

Watershed Health in Wilderness, Roadless, and Roaded Areas of the National Forest System

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Photo by John McCarthy

Introduction

This white paper presents the results of a national-scale overlay of watershed condition data on three general types of land management categories in the 193 million-acre National Forest System – designated Wilderness, Inventoried Roadless Areas, and all other lands. The findings presented here are made possible by new information about watershed conditions generated through the U.S. Forest Service’s Watershed Condition Framework (USDA Forest Service 2011a).

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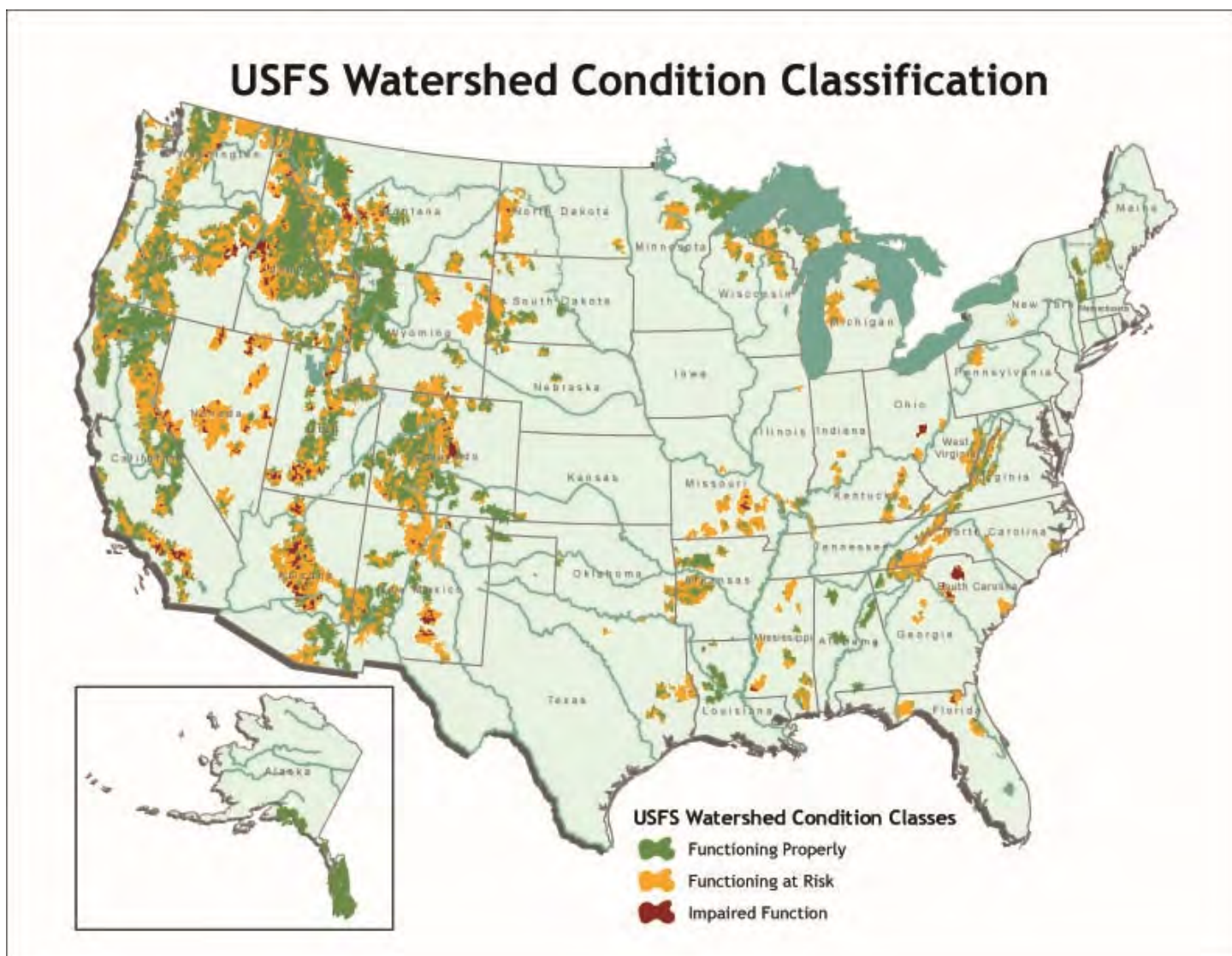
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Watershed Condition Framework

On June 3, 2011, Secretary of Agriculture Tom Vilsack announced the release of a national map that characterizes the health and condition of National Forest System lands in more than 15,000 watersheds across the country (USDA Press Office 2011). The U.S. Forest Service's Watershed Condition Classification Map is the first step in the agency's six-step Watershed Condition Framework process, and is the agency's first national assessment of watershed health across all 193 million acres of National Forest System lands. It is also the first time that the Forest Service has created a process to allow data from local watershed assessments to be collected and evaluated at the national level.

The Forest Service's watershed framework identifies three watershed condition classifications: Class 1 for "properly functioning", Class 2 for "functioning at risk," and Class 3 for "impaired." These represent watersheds that display high, medium, or low "geomorphic, hydrologic, and biotic integrity relative to their natural potential condition" (USDA Forest Service 2011a). The national Watershed Condition Classification Map is displayed in Map 1.



Map 1. This map of the USFS Watershed Condition Framework illustrates a new assessment of watershed health across all lands of the National Forest System.

The condition class mapping was undertaken by local Forest Service interdisciplinary teams using a national set of 12 watershed condition indicators, which are listed in Table 1. Each of the dozen indicators was assessed through a simple score card approach using a defined set of numeric, descriptive, or map-derived attributes. For example, the Aquatic Habitat condition indicator was evaluated using three attributes: habitat fragmentation, large woody debris, and channel slope and function.

WATERSHED CONDITION INDICATORS	
Watershed Quality	Riparian/Wetland Vegetation
Water Quantity	Fire Regime or Wildfire
Aquatic Habitat	Forest Cover
Aquatic Biota	Rangeland Vegetation
Roads and Trails	Terrestrial Invasive Species
Soils	Forest Health

Table 1. A list of the twelve watershed condition indicators that contributed to the USFS Watershed Condition Framework.

Detailed instructions for applying the indicators and associated attributes and for computing the watershed condition scores are contained in a technical guidebook (USDA Forest Service 2011b). Recognizing the wide variety of ecological settings across the National Forest System, the assessment process relied on local professional expertise and judgment to interpret the indicators and assess watershed condition. The Forest Service’s sampling of 15,000 watersheds provides a detailed data source and opportunities for robust national-level analysis.

Land Management Categories

The National Forest System can generally be divided into three broad land management categories: designated Wilderness areas, Inventoried Roadless Areas, and all other lands (commonly referred to as the “managed landscape” or “roaded areas”). The proportion of National Forest System land within each of the three categories is displayed in Figure 1 and the location of these land management areas is shown in Map 2.

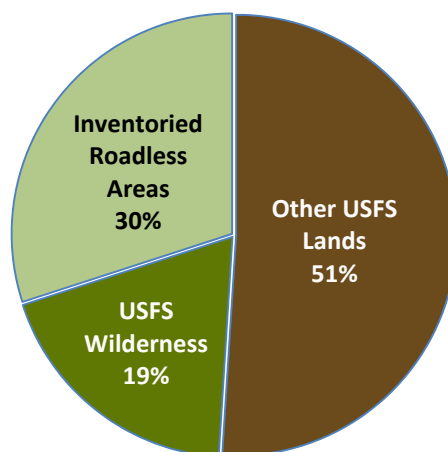
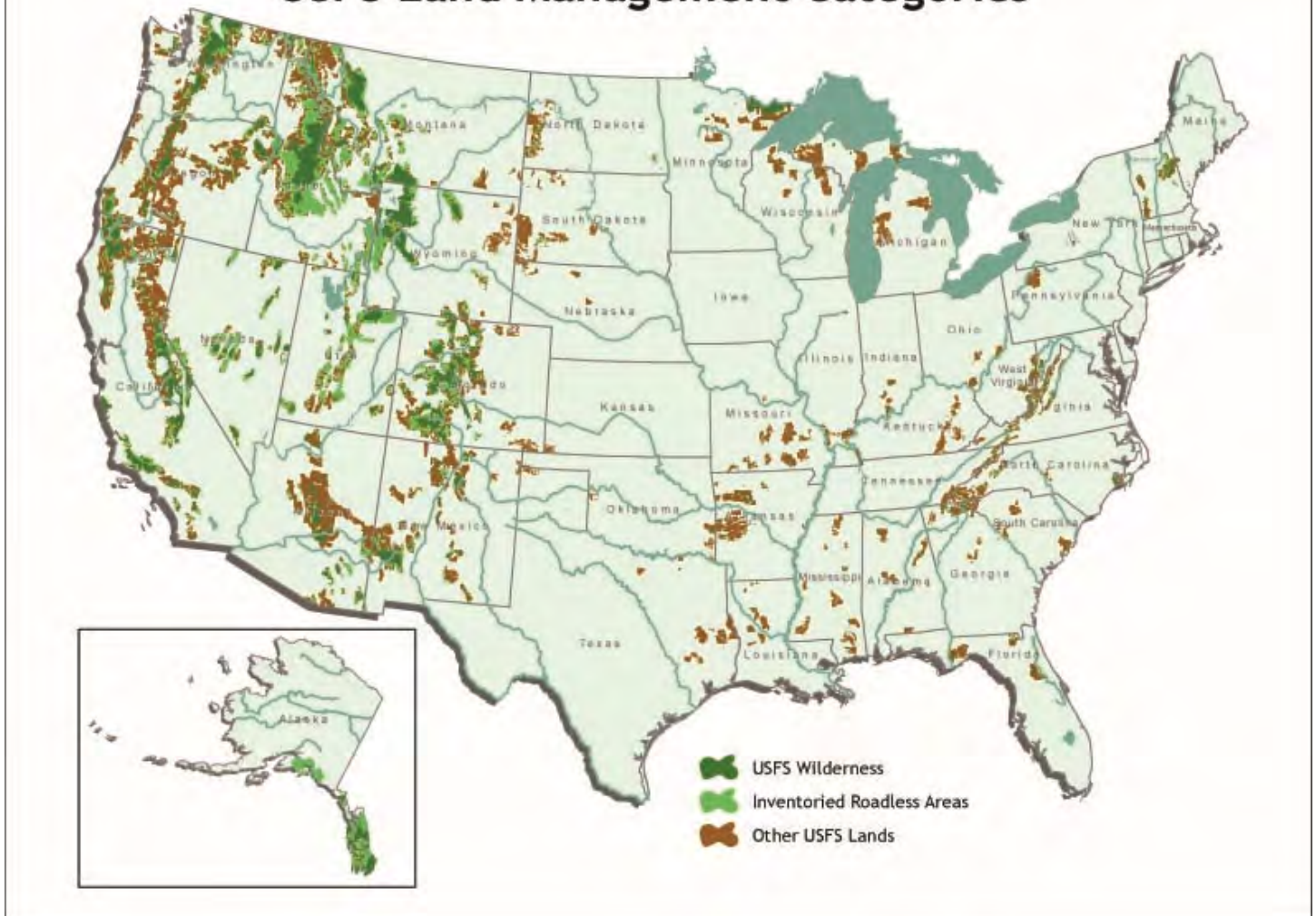


Figure 1. Land management categories as a percentage of the total National Forest System.

USFS Land Management Categories



Map 2. This map illustrates three levels of protection for National Forest System lands: congressionally designated Wilderness, lands identified as roadless under the 2001 Roadless Area Conservation Rule, and all remaining National Forest System lands.

Congress has designated a total of 439 national forest Wilderness areas, covering 36.2 million acres or 19 percent of the entire National Forest System. The Wilderness Act of 1964 does not specifically mention watershed health or water quality as selection criteria or management objectives. Instead, the Act defines Wilderness as “undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions.”⁵ The Act generally prohibits road building, logging, mining, and motor vehicles. Wilderness designation provides the strongest level of legal protection among the three land management categories used in this analysis. However, livestock grazing is generally allowed in all three land categories.

⁵ 16 U.S.C. 1131(c).

Inventoried Roadless Areas include 58.5 million acres that the Forest Service identified as warranting long-term administrative protection under the 2001 Roadless Area Conservation Rule (USDA Forest Service 2000). Representing 30 percent of all National Forest System lands, Inventoried Roadless Areas are unevenly distributed across the country, but are located in most national forests and grasslands. The 2001 Roadless Rule's definition of roadless area characteristics lists high quality or undisturbed soil and water and sources of public drinking water as among the resources that are often present in or characterize Inventoried Roadless Areas.⁶ The Roadless Rule generally prohibits road building and commercial logging, but – unlike the Wilderness Act – does not regulate mining or motorized recreation. Thus, the Inventoried Roadless Areas represent an intermediate level of protection between Wilderness and roaded portions of the National Forest System.

The remaining 99 million acres or 51 percent of the National Forest System encompass a wide variety of lands with different land management histories and objectives. Representing the “managed landscape,” these lands contain the vast majority of the 370,000 miles of roads in the National Forest transportation system. Much of the land has been logged, reforested, mined, and otherwise managed for commodity extraction or other commercial uses, but some areas are lightly roaded and contain relatively intact old-growth forests and riparian vegetation. Management direction and environmental safeguards are primarily contained in the local land and resource management plans developed by the Forest Service pursuant to the National Forest Management Act of 1976 and the Multiple-Use Sustained-Yield Act of 1960. During the past decade, Congressional laws and agency policies have increasingly emphasized restoration of national forest lands and resources.⁷

Purpose and Limitations

The purpose of this analysis is to evaluate, quantify, and display at a national scale the spatial relationships and correlations between the three watershed condition classes and the three land management categories discussed above. It is not intended to identify causal relationships; therefore, we have not attempted to identify and isolate any potentially confounding variables, of which there are undoubtedly many. Nor have we attempted to conduct any geographic analysis smaller than the national scale (such as by Forest Service regions, individual states, or specific national forests). While we recognize that there is potential for significant regional and local variability in these relationships, such smaller-scale evaluation is beyond the scope of this analysis. Suggestions for additional analysis along these lines are presented in the section on Further Research.

Methods

This analysis was completed using Geographic Information Systems (GIS) data from a variety of sources. The U.S. Forest Service (USFS) supplied both the Watershed Condition Framework (WCF) and Inventoried Roadless Areas (IRA) datasets.⁸ The agency did not supply the USFS boundary information, as the detailed data layer used in the WCF analyses was not available for public distribution. Several USFS boundary data layers were considered in its place, and the U.S. Geological

⁶ 36 C.F.R. 294.11.

⁷ Examples include the Healthy Forest Restoration Act of 2003, the Collaborative Forest Landscape Restoration Act of 2009, and congressional appropriations since 2007 for the Legacy Roads and Trails Remediation Program.

⁸ Watershed Condition Framework: <http://www.fs.fed.us/publications/watershed/>. IRA, lower 48 states: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm8_037469.html. IRA, Chugach National Forest: <http://fsgeodata.fs.fed.us/rastergateway/alaska/chugach/roadless.html>. IRA, Tongass National Forest: <http://seakgis.alaska.edu:8080/geoportal/catalog/main/home.page>.

Survey Protected Areas Database had the most detailed boundaries in a national-scale dataset.⁹ Lastly, Wilderness.net, a multiple government agency partnership,¹⁰ supplied the Wilderness dataset.¹¹

Each source dataset was processed initially to a common map projection (Albers Equal Area Conic), as well as error-checked for obvious spatial incongruities, and queried if needed to extract the records needed for overlay analysis.

Additional processing was required to finalize the IRA dataset. When this dataset was overlaid with the Wilderness dataset, there were significant areas of overlap. Since the Wilderness and IRA designations are mutually exclusive, these datasets should not have these overlapping areas. It was assumed that the overlapping areas could be attributed to the greater accuracy and up-to-date status of the Wilderness dataset, and that many of the IRA designations in the IRA dataset had in fact been re-designated as Wilderness. For this reason, all the overlapping areas in the IRA dataset were removed, but retained in the Wilderness dataset. In addition, the polygons in the resulting IRA dataset were analyzed and those losing greater than or equal to 92 percent of their area (representing about 23 polygons and 16,874 acres nationwide) were also removed.

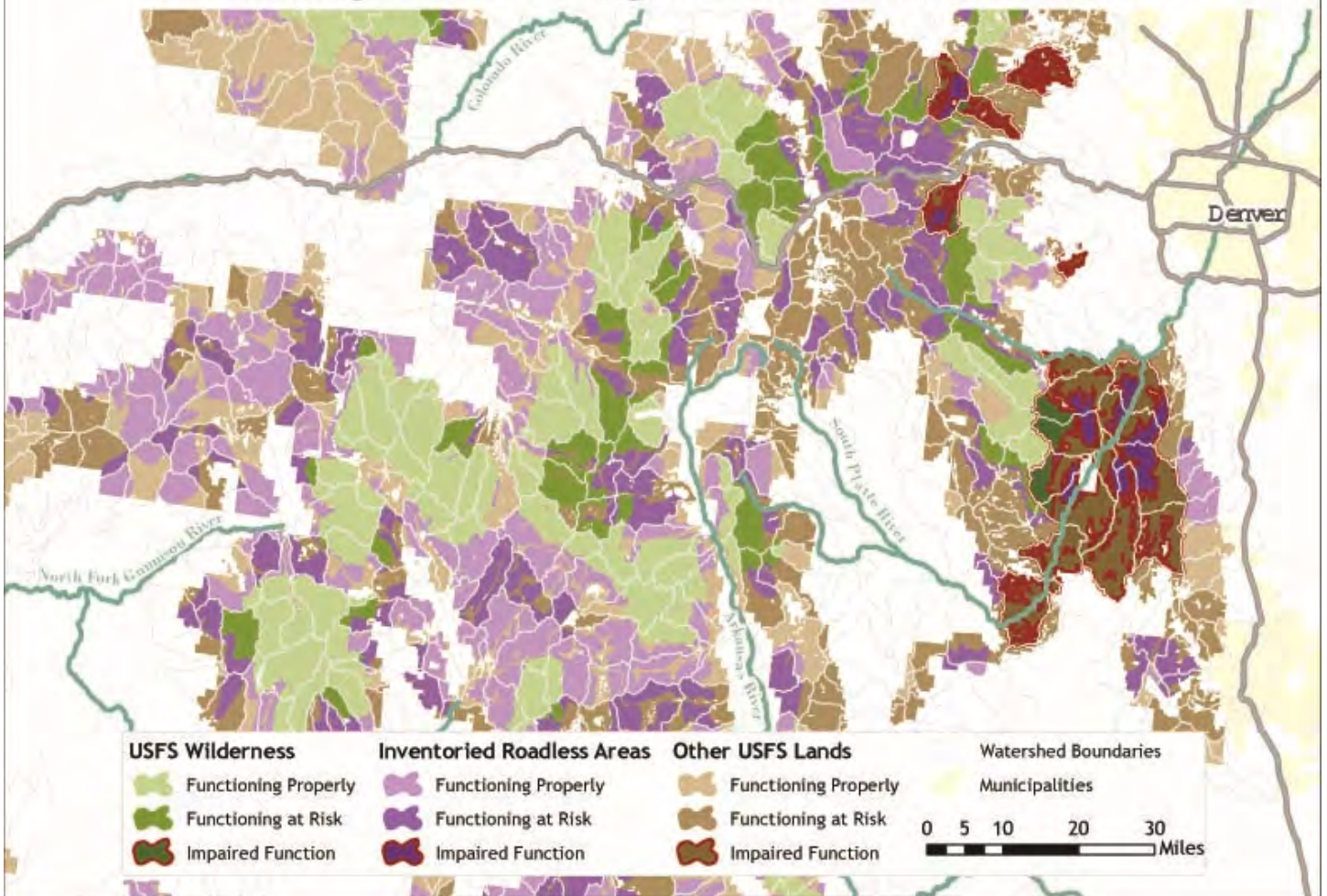
The Wilderness, IRA, and USFS boundary datasets were then merged and further processed to facilitate analysis. The analysis consisted of a spatial overlay between the merged dataset and the WCF dataset, followed by a frequency analysis to determine national acreage totals by land designation classes and WCF condition classes.

⁹ USGS PAD: <http://gapanalysis.usgs.gov/data/padus-data/padus-data-download/>

¹⁰ Wilderness.net is a collaborative partnership between the College of Forestry and Conservation's Wilderness Institute at The University of Montana, the Arthur Carhart National Wilderness Training Center, the Aldo Leopold Wilderness Research Institute, the US Bureau of Land Management, the US Fish & Wildlife Service, the US Forest Service, and the US National Park Service.

¹¹ Wilderness: <http://www.wilderness.net/index.cfm?fuse=NWPS&sec=geography>

Sample Map of Watershed Classes and Management Categories in Central Colorado



Map 3. This map illustrates the nine possible combinations of three watershed condition classes and the three land management categories for a sample of National Forest lands in Colorado.

Map 3 provides an illustrative example from Colorado of the GIS overlay analysis of watershed conditions and land designations. The analysis produced nine combinations of the three different watershed condition classes (Properly Functioning, Functioning At Risk, and Impaired) and the three land designations (Wilderness Areas, Roadless Areas, and Other National Forest Lands). The Colorado example map displays several of the nine combinations of watershed conditions and land designations on national forest lands in the vicinity of Denver.

Results

Our GIS overlay analysis found a strong spatial association at a national scale between watershed health and protective land designations in the National Forest System. The overall results are displayed in Table 2 (by acreage) and Figure 2 (by percentage).

	Properly Functioning	Functioning At Risk	Impaired Function	Total Land in USFS Management Category
USFS Wilderness	29.0	6.7	0.5	36.2
Inventoried Roadless Areas	36.7	19.2	1.2	57.1
Other USFS Lands	37.4	56.9	4.6	98.9
Total USFS Land in Condition Class	103.1 (54%)	82.8 (43%)	6.3 (3%)	192.2 (100%)

Table 2. Acreage of land in the nine possible combinations of watershed condition classes and land management categories in the National Forest System (in millions of acres).¹²

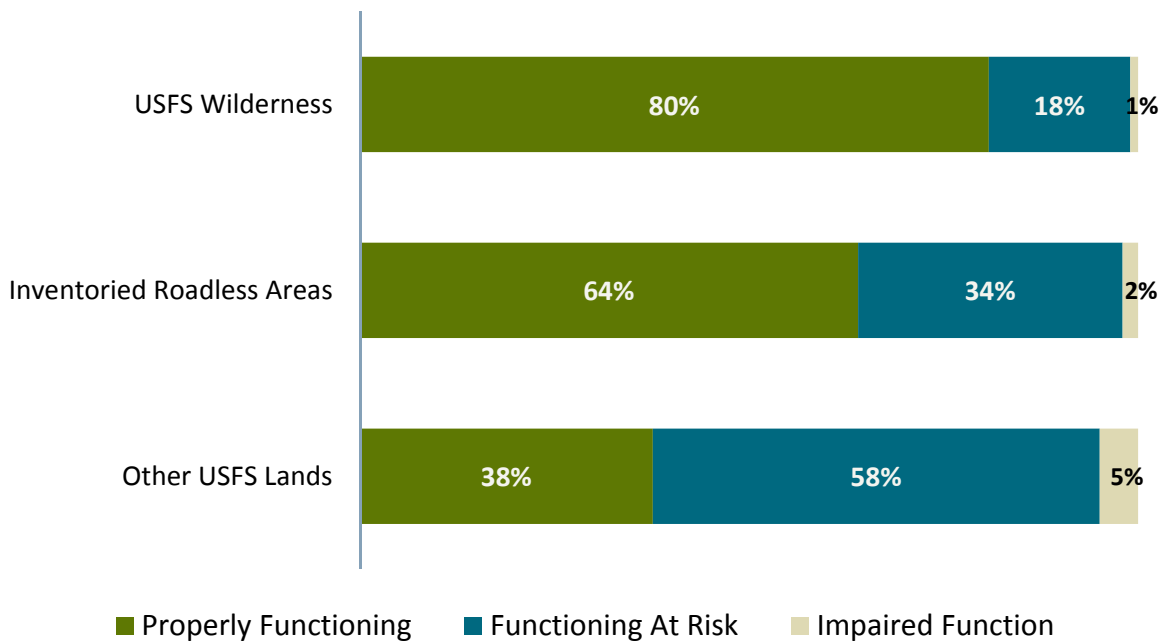


Figure 2. For each land management category, this chart shows the percent of its area in each of the three watershed condition classes.

The Watershed Condition Framework data identifies 54 percent of all NFS land in properly functioning watersheds, 43 percent in watersheds functioning at risk, and just 3 percent in impaired watersheds. However, these proportions are not evenly distributed across the three land designation categories.

¹² Acreage figures are calculated from the best available GIS data at the national scale, but do not always exactly match USFS published acreage figures. However, variances in acreages are small relative to the acreages of overlapping watershed classes and lands protection categories that are the subject of this paper.

Designated Wilderness areas are most frequently spatially coincident with healthy watershed conditions. Eighty percent of the land within designated Wilderness is located in properly functioning watersheds, while 18 percent is in at-risk watersheds and just 1 percent is in impaired watersheds.

Watershed conditions in Inventoried Roadless Areas are not as healthy as in designated Wilderness, but almost two-thirds of their area is still in properly functioning condition. Sixty-four percent of the IRA acreage is in properly functioning watersheds, 34 percent is in at-risk watersheds, and 2 percent is in impaired watersheds.

Finally, other Forest Service lands – which make up slightly more than half of the National Forest System – tend to have the least healthy watershed conditions. While 38 percent of the managed landscape is in properly functioning watersheds, most of the roaded lands are in watersheds that are either functioning-at-risk (58 percent) or impaired (5 percent).

Discussion

The results of this GIS overlay analysis suggest that watershed conditions tend to be best in areas protected from road construction and development. National forest lands that are protected under the Wilderness Act, which provides the strongest safeguards, tend to have the healthiest watersheds. Watersheds in Inventoried Roadless Areas – which are protected from road building and logging by the Roadless Area Conservation Rule – tend to be less healthy than watersheds in designated Wilderness, but they are considerably healthier than watersheds in the managed landscape. Of course, an area's physical characteristics and management history may well have a greater impact on watershed condition than its current legal status. Wilderness areas are typically large tracts of wild land designated by Congress on the basis of their pristine natural features, including the absence of roads and clearcuts. Roadless areas, by definition, contain at least 5,000 acres that are generally free of roads and associated development.

As noted in the Introduction, this analysis does not attempt to identify causal relationships, since there are many other variables besides land designations that could be at play. Factors such as elevation, temperature, and precipitation might explain differences in watershed conditions better than land designations do. Some of the associations may simply be a function of the way in which the Watershed Condition Framework assessment index was constructed. For example, one of the twelve assessment indicators was road and trail condition, which included attributes of road/trail density, maintenance, proximity to water, and risk of mass wasting. Since Wilderness and roadless areas typically have no roads, this part of the assessment process may tend to bias the results toward better condition ratings in those areas.

However, the relationship between forested wild lands and watershed health is well documented in the scientific literature. For example, the Forest Service's Interior Columbia River Basin Ecosystem Assessment (1996) found a positive relationship between unroaded areas and "strongholds" of high-quality habitat for salmon, steelhead, bull trout, and other key salmonid species. An evaluation of the role of Wilderness areas in conserving aquatic biological integrity in western Montana concluded that "the importance of wilderness in aquatic conservation is extraordinary" (Hitt and Frissell 2000). In contrast to Wilderness and roadless areas, "the roaded, intensively managed landscapes of the other national forest lands have been closely correlated with heavily sediment-laden streams and dramatic changes in flow regimes" (DellaSala et al. 2011). The Forest Service's environmental impact statement for the Roadless Rule explains that the presence of roads has a major influence on stream and watershed conditions: "Without the disturbances caused by roads and the activities that they enable, stream channel characteristics are less likely to be adversely altered compared with stream channel conditions in roaded areas" (USDA Forest Service 2000).

Further Research

The Forest Service's Watershed Condition Framework Condition Classification Map opens up new research opportunities to improve our understanding of how to maintain and improve healthy watersheds. Our analysis is an example of how the Watershed Condition Framework data can be applied at a national scale to correlate watershed condition and land management categories. Following are a few examples of further research needs and opportunities:

Similar, finer-scale analyses could be done at a more local level – such as for a single state or national forest – using the same management categories or other map-based categories that are relevant to a local jurisdiction – such as forest plan management areas.

GIS overlay analysis could explore the relationship between watershed health and various physical characteristics such as elevation, precipitation, slope, soils, and fire history.

Statistical multi-variate analysis could help explain differences in watershed condition by isolating certain attributes, such as determining the extent to which road density affects the condition classification of Wilderness and roadless areas.

Further research could examine vulnerability of watershed condition to climate change, species invasion, uncharacteristic fire, and other anticipated changes.

Conclusion

Covering more than 15,000 individual watersheds across the National Forest System, the Forest Service's Watershed Condition Classification Map provides a useful means of comparing watershed conditions with a variety of geophysical features, management histories, and other variables. Our nationwide GIS overlay of the three watershed condition classes with three broad land management designations – Wilderness, Inventoried Roadless Areas, and roaded areas – found a strong spatial association between watershed health and protective designations. This finding is consistent with previous scientific studies of aquatic resources in roaded and unroaded landscapes. Regional and finer-scale analyses of the watershed condition and land designation data would improve our understanding of the factors that determine watershed health.

Acknowledgements

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