capability to produce seed or vegetative tillers is slightly reduced relative to recent climatic conditions.</td>
<td>Capability to produce seed or vegetative tillers is not reduced relative to recent climatic conditions.</td>
</tr>
</tbody>
</table>

* Descriptions for each indicator should be more specific than those listed in the Generic Descriptors, if possible, and refer to the criteria included in the None to Slight description, which is based on the Reference Sheet (Appendix I).
Evaluation Sheet (Front)

Aerial Photo: ______________________

Management Unit: ____________________  State: ____________________  Office: ____________________  Range/Ecol. Site Code: ____________________

Ecological Site Name: ____________________  Soil Map Unit/Component Name: ____________________

Observers: ____________________  Date: ____________________

Location [description]: ____________________

T. ___  R. _____  or _____  N. Lat.  Or  UTM E _________ m  Position by GPS Y / N

Sec. _______  T _______  W. Long.  N _______ m  Datum ______

UTM Zone _______  Photos taken? Y / N

Size of evaluation area: ____________________

Composition (Indicators 10 and 12) based on: ___ Annual Production, ___ Cover Produced During Current Year or ___ Biomass

<table>
<thead>
<tr>
<th>Soil/site verification:</th>
<th>Evaluation Area:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range/Ecol. Site Descr., Soil Surv., and/or Ecol. Ref. Area:</td>
<td>Evaluation Area:</td>
</tr>
<tr>
<td>Surface texture:</td>
<td>Surface texture:</td>
</tr>
<tr>
<td>Depth: very shallow, shallow, moderate, deep</td>
<td>Depth: very shallow, shallow, moderate, deep</td>
</tr>
<tr>
<td>Type and depth of diagnostic horizons:</td>
<td>Type and depth of diagnostic horizons:</td>
</tr>
<tr>
<td>1.</td>
<td>1.</td>
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<tr>
<td>2.</td>
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<td>3.</td>
<td>3.</td>
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<td>4.</td>
<td>4.</td>
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<tr>
<td>Parent material</td>
<td>Parent material</td>
</tr>
<tr>
<td>Slope</td>
<td>% Elevation</td>
</tr>
<tr>
<td>Average annual precipitation</td>
<td>inches</td>
</tr>
</tbody>
</table>

Recent weather (last 2 years): (1) drought, (2) normal, or (3) wet

Wildlife use, livestock use (intensity and season of allowed use), and recent disturbances:

_________________________
_________________________
_________________________

Off-site influences on evaluation area:

_________________________
_________________________
_________________________

Criteria used to select this particular evaluation area as REPRESENTATIVE (specific info. and factors considered; degree of "representativeness")

_________________________
_________________________
_________________________

Other remarks (continue on back if necessary)

_________________________
_________________________

Reference: [1] Reference Sheet: ____________________; Author: ____________________; Creation Date: ____________________

or [2] Other [e.g., name and date of ecological site description; locations of ecological reference areas]
## Evaluation Sheet (Back)

<table>
<thead>
<tr>
<th>Departure from Expected</th>
<th>Code</th>
<th>Instructions for Evaluation Sheet, Page 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>None to Slight</td>
<td>N,S</td>
<td>(1) Assign 17 indicator ratings. If indicator not present, rate None to Slight</td>
</tr>
<tr>
<td>Slight to Moderate</td>
<td>S,M</td>
<td>(2) In the three grids below, write the indicator number in the appropriate column for each indicator that is applicable to the attribute.</td>
</tr>
<tr>
<td>Moderate</td>
<td>M,ME</td>
<td>(3) Assign overall rating for each attribute based on preponderance of evidence.</td>
</tr>
<tr>
<td>Moderate to Extreme</td>
<td>M,TE</td>
<td>(4) Justify each attribute rating in writing.</td>
</tr>
<tr>
<td>Extreme to Total</td>
<td>E,T</td>
<td></td>
</tr>
</tbody>
</table>

### Indicator | Rating | Comments
--- | --- | ---
1. RIIs |  |  |
2. Water flow Patterns |  |  |
3. Pedestals and/or terraces |  |  |
4. Bare ground |  |  |
5. Gulches |  |  |
6. Windscoured, blowouts, and/or deposition areas |  |  |
7. Litter movement |  |  |
8. Soil surface resistance to erosion |  |  |
9. Soil surface loss or degradation |  |  |
10. Plant community composition and distribution relative to infiltration |  |  |
11. Conspicuous layer |  |  |
12. Functional/inefficient groups |  |  |
13. Plant mortality/deadence |  |  |
14. Litter amount |  |  |
15. Annual production |  |  |
16. Invasive plants |  |  |
17. Reproductive capability of perennial plants |  |  |

### Attribute Rating

<table>
<thead>
<tr>
<th>Attribute Rating</th>
<th>Justification</th>
<th>Soil &amp; Site Stability</th>
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<table>
<thead>
<tr>
<th>Attribute Rating</th>
<th>Hydrologic Function</th>
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</table>

<table>
<thead>
<tr>
<th>Attribute Rating</th>
<th>Biotic Integrity</th>
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<tbody>
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</tbody>
</table>

### E-T/M-E M S-M N-S

S (10 indicators): Soil & Site Stability Rating:

H (10 indicators): Hydrologic Function Rating:

B (9 indicators): Biotic Integrity Rating: