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The Integrated Restoration and Protection Strategy of USDA Forest Service Region 1: A Road Map to Improved Planning

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Abstract Core design components of the Ecosystem Management Decision Support system were used to develop and implement the integrated restoration and protection strategy of the Northern Region of the U.S. Department of Agriculture Forest Service. Scenarios that spatially optimized hazardous fuel reduction, protected developed recreation values, and improved watershed conditions are presented to illustrate how the evaluation and decision modeling capabilities of the decision support system can be used sequentially in both strategic and tactical planning.

Keywords Landscape analysis · Restoration planning · Departure analysis · Vegetation pattern · Vegetation structure · Spatial decision support · EMDS

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1 Introduction

The U.S. Department of Agriculture, Forest Service (USFS) embraced the philosophy of "ecosystem management" in its 2008 Planning Rule direction concerning the multiple-use, sustained-yield management of its National Forest System lands (USDA Forest Service 2007). According to Christensen et al. (1996), ecosystem management is "driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function." In this light, a major requirement of the 2008 Planning Rule was that forest plans (the primary land and resource management plans of the USFS) provide a strategic vision for maintaining the sustainability[1] of ecological, economic, and social systems across USFS lands. Sustainability consists of realizing desired social, economic, and ecological conditions and trends that interact at varying spatial and temporal scales, and embody the principles of multiple-use and sustained yield.

There is increasing evidence that ecosystem resilience[2] is needed to reach the goal of sustainable management and sustainable ecosystems (Walker et al. 2002; Brand 2009). Indeed, resilience has been described as one of the core underpinnings of sustainable states.[3] Thus, identifying resilience mechanisms must be a primary objective of integrated ecological assessments (Bourgeron et al. 2009), the results of which can then be used to frame and focus ecosystem management.

In forest planning, the strategic vision for ecosystem management is articulated by identifying desired conditions for key ecosystem components that are to be achieved over a 50- to 100-year planning horizon. For example, maintenance of terrestrial ecosystem sustainability involves two primary components: ecosystem diversity and species diversity—central elements of ecosystem management and stewardship (Chapin et al. 2010). Forest plans also include objectives that provide measurable and time-specific (5- to 10-year reporting cycles) projections of management activities and related product flows needed to achieve desired conditions. In this context, the Integrated Restoration and Protection Strategy (IRPS) of the Northern Region (USDA Forest Service) assists with tactical planning for the implementation of strategic forest plan objectives.

The Northern Region of the USFS (including the States of Montana, North Dakota, northern Idaho, and small portions of South Dakota and Wyoming, Fig. 1) recently updated its IRPS (www.fs.usda.gov/goto/r1/irps) using the framework of

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[1] Sustainability is defined here as meeting the needs of the present generation without compromising the ability of future generations to meet their needs.

[2] The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks; Holling (2001), Walker et al. (2004).

[3] A sustainable state is one which satisfies minimum conditions for ecosystem resilience through time (Perman et al. 2003).

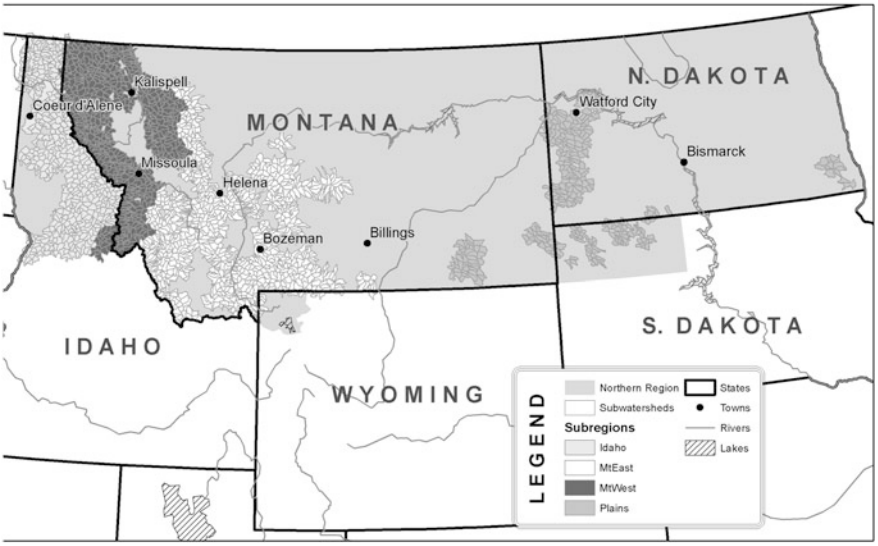

Fig. 1 Location map for the Northern Region of the USDA Forest Service. The figure shows the subwatersheds within the Region that were included in the IRPS assessment (all subwatersheds with at least 1 % USFS ownership) as well as the subregions used for subregional analyses

the Ecosystem Management Decision Support (EMDS) system (Reynolds et al. 2003). Use of the decision support system (DSS) provided a consistent, transparent, and reproducible approach to identifying and prioritizing restoration opportunities, while setting the context for collaboration among all stakeholders in an all-lands approach. The Northern Region IRPS provided information to help local units identify and prioritize potential watersheds for accomplishing forest and grassland plan goals and objectives. It was also intended to assist local units in developing and ranking integrated projects addressing land and water restoration; community wildfire protection plans; and sustainable, resilient, and desired conditions as described in forest and grassland management plans. It provides resource information on values that may be vulnerable or at risk to specific agents of change, including disturbance agents, to help units develop integrated projects. Planning processes such as IRPS are inherently complex. They require the participation of numerous actors, involve decisions within and across spatiotemporal scales and administrative boundaries, and are subject to rapid potential changes in short-term objectives.

The primary goal of this chapter is to provide an example of a regional IRPS implementation that used a flexible yet internally consistent DSS framework. The specific objective is to present its use in the second phase of the IRPS to guide the actual planning process when further plan simplification was required. EMDS was used to develop a prototype knowledge-based system for evaluating ecosystem sustainability (the desired conditions) and decision models to identify priority areas for integrated landscape restoration (the objectives) (Jensen et al. 2009). The result was a prototype DSS that addressed a subset of management issues, and served as a proof of concept for subsequent development. Changes in short term priorities, technological constraints, timelines, and other unforeseen factors resulted in development of a simplified DSS that used the core EMDS components and design principles. In the discussion, we revisit the potential role of EMDS in future applications of the Northern Region IRPS DSS, considering advances in technology since the current project was completed.

2 The Northern Region Integrated Restoration and Protection Strategy

The Northern Region IRPS assessed several key planning questions and identified opportunities and potential priorities for 19 key single resource values that may be at risk to current or projected disturbance and other agents of change, stratified into six individual themes (Table 1). These individual key resource scenarios became the resource objectives for which the DSS helped provide a potential spatial opportunity solution. The individual assessments considered the same three components as the EMDS prototype (Jensen et al. 2009): values, risks, and feasibility. The assessment identified a value (a key resource component), assessed current and projected risks or hazards associated with the value, and then by assigning a weight to these factors, determined the relative opportunity to minimize or reduce the risk factors to restore a more sustainable and resilient condition. In application at the regional scale, feasibility information was not readily available at the broad scale, but rather became a very important factor at finer scales for locating actual project areas. There are many examples of feasibility factors, including but not limited to Forest Plan Standards, Management Area Direction, access, partnership opportunities, and collaborative interest. Greater details of the Northern Region IRPS process, the DSS, and results are discussed in Reynolds et al. (2013).

2.1 Decision Model Design

The overall architecture of the Northern Region IRPS DSS was essentially a three-tiered decision model that retained the core design of the prototype EMDS while simplifying the process in response to technological constraints, changes in short-term priorities, concerns about the complexity of the DSS, and the need for a faster implementation of the strategy update.

At level 1 (the lowest level), the assessment data for each of the 19 scenarios were evaluated by a scenario-specific decision model. An example of this is the

Table 1 Primary resource objectives (scenarios) and associated theme areas in the IRPS

Theme 1: Restoration of forests, grasslands, and human communities to a more resilient condition
Scenario 1A: Community fire resilience
Question: Which human community areas are most critical for improving fire resilience due to burn probability or insect and disease risk?
Scenario 1B: Vegetation resilience and current departure from desired conditions in forested areas
Question: Which forest areas offer the best opportunities to improve vegetation resilience to meet forest plan desired condition due to high departure from historic conditions, crown fire burn probability, or insect and disease risk?
Scenario 1C: Ecosystem resilience and vulnerability in non-forested areas
Question: Which non-forest areas offer the best opportunities to improve non-forest ecosystem resilience due to composition of non-forest types with noxious weed risk and/or departure from historic fire regime (lack of fire) or grazing risk?
Theme 2: Restoration and maintenance of wildlife habitats, including restoration of more resilient vegetation conditions where appropriate, to meet ecological and social goals
Scenario 2A: Whitebark pine ecosystems
Question: Which forest areas offer the best opportunities to restore whitebark pine and associated habitats, considering the high level of mortality from white pine blister rust, mountain pine beetle, and high levels of wildfire burn probability due to succession to spruce-subalpine fir vegetation?
Scenario 2B: Low elevation dry forest communities
Question: Which forest areas offer the best opportunities to restore resiliency of composition and density of dry forest communities and associated habitats, given current and projected insect and disease and high levels of wildfire burn probability due to uncharacteristic high forest density?
Scenario 2C: Dry shrublands (low elevation sagebrush)
Question: Which low-elevation sagebrush areas offer the best opportunities to restore resilience of composition and density and associated habitats, given current levels of conifer encroachment and high levels of wildfire burn probability?
Scenario 2D: Aspen communities
Question: Which aspen habitat areas offer the best opportunities to restore resilience of composition and density and associated habitats, given current levels of conifer encroachment and high levels of wildfire burn probability?
Scenario 2E: Woody draw communities
Question: Which woody draw habitat areas offer the best opportunities to restore resilience of composition and density and associated habitats, given current levels of conifer encroachment, grazing, and high levels of wildfire burn probability?
Scenario 2F: Mixed grass prairie
Question: Which mixed grass prairie habitat areas offer the best opportunities to restore resilience of composition and density and associated habitats, given current levels of conifer encroachment, grazing, and high levels of wildfire burn probability?
Scenario 2G: Riparian areas, wetlands, and seeps
Question: Which riparian and wetland areas offer the best opportunities to restore resilience of composition and density and associated habitats, given current levels of noxious weed hazard, grazing, motorized access, and high levels of wildfire burn probability?
Scenario 2H: Big game winter range
Question: Which big game winter range areas offer the best opportunities to restore resilience of composition and density and associated habitats, given current levels of noxious weed hazard, current vegetation composition and structure vulnerability to disturbance agents, grazing, motorized access, and high levels of wildfire burn probability?

(continued)

Table 1 (continued)

Scenario 2I: Threatened and endangered core grizzly bear habitat
Question: Which core grizzly bear habitat areas offer the best opportunities to provide increased security, considering current open road and motorized trail access and other human disturbance potential?
Theme 3: Restoration and maintenance of resilient, high-value watersheds
Scenario 3: Watershed quality (sediment)
Question: Which subwatersheds are best for restoration due to municipal watershed use, section 303(d) listings, and/or presence of multiple risk factors?
Theme 4: Restoration of high-value fisheries streams—developing more resilient habitat
Scenario 4: Threatened, endangered, and sensitive fish species
Question: Which watersheds are best for restoration due to Forest Plan revision, aquatic species priority, or have multiple risk factors?
Theme 5: Restoration and protection of recreation sites and scenic vistas
Scenario 5A: Safety
Question: Which areas are most important to protect or restore due to high concentrations of use with existing or potential hazard trees due to insects and disease and in areas with high burn probability?
Scenario 5B: Investment protection
Question: Which areas are most important to protect from an investment perspective (e.g., high investment areas that are at risk of damage)?
Scenario 5C: Recreation setting restoration
Question: Which recreation settings are priority areas for restoration (e.g., high-use dispersed recreation areas in vulnerable subwatersheds)?
Scenario 5D: Scenic integrity restoration
Question: Which areas are most important to restore or enhance (e.g., high visibility areas with low or very low scenic integrity)?
Scenario 5E: Scenic integrity protection
Question: Which areas are most important to protect from degradation (e.g., highly visible areas with very high or high existing scenic integrity)?
Theme 6: Protection of people, structures and community infrastructure (roads, trails, bridges, power corridors, recreational developments, etc.) highlighting current and projected mountain pine beetle and wildfire effects
To consider public safety and protection of infrastructure, this theme uses scenarios 1A, 5A, and 5B a second time, based on current regional priorities
Question: Which community areas are best to improve fire resilience due to burn probability or insect and disease risk? (Scenario 1A)
Question: Which areas are most important to protect or restore due to high concentrations of use? (Scenario 5A)
Question: Which areas are most important to protect from an investment perspective? (Scenario 5B)

Within each theme, resource values or scenarios are assessed via a planning question

scenario that addressed resilient forest vegetation condition relative to Desired Condition (DC), S1B (Fig. 2a). It included an assessment of departure of dominance type (similar to forest cover type), contrasting existing condition as a percentage of area versus DC, departure of size class relative to DC, and departure of forest density relative to DC. Examples of risks include loss of western white pine type to root disease and homogenization of forest size classes that leads to susceptibility to disturbance agents such as mountain pine beetle.

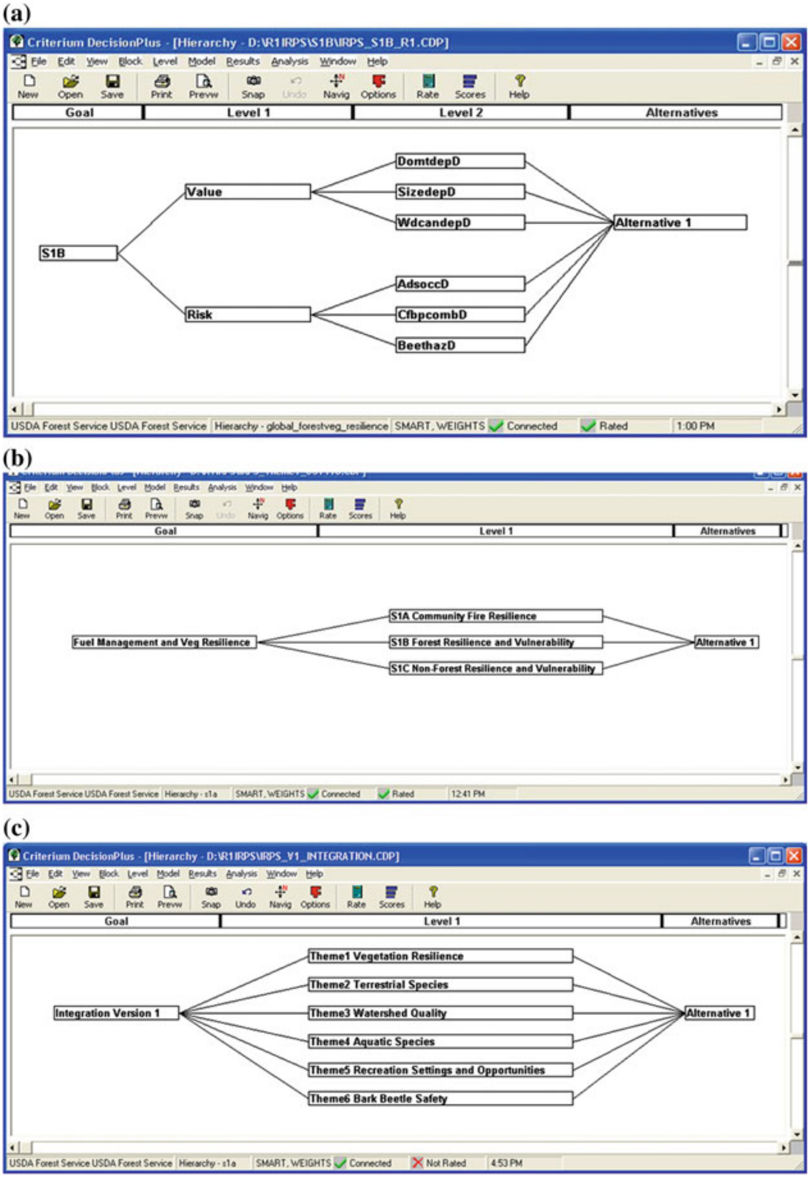

Fig. 2 Decision models used in the IRPS decision support system. **a** An example of the decision model for scenario S1b that addresses resilient forest vegetation condition relative to desired condition. Subcriteria considered under the value criterion include departure of dominance type (similar to forest cover type) relative to desired conditions (DomtdepD), departure of size class relative to desired conditions (SizedepD), and departure of forest density relative to desired condition (WdcandemD). **b** Decision model for priorities under theme 1 (restoration of forests and grasslands, directly adjacent human communities, to a more resilient condition). The goal object refers to the theme itself. Criteria at level 1 of the model, and prefaced by S1A, S1B, and S1C, refer to the three scenarios under the theme. **c** Top-level IRPS decision model, integrating across all themes. See Table 1 for definitions of all scenarios under each theme

At level 2, the 19 scenarios were organized into six broad themes (Table 1). A priority score for each theme was calculated for each theme-specific decision model at level 2. Figure 2b provides an example of three scenarios for vegetation resilience (theme 1). In the current version of the DSS, the priority score for a theme was simply calculated as the average priority score over all scenario components of the theme, meaning that all scenario priorities in a theme were equally weighted, and therefore contributed equally to the priority score for the theme. However, more generic decision models for theme priorities could easily be designed, allowing for differential weights on component scenario priorities, if desired by managers. Finally, at level 3 (Fig. 2c), an overall IRPS priority score was calculated, considering the contributions of the priorities of the six themes.

The overall DSS addressed the same question as the EMDS prototype (Jensen et al. 2009): Where in the Northern Region do all of the identified multiple values at risk show potential priority opportunities for restoration or protection of values to identified risk factors? At level 3, as in level 2, the contribution of each theme priority score to the overall decision score was equally weighted. An alternative approach might have weighted the priorities of contributing themes by the number of scenarios in the theme, a technique known as structural adjustment (Saaty 1992). The effect of structural adjustment is to ensure that all scenarios contribute equally to the final overall priority score. In other words, the contribution of any particular scenario is not diluted by belonging to a theme with a large number of scenarios. The decision to weight themes equally, rather than preserving the equality of scenario contributions, was made by Northern Region leadership, who felt it was preferable to maintain the equality of theme contributions to the overall priority score.

2.2 Implementation

Subwatersheds were used as the unit of analysis. During the implementation phase, restricting the analysis to subwatersheds with 10, 5, and 1 % USFS lands was considered. The Regional leadership team decided to include subwatersheds with at least 1 % USFS lands, because (1) the National Watershed Condition Assessment (Potyondy and Geier 2011) was being performed at that level of National Forest ownership, and (2) the Community Fire Resilience (S1A) and Safety (S5A) scenarios were significantly different with inclusion of these subwatersheds.

Selection of scenario (input) data sources was done with Regional and Forest specialists to identify potential value, risk, and feasibility data sources, and then mapping them to evaluate coverage and consistency issues. Initially, over 120 scenario data sources were identified. During the design phase, several scenario data sources were identified for use in multiple scenarios. For example, a bark beetle risk input was identified for use in six scenarios. In the implementation phase, scenarios with very similar inputs from different data sources were evaluated to simplify them to a single data source when possible. A few scenario inputs had consistency problems across the region because data were compiled from different sources, some regional and others local. An attempt was made to normalize local data sets when they were compiled into regional layers, but there were still noticeable differences when mapped. In this case, local spatial or thematic accuracy was gained at the expense of regional consistency.

A wide range of data types was proposed as inputs to the scenarios, including single feature GIS layers (vector and raster), modeled raster data from multiple sources, modeled vector data from multiple sources, data summaries from the USFS Forest Inventory and Analysis (FIA) program, tabular data summaries, and categorical or binary data. The wide range of data types presented unique challenges for characterizing values of scenario inputs to analysis units. A subwatershed GIS layer with all subwatersheds meeting the 1 % USFS lands requirement was created. A summary table was created from the GIS layer and an attribute was added for every scenario input summary value. As each scenario input summary was calculated, the table was filled in for every subwatershed. This created a simple spreadsheet approach, in which all scenario inputs were located together. Scenario opportunity scores could be calculated from the table, an important consideration for later processing steps.

Several scenario inputs were originally derived from NetWeaver logic models that interpreted and synthesized information from multiple data sources to produce a composite result ("NetWeaver"). However, concerns were raised about the complexity of the logic models and the software. Scenario inputs using NetWeaver logic models were simplified from multi-data-source logic models to single data sources. Scenario inputs that could not be simplified to single data sources were simplified to summaries of multiple data sources. An example is the *road risk* criterion in the Watershed Quality Scenario (S3A) that had three inputs: miles of roads, miles of road within 60 m of streams, and number of stream crossings. To simplify the process, an attribute was added to the value and risk input table for each of the road risk components and then a formula was used to combine the three inputs into a single road risk input:

$$\begin{aligned} \mathit{road\ risk} = {} & (\mathit{road\ density} * 0.2) + (\mathit{riparian\ road\ density} * 0.4) \\ & + (\mathit{stream\ crossings} * 0.4) \end{aligned}$$

in which the three input fields were each first normalized to a standard [0, 1] range (see below). All scenario inputs with multiple components similarly had their attributes added to the value and risk input table so they could be recalculated if necessary.

Many decision models employ a general formula of normalizing inputs, multiplying each input by a weight, and then summing the results to obtain an overall decision score. Because the value and risk inputs had different data types and ranges, they were normalized to a [0, 1] range so they could be summed. A minimum–maximum normalization process was used for all scenario inputs. The minimum and maximum range for each scenario input was based on the range of data values over all subwatersheds in the analysis. To meet time constraints and to simplify the process, the scenario opportunity scores were calculated in ArcMap using the following general formula:

$$\begin{aligned} \mathit{Scenario\ Score} = & ((\mathit{value}1 - \mathit{value}1_{\min})/(\mathit{value}1_{\max} - \mathit{value}1_{\min}) * \mathit{weight}_{\text{value1}}) \\ & + ((\mathit{value}2\ldots) + (\mathit{risk}1\ldots) + \ldots) \end{aligned}$$

Decision-model weights for scenario inputs could be changed, and the results viewed in ArcMap in a manner analogous to EMDS. This allowed Regional and National Forest staff to try several versions of scenario inputs and decision-model weights to test the reasonableness of model outputs.

After the scenarios and themes were finalized, four subregional areas were analyzed separately. It was noted that several scenarios had significant differences across the Northern Region due to ecological or resource factors. The Northern Region was spatially partitioned into the Northern Idaho (Idaho Panhandle, Clearwater, and Nez Perce Forests), Western Montana (Kootenai, Flathead, Lolo, and Bitterroot Forests), Eastern Montana (Beaverhead-Deerlodge, Lewis-Clark, Helena, Gallatin Forests, and Beartooth Ranger District [RD] of the Custer Forest), and Plains (Ashland and Sioux RD of the Custer Forest and the Dakota Prairie Grasslands) subregions (Fig. 1). In this case, only subwatersheds within a subregion were used to generate the minimums and maximums for each value and risk input during normalization. In the wildlife theme, some scenarios were excluded from the theme score if the resource did not occur in the subregion.

2.3 IRPS Products

For each scenario, values, risks, and feasibility were assessed for every subwatershed in the Northern Region analysis area (n = 2132). Formulas (Reynolds et al. 2013) were used to calculate opportunity scores for each subwatershed. Higher opportunity scores indicate greater potential opportunity for restoration or protection of a given resource.

Some key findings from the assessment for restoration and protection are:

1. Significant departure from desired forest conditions has resulted in less than desired resilience of forest vegetation as identified in theme 1, which emphasizes the need to:
   a. prioritize restoration of tree composition of western white pine, whitebark pine, western larch, aspen, and ponderosa pine;
   b. reduce forest density on dry forest types (ponderosa pine and Douglas-fir); and
   c. reduce invasive species affecting native ecosystems.
2. Theme 2 indicates priority restoration of wildlife habitat in short supply.

3. Theme 3 indicates restoration of watershed function, including reduction of sedimentation and chemical contamination, and protection or restoration of municipal and watershed water quality.
4. Theme 4 indicates restoration of key fish species habitat.
5. Theme 5 emphasizes restoration and protection of recreation facilities and scenic landscapes.
6. Theme 6 emphasizes protection of people associated with social infrastructure.

Mapped solutions of each of the 19 management concerns indicated the relative priority of potential opportunities to restore aquatic and terrestrial ecosystems, and to protect or sustain many ecosystem services. When scenario assessments were aggregated into the six themes, and then integrated into a single IRPS model across all themes, potential watersheds with multiple resource priorities in the same areas were identified, suggesting areas where the agency could pursue actions that can meet multiple objectives.

Maps (http://www.fs.usda.gov/goto/r1/irps) and histograms of opportunity scores by subwatershed were produced for each of the IRPS themes and scenarios. These maps provide a spatial representation of the key findings across the Northern Region. Analogous map products for each of the four subregions were also created to show how opportunity scores change when evaluating against only those subwatersheds in a geographic subset of the region; Fig. 3 presents mapped opportunity scores for the six themes in northern Idaho and western Montana.

The map for theme 1 (Fig. 3a) summarizes which vegetation communities are most vulnerable, due to their present condition, to disturbance risk agents such as severe fire and potential and actual bark beetle outbreaks. Included in the map for theme 2 (Fig. 3b) are key wildlife habitats that are most vulnerable to disturbance risk factors such as severe fire, bark beetle potential, noxious weeds, and increased forest density. The map for theme 3 (Fig. 3c) includes watersheds that have relative opportunities to reverse trends from risk factors such as too many stream crossings, abandoned mines leaking toxic chemicals, grazing in riparian areas, and high probabilities of severe insect and fire disturbances in the future. The map for theme 4 (Fig. 3d) shows relative opportunities to address key fish species habitat with risk factors that include fish passage problems, road crossings, grazing in riparian areas, abandoned mine sites near streams, dispersed recreation sites next to streams, and water diversions such as dams. In the map for theme 5 (Fig. 3e), relative opportunities are indicated for improving conditions associated with both developed and dispersed recreation sites, as well as opportunities to improve or protect scenery. The map for theme 6 (Fig. 3f) shows relative opportunities to address public safety issues within social infrastructure developments such as in the "wildland-urban interface", developed recreation sites, roads, and power lines that have risk factors caused by the potential for severe fire or bark beetle outbreaks. A map integrating all of the themes illustrates potential locations for addressing multiple management objectives for restoration or protection in a subregional area (Fig. 4).

The DSS products are currently being used as a starting point, combined with local site-specific information such as input from partnerships and collaborative

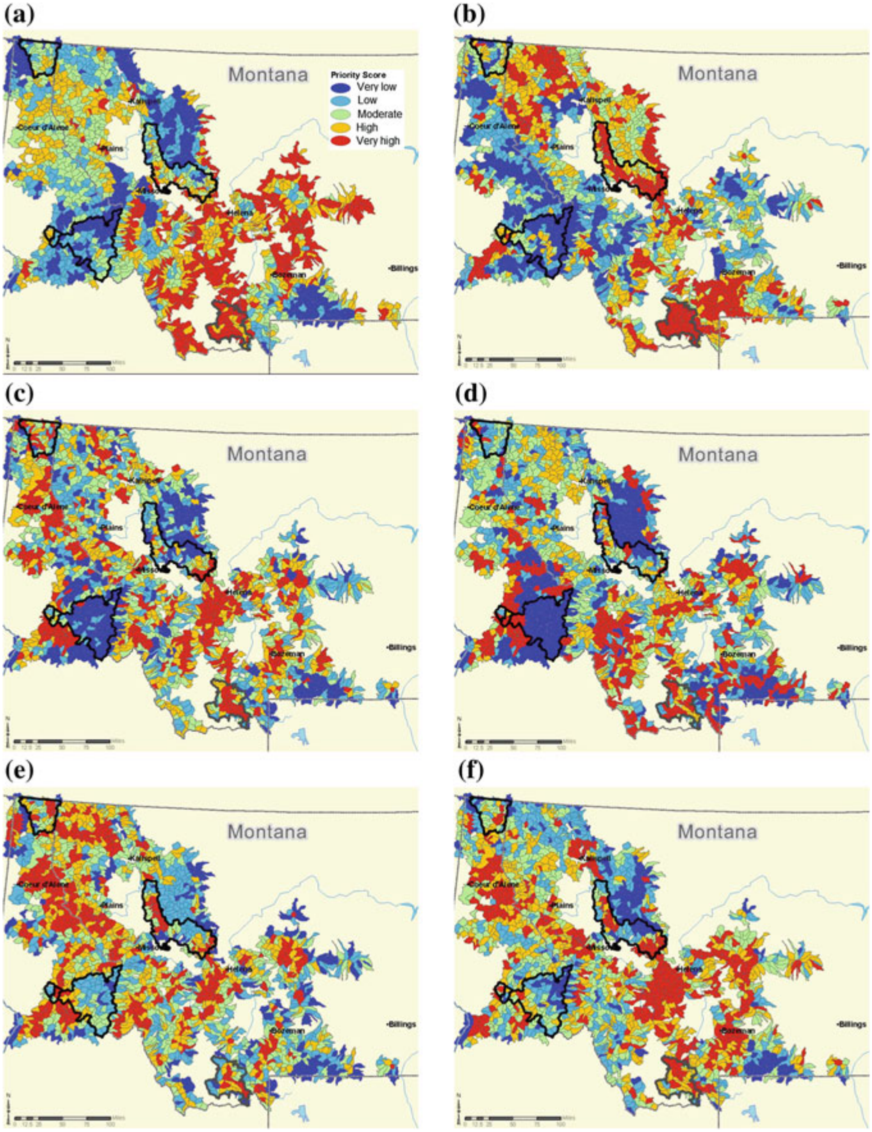

Fig. 3 Northern Idaho and western Montana opportunity scores for **a** restoration of vegetation composition and structure that is vulnerable to uncharacteristic disturbances due to departure from desired conditions; **b** restoration of wildlife habitat vulnerable to multiple risk factors; **c** watershed management and water quality restoration; **d** aquatic species habitat restoration; **e** restoration and protection of recreation facilities; and **f** public safety and infrastructure protection. *Black boundaries* indicate Collaborative Forest Landscape Restoration Act areas

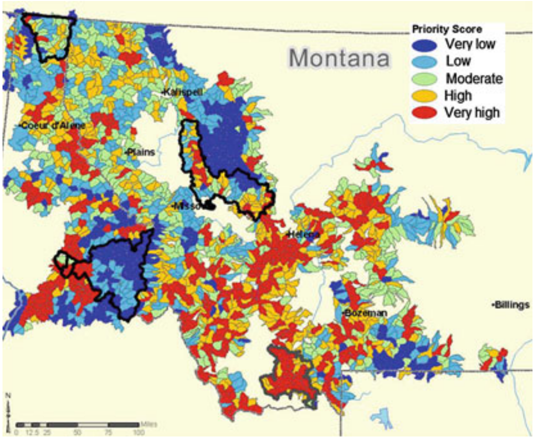

Fig. 4 Theme integration to achieve multiple objectives in the same area at the same time

groups, to identify and sequence priority integrated restoration proposals. This has occurred within Collaborative Forest Landscape Restoration Program (CFLRP) areas on multiple Forests, and has occurred Forest-wide on several Forest Units.

3 Discussion

3.1 What Worked Well

The overall approach in the design of the EMDS prototype and subsequent IRPS application required identification of key resource objectives (as reflected in scenario values) by resource specialists. However, it is important to note that managers (line officers, in the case of the Forest Service) also were critical participants in the process to validate that these were, in fact, the important issues to address in the Northern Region IRPS. The overall assessment of priorities was designed to respond to planning questions related to particular resource values. Identification of the associated objectives gave the strategy team a more integrated perspective of restoration and protection objectives.

Both the EMDS prototype and the subsequent IRPS application required a large volume of data and GIS layers due to the number of planning questions addressed in the assessments. This situation had both positive and negative implications. On the negative side, the data sets were time-consuming and expensive to develop. However, once developed, the data sets in aggregate were seen as a very valuable and powerful asset for the Northern Region, providing context for finer scale evaluations. These default data sets were highly consistent across the entire regional landscape, and can subsequently be enhanced with local data to be much more effective at identifying actual project opportunities in the context of regional landscape conditions.

One of the key findings, after completing the IRPS assessment and evaluation at the regional scale, was that the potential opportunity areas not only provided a useful starting point for discussions, but also afforded a useful context for developing feasible project-opportunity areas. When locally determined feasibility factors are combined with a consistent identification of value and risk factors, local project areas ripe for consideration can be identified. In addition to the 19 regional-scale resource assessments, others may be added at the local level to better address questions such as “why here?” and “why now?”

3.2 How the Intended Audience Received the IRPS DSS

The effectiveness of any assessment depends equally on the scientific methodology and the participation of key actors. At least initially, there has been mixed reaction to the IRPS DSS and subsequent assessment by Forest and Grassland Units. This mixed reaction was based on differences in local interpretation of how the assessment was intended to be used. The USFS units that perceived it as a consistent methodology, to which additional items (such as feasibilities factors) could be added, found it a useful starting point and a consistent framework that can be applied at finer scales. This was indeed a primary purpose of the application. In addition, the overall approach presented here offers the opportunity to integrate other assessments related to major national initiatives at regional and finer scales, for example, by integrating those assessments as new scenarios to be included in an overall opportunity assessment to support forest planning or identification of project-opportunity areas. On the other hand, the USFS units that interpreted the IRPS as a final solution for priority opportunities, or were concerned that this framework had direct and immediate implications for budget allocation to units, were intent on showing why it was not, or should not be, a final solution.

4 Conclusions

Use of EMDS-based analysis methods enabled evaluation of multiple resource values in a transparent manner and produced output maps that displayed high-priority treatment areas. The weighting used for the scenarios can be modified to meet changing needs or modified as information and knowledge increase over time. A by-product of this work was the development of a consistent set of region-wide data themes that have been added to the Northern Region’s spatial data library for subsequent use in planning efforts. The result of this work provides consistent interpretations of ecosystem status for future monitoring of current and desired conditions.

Results from the IRPS process in the Northern Region and its associated EMDS prototype (Jensen et al. 2009) suggest that knowledge-based systems such as EMDS are well suited to both strategic and tactical planning, and the following points merit consideration in future National Forest (and other land management) planning efforts:

- Logic models provide a consistent, transparent, and reproducible method for evaluating broad propositions about ecosystem sustainability and resilience. For example: are watershed integrity, ecosystem and species diversity, social opportunities, and economic integrity in good shape across a planning area? The ability to evaluate such propositions in a formal logic framework also allows users the opportunity to determine statistical changes in outcomes over time, which could be very useful for regional and national reporting purposes and for addressing litigation.
- The use of logic and decision models in strategic and tactical Forest planning provides a repository for expert knowledge (corporate memory) that is critical to evaluation and management of ecosystem sustainability and resilience over time. This is especially true for the USFS and other federal resource agencies, which are likely to experience rapid turnover in resource specialist positions within the next several years due to retirements.
- Use of NetWeaver scores in decision models is an efficient and effective method for synthesizing the typically large amounts of information needed to support integrated landscape restoration (Jensen et al. 2009). Moreover, use of logic and decision models to design customized scenarios for integrated landscape restoration offers substantial improvements to traditional GIS-based procedures such as suitability analysis. In particular, the approach demonstrated by Jensen et al. (2009) is not only much more flexible, but also can more easily accommodate much greater complexity than traditional approaches.

4.1 Opportunities for Improvement

The following recommendations would improve various dimensions of the IRPS DSS and its implementation during the assessment phase:

- *Capturing locally available data.* We anticipate the datasets and model will be improved and modified with locally available data.
- *Sensitivity analysis.* The IRPS can be analyzed to determine the importance of the information datasets included in the analysis as well as model weights. Mathematically, the influence of each resource information dataset included in the analysis can be analyzed to determine how much it contributes to the overall score of the resulting prioritization. The most influential datasets should be reviewed to determine whether they accurately represent the management situation on the ground. Concurrently, the weights of the individual datasets or scenarios can be quickly and easily changed to determine the sensitivity of

weights to the different scenarios. More time and attention should be given to those weights that have the greatest impact on overall scenario scores. Additionally, this type of analysis can be used in a collaborative setting to allow collaborators to explore and understand the implications of the assumptions in the model on the resulting opportunity scores.

- *Continuous feedback*. Most datasets used in the Northern Region IRPS analysis are in a constant state of flux. New information becomes available to bolster the existing data, catastrophic disturbance events occur, roads are built and decommissioned, and watershed restoration work is implemented. These are but a few of the changes that occur and cause the data to become obsolete shortly after they are obtained. Therefore, if one could capture this information in an efficient manner, the datasets and model process could be updated periodically to assist with making current, informed decisions.
- *Future use of EMDS*. The regional IRPS DSS closely replicates data processing methods in EMDS, without using the EMDS software to calculate scenario values, partly in response to real and perceived technological constraints. Future versions of EMDS should be able to provide sufficient technological benefits to warrant full or partial adoption for the IRPS analysis process. For example, the next planned release of EMDS will facilitate development of web-based applications ("EMDS 5.0 and Beyond") that would allow internal users and external partners easy access to the datasets and assumptions of the IRPS product, or allow them the ability to quickly and transparently modify some of the assumptions to assess the implications of alternate management schemes.

4.2 Future Applications

The IRPS datasets are region-wide in spatial extent, and include subwatersheds in which at least 1 % of the land area is managed by the Forest Service. This results in a database that includes a significant portion of the landmass in Montana and northern Idaho. Within these subwatersheds, the condition of the land owned and administered by the USFS is known, and in some cases, the condition of non-USFS land is known as well. Most appropriately, analyses can be conducted at the USFS ownership level and on a scale that covers the entire Northern Region. Issues common to all ownerships across the entire Region, such as water quality, can be assessed to determine the key subwatersheds within the Region that could benefit from concentrated restoration activity.

The IRPS framework creates a platform on which future-year planning can occur. Three additional steps should be taken for this to occur. First, the datasets should be updated to include better locally-maintained data where appropriate. Second, the scenarios may need to be reformulated to better describe the issues of more local planning efforts. For instance, if the primary goal of a local plan is to schedule timber activities from which the revenues will be used to improve deteriorated stream crossings, it may not make sense to include information about oil and gas wells. Third, additional feasibility criteria should be developed by the Forests to describe, for example, where it is possible for activities to occur. Such criteria could include timber management feasibility, or opportunities for prescribed burning, among others. Ultimately they should be aligned with the goals of the planning exercise.

Finally, the IRPS product has significant potential to facilitate interactions among partners and collaborators, especially in working meetings. The product can be rapidly modified for real-time, in-person updates that can be displayed in live meetings. This process facilitates immediate analysis of a number of different ideas, for which the effects of different weighting schemes and scenario compositions, for example, can be interactively displayed and evaluated with groups of collaborators.

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References

Bourgeron PS, Humphries HC, Riboli-Sasco L (2009) Regional analysis of socio-ecological systems. Nat Sci Sociétés 17:185–193

Brand F (2009) Critical natural capital revisited: ecological resilience and sustainable development. Ecol Econ 68(3):605–612

Chapin FS III, Carpenter SR, Kofinas GP, Folke C, Abel N, Clark WC, Olsson P, Stafford Smith DM, Walker B, Young OR, Berkes F, Biggs R, Grove JM, Naylor RL, Pinkerton E, Steffen W, Swanson FJ (2010) Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends Ecol Evol 25:241–249

Christensen NL, Bartuska AM, Brown JH, Carpenter S, D'Antonio C, Francis R, Franklin JF, MacMahon JA, Noss RF, Parsons DJ, Peterson CH, Turner MG, Woodmansee RG (1996) The scientific basis for ecosystem management. Ecol Appl 6(3):665–691

Holling CS (2001) Understanding the complexity of economic, ecological, and social systems. Ecosystems 4:390–405

Jensen M, Reynolds K, Langner U, Hart M (2009) Application of logic and decision models in sustainable ecosystem management, 2009. In: Proceedings of the 42nd Hawaii international conference on systems sciences, Waikoloa, Hawaii, pp 5–8 Jan 2009

Perman R, Ma Y, McGilvray J, Common M (2003) Natural resource and environmental economics. Addison Wesley Longman, USA

Potyondy J, Geier T (2011) Watershed condition classification technical guide U.S. Department of Agriculture Forest Service FS-978. www.fs.fed.us/publications/watershed/watershed_classification_guide.pdf

Reynolds K, Bollenbacher B, Fisher C, Hart M, Manning M, Henderson E, Sims B (2013) Decision support for the integrated restoration and protection strategy for forest service region one, WO FS Series (in preparation)

Reynolds KM, Rodriguez S, Bevans K (2003) User guide for the ecosystem management decision support system, version 3.0. Environmental Systems Research Institute, Redlands, p 82

Saaty TL (1992) Multicriteria decision making: the analytic hierarchy process. RWS Publications, Pittsburgh

USDA Forest Service (2007) Forest service manual 1900 land management planning, Washington DC

USDA Forest Service (2010) LMP monitoring and evaluation: a monitoring framework to support land management planning northern region supplement to Washington office level M&E framework. Northern Regional Office, Missoula, Montana. Unpublished planning M&E framework document

Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability in social-ecological systems. Ecol Soc 9:5. http://www.ecologyandsociety.org/vol9/iss2/art5

Walker B, Carpenter S, Anderies J, Abel N, Cumming GS, Janssen M, Lebel L, Norberg J, Peterson GD, Pritchard R (2002) Resilience management in social-ecological systems: a working hypothesis for a participatory approach. Conserv Ecol 6(1):14. http://www.consecol.org/vol6/iss1/art14/