Chapter 13: Effects of Climate Change on Ecosystem Services

Travis W. Warziniack, Matthew J. Elmer, Chris J. Miller, S. Karen Dante-Wood, Christopher W. Woodall, Michael C. Nichols, Grant M. Domke, Keith D. Stockmann, John G. Proctor, and Allison M. Borchers

Introduction

Ecosystem services are benefits to humans from the natural environment. These benefits that humans derive from ecosystems are the tangible connection between society and the natural environment. Some of these benefits are timber harvesting, rangeland grazing, municipal water use, carbon sequestration, and pollinators—all discussed in this chapter. The typology developed by the 2005 Millennium Ecosystem Assessment (box 13.1) defines four broad categories of ecosystem services that help to organize our understanding of the relationship between natural resources and human benefits. Although this approach obscures complex relationships between natural and human systems, two important caveats are relevant to discussions of ecosystem services and anticipated climate change effects. First, these categories are not exclusive, and many natural resources fall under multiple categories depending on the context. For example, the consumption of water can be considered a provisioning service, the process of purifying water a regulating service, the use of water for recreation a cultural service, and the role of water in the life cycle of organisms a supporting service. Second, these categories are interdependent, such that individual services would not exist without the functioning of a broad set of ecosystem services.

This assessment provides an understanding of the ability of public lands to sustainably supply ecosystem services, focusing largely on the environmental condition of the land. This chapter is intended to highlight potential climate change effects on ecosystem service flows, for which management decisions can help users mitigate or adapt to these effects, and illustrate tradeoffs in the decision-making process. This approach is consistent with requirements under the Forest Planning Rule of 2012, in which the U.S. Department of Agriculture Forest Service (USFS) is required to formally address ecosystem services in land management plans for National Forests (USDA FS 2012a). The National Park Service does not have specific mandates concerning ecosystem services, but the agency has incorporated ecosystem service considerations into management planning and made ecosystem services a key part of its 2014 Call to Action (NPS 2014). The Bureau of Land Management (BLM) has also identified nonmarket environment values, synonymous with ecosystem services, as an increasingly important consideration for land management (Roberson 2013).

Managing for ecosystem services on public lands involves balancing uses across a wide range of stakeholders, potential impacts, and legal obligations. In rural areas of the Intermountain West, people rely on public lands for fuel, food, water, recreation, and cultural connection. Near urban areas such as Boise, Idaho, and along the Wasatch Front of Utah, recreation opportunities on Federal lands have been an important driver of economic growth, but mandates to manage for multiple use of natural resources can create situations in which some ecosystem services conflict with others. For example, managing lands for nonmotorized recreation may conflict with managing for motorized recreation, timber, and mining, yet it may complement management for biodiversity and some wildlife species.

Stakeholders and workshop participants in the Intermountain Adaptation Partnership (IAP) assessment helped identify and prioritize ecosystem services likely to be affected by both climate change and management decisions.

Box 13.1—Definitions of Ecosystem Services Categories

Provisioning services: products obtained from ecosystems, including timber, fresh water, wild foods, and wild game.

Regulating services: benefits from the regulation of ecosystem processes, including the purification of water and air, carbon sequestration, and climate regulation.

Cultural services: nonmaterial benefits from ecosystems, including spiritual and religious values, recreation, aesthetic values, and traditional knowledge systems.

Supporting services: long-term processes that underlie the production of all other ecosystem services, including soil formation, photosynthesis, water cycling, and nutrient cycling.

We focus on: (1) timber and other wood products, (2) livestock grazing, (3) municipal water, (4) carbon sequestration, and (5) pollinator health.

Timber, Building Materials, Other Wood Products, and Biomass

Broad-Scale Climate Change Effects

Wildfire, drought, and insect outbreaks can cause significant levels of tree mortality (Chapter 8), decreasing potential timber outputs and having a deleterious effect on forest health in general. Although temperature and precipitation may have some effect on regional vegetation, the direct effects on timber are likely to be small. More important to timber are the societal and policy changes that affect timber quotas and levels of actual harvest and silvicultural treatments, such as thinning and fuels reduction. For example, conservation of rare species, protection of riparian areas, and maintenance of viewsheds near populated areas generally limit the amount of timber that can be cut in certain landscapes. This, in turn, affects the economic viability of wood processing operations and the local job market. There will be additional indirect effects on timber if climate change significantly affects wildfire occurrence and insect outbreaks.

Current Conditions—Forest Industry

Timber Harvests on National Forests

Timber production in the IAP region is affected by both regional and national trends in the forest industry, the economy, and policy. Housing starts, a key indicator of demand for sawtimber, are only now beginning to recover from the recent U.S. recession but are still much lower than before 2007 (USDA FS 2016b). Although demand for pulpwood and residues for energy (especially wood pellets) has increased significantly, most of the material comes from the southern United States, not the West.

Timber volume cut on National Forests in the USFS Intermountain Region peaked in 1988 (480 million board feet) and declined by 87 percent through 2005 (63 million board feet) (fig. 13.1). Cut volumes stabilized somewhat after 2005, varying from 80,000 to 113,000 MBF between 2006 and 2014. Cut volumes equaled or exceeded volume sold from the mid–1980s to the early 2000s, but cut volume was generally less than volume sold after 2004 (USDA FS 2015c, 2016b). Cut volumes from National Forests include volume from small sales (less than $300) (accounting for the vast majority of sales), as well products other than log

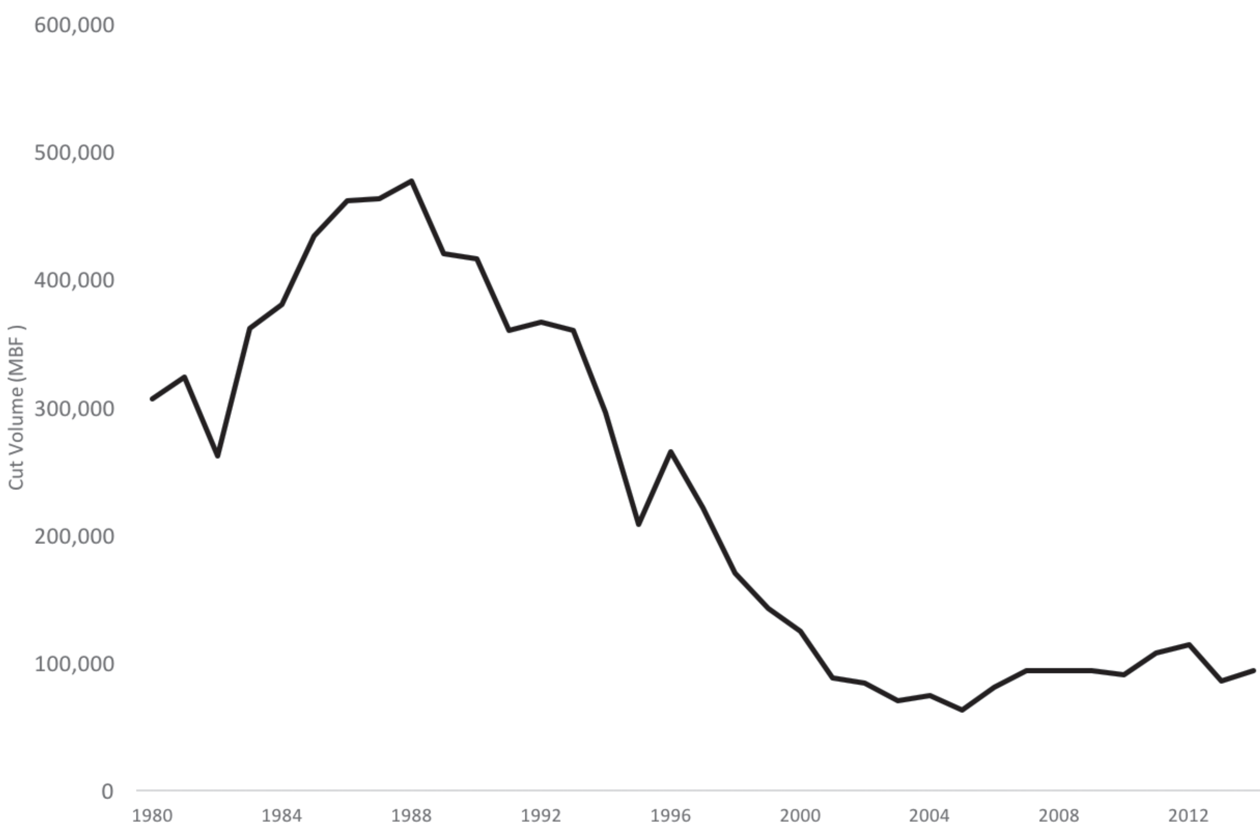

Figure 13.1—Timber volume harvested in national forests in the U.S. Forest Service Intermountain Region (1980–2014) (USDA FS 2016a). Small sales (<$300) contribute substantial percentages of cut volume and value, and are included here. Nonconvertible forest products (e.g., Christmas trees, boughs) are not included.

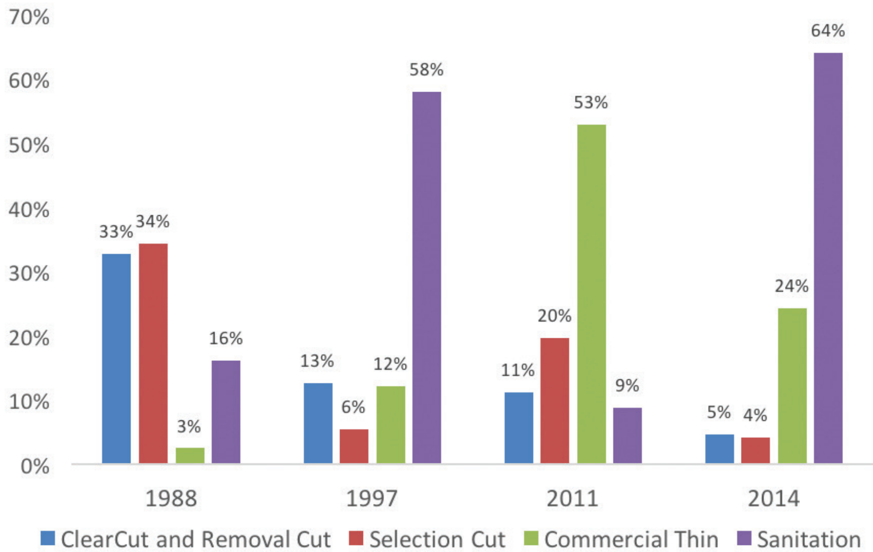

Figure 13.2—Changes in harvest type in national forests in the U.S. Forest Service Intermountain Region (percentage of all commercial harvest acres) (USDA FS 2015). Includes harvests where commercial sales occurred, as compiled by Forest Service TRACS (through 2004) and FACTS (after 2004) systems.

(POL) material. These sources amount to a substantial percentage of cut volume; volume from small sales and non-saw and POL material may not be utilized or processed by larger mills.

Average price of cut timber on National Forest System (NFS) lands (inflation-adjusted) increased after 1988, peaking at $248/thousand board feet (1997). However, prices fell dramatically after 1997 to a low of $17/thousand board feet (2011) and remained low through 2014 (USDA FS 2016b). Prices reflect trends in conditions, availability of timber substitutes, and types of harvesting (and the increasing proportion of non-saw material sold at a very low price). Traditional commercial harvesting (e.g., clear cuts, and removal and selection cuts) accounted for a majority of harvest in 1988 (fig. 13.2) when prices and volumes of cut timber remained high on NFS lands. Commercial thinning and sanitation cuts dominate in later years (1997–2014), altering the mix of merchantable timber harvested. These changes were caused by declining prices of cut timber, declining numbers of mills, and broader-scale market trends, especially after the 2007 recession.

Timber harvest and residue production are projected to increase steadily in the United States through 2060 because of global demand for wood products and bioenergy (Headwaters Economics 2016b). It is unclear whether this projected trend will also occur in the IAP region, and these projections can be affected by national and global economic factors. Improved capability to utilize small-diameter trees, alternative species, and biomass can help restore harvest values, influence markets, and expand capacity of forest management to adapt to changing conditions.

Forest Industry Employment

The sensitivity of local economies to climate-induced shifts in timber supplies is a function of the condition and trend of the forestry and wood products manufacturing sectors within the IAP region. Here we discuss employment in the forestry and logging sector, capacity in the primary wood products manufacturing sector, and timber harvest on NFS lands.

In addition to the sensitivity of timber-related industries to climate change, the capacity for forest management and health to adapt to climate change is also a function of the availability and capacity of harvest and forestry contractors. Forest management in many areas of the Intermountain West is now dominated by forestry service-type work and contracts, targeting thinning and similar projects for improving forest health, reducing fuels, and managing areas affected by fire or insects (e.g., Vaughan and Mackes 2015).

The IAP region includes counties within areas of economic influence for relevant National Forests, as adopted by the "National Forest Economic Contributions" program (USDA FS 2017). Areas of economic influence are based on the flows of goods and services (including labor) that support regional economies and may therefore include counties outside the physical boundaries of National Forests.

Timber employment accounts for a relatively small portion of all private employment (table 13.1). Similar to the U.S. timber industry as a whole, the timber industry in the IAP region has declined considerably, with variation among different subsectors. Growing, managing, and harvesting accounts for 2 to 19 percent of timber employment in the IAP subregions and is highest (by percentage) in the Southern Greater Yellowstone and Middle Rockies subregions. Primary wood products manufacturers (sawmills and paper mills) are firms that process timber into manufactured goods such as lumber or veneer and facilities such as biomass power or particleboard plants that use wood fiber residue directly from harvest sites or timber processors. Employment in primary wood products manufacturing accounts for 25 percent of all forest industry employment in the IAP region, comparable to the national level of 30 percent. Plywood and engineered wood operations rely heavily on mill residues (clean chips) rather than byproducts from forest restoration and fuels treatments. Pulp and chip conversion, biomass and energy use, and pellet-producing operations are more likely

Table 13.1—Summary of timber employment in the IAP region and subregions for 2014. Employment is reported in County Business Patterns, excluding government, agriculture, railroads, and self-employed. From "Profiles of Timber and Wood Products" (Economic Profile System) and U.S. Dept. of Commerce (2014).

	IAP subregions						
Economic sector	Middle Rockies	S. Greater Yellowstone	Uintas and Wasatch Front	Plateaus	Great Basin and Desert	IAP region	United States
	Employment (no. full- and part-time jobs)						
Timber (forest industry)	5,155	172	4,289	982	2,897	12,287	840,700
Growing & harvesting (+managing)	726	33	86	46	173	1,035	109,294
Sawmills & paper mills	1,621	57	618	224	814	3,040	254,837
Wood products manufacturing	2,808	82	3,585	712	1,910	8,212	476,569
	Timber employment (percent of total private employment)						
	1.51	0.33	0	0.42	0.25	0.47	0.69
	Percent of timber employment						
Growing & harvesting (+managing)	14	19	2	5	6	8	13
Sawmills & paper mills	31	33	14	23	28	25	30
Wood products manufacturing	54	48	84	73	66	67	57
	Percent change in employment (1998-2014)						
Timber (forest industry)	-43	-39	-14	-5	2	-28	-38
Growing & harvesting (+managing)	-59	-84	-33	-90	-30	-57	-34
Sawmills & paper mills	-51	-20	-26	-24	-20	-43	-41
Wood products manufacturing	-34	-4	-12	8	20	-16	-37

consumers of biomass and roundwood as byproducts from forest restoration and treatments. Pulp and paper mills account for the remaining 1 percent of primary manufacturing employment.

Secondary wood products are converted paper and other wood products typically manufactured after leaving a mill (wood products manufacturing), and they account for more than double the employment of the other two sectors combined. The vulnerability of secondary wood products manufacturing facilities to regional timber supply trends is unknown.

Capacity and Utilization: Primary Wood Products Manufacturing, Residues, and Biomass

The total number of active mills in the IAP region declined 17 percent across the survey periods shown in table 13.2 (BBER 2016). In contrast, the total number of active mills that can handle residue or biomass (e.g., byproducts from wood products manufacturing and forest restoration treatments) increased by 20 percent over the same period. Relatively few mills or processing facilities currently handle biomass or residue (18 for the period 2011–2014) in the IAP region. The number of post and pole mills, which can handle smaller diameter timber, decreased from 15 to 13 over the survey periods.

Table 13.2—Change in number of active timber mills and processing facilities in the IAP region (from BBER 2016). Time periods (2006-2010, 2011-2014) refer to years over which survey data were collected across different States. Residue or biomass uses include wood shavings, pulp and chip conversion, particleboard, fuel pellets, biomass, and bark products.

	2006-2010	2011-2014
Total - residue or biomass users	15	18
Total - all mills	130	108
Shavings - wood	0	1
Sawmills	45	40
Pulp/chip conversion	2	2
Post & small pole	15	13
Plywood	1	1
Pellet mill	1	2
Particleboard/medium-density fiberboard	2	1
Log home	39	30
Log furniture	15	6
Fuel pellets	0	1
Biomass	7	7
Bark products	3	4

Mills are most heavily concentrated in the Middle Rockies, followed by the Uintas and Wasatch Front and Southern Greater Yellowstone subregions (table 13.3). These results are mostly consistent with timber employment data, with the exception of the Southern Greater Yellowstone subregion, where employment in mills and processing facilities is lowest, suggesting that mills may be relatively smaller there.

Although few mills or timber processing facilities handle biomass or residue, evidence from three geographic areas suggests that the number of these facilities may be increasing in three subregions. Most facilities handling biomass or residue are located in the Middle Rockies, where mill numbers have remained static. No facilities handling biomass or residue exist in the Plateaus subregion.

Log capacity decreased 22 percent for the IAP region over the period 2006–2014, mainly because of reduced capacity in the Middle Rockies subregion. Log capacity utilization has been steady (66 percent) for the IAP region (table 13.4). Utilization is lowest for the Plateaus subregion (14 percent), and highest for the Middle Rockies and Great Basin and Semi Desert subregions (70–75 percent) for the most current data (2011–2014). Residue and biomass use capacity in the IAP region has declined 5 percent, from 920,000 (2006–2010) to 870,000 (2011–2014) bone-dry tons per year (BBER 2016). Residue capacity utilization fell from 79 percent to 47 percent over the same period. Although a high capacity utilization may reflect a healthy industry (and a low number may reflect the opposite), it is noteworthy that an industry operating under full capacity typically has a greater ability to respond to changes in market supply and demand. For example, an area with excess capacity may be better able to respond to an influx of material from salvage logging following wildfire.

Sensitivity to Climate Change

Changes in productivity caused by increased temperatures could be significant, with productivity potentially decreasing in lower-elevation, moisture-limited areas (Chapter 6). However, policy has been the driving force behind timber production in the past, and that is likely to continue in the future. The current low level of harvest is not expected to change significantly in the future and will have a minimal effect on vegetation patterns across large landscapes. Strategic areas could be targeted for specific objectives (e.g., fuels, wildlife), but under a changing climate, disturbances such as fire, insects, and diseases will be the major change agent in forests in the IAP region (Chapter 8).

Expected Effects of Climate Change

Primary timber species in the IAP region, such as ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*), are drought tolerant and are expected to undergo only a slight decrease in abundance in the near term. However, potential increases in productivity, particularly in higher-elevation areas, could offset those losses to some

Table 13.3—Change in number of active timber mills and processing facilities in IAP subregions (from BBER 2016). Time periods (2006-2010 and 2011-2014) refer to years over which survey data were collected across different States. Residue or biomass uses include wood shavings, pulp/chip conversion, particleboard, fuel pellets, biomass, and bark products.

	Middle Rockies		S. Greater Yellowstone		Uintas and Wasatch Front		Plateaus		Great Basin and Desert	
	2006-2010	2011-2014	2006-2010	2011-2014	2006-2010	2011-2014	2006-2010	2011-2014	2006-2010	2011-2014
Residue or biomass	10	10	1	2	1	2	nd[a]	nd	3	4
All mills	71	56	12	15	29	24	9	5	9	8

[a]No data.

extent, but overall growth will likely decrease in the long term (Chapter 6). In addition higher-elevation areas may be less accessible for harvesting via existing infrastructure.

The indirect effects of climate change and associated stressors are expected to alter some forests at large spatial scales. For example, increased temperatures and shorter, warmer winters have resulted in large outbreaks of mountain pine beetles (*Dendroctonus ponderosae*) in much of the Intermountain West (Chapter 8). "Insect friendly" conditions, combined with stressed trees, amplified vulnerability to insect infestation. Increased disturbances such as wildfire and possibly some fungal pathogens associated with a warmer climate may reduce merchantable timber and non-timber forest products. Although the primary timber species in this area are fire tolerant, the current elevated fuel loadings from fire exclusion may lead to an increase occurrence of crown fires that will potentially kill mature trees. Such mortality events would produce a short-term positive shock in the timber supply, as fire kill becomes salvaged wood, although salvage logging may be hindered by a number of logistical and permitting hindrances. For example, location of salvageable wood may not be accessible. In addition salvageable wood can be harvested only within a limited time after the disturbance, and logging and mill capacity are unlikely to be able to fully respond to a sudden influx in supply, especially in the case of a large disturbance. Furthermore, the environmental impact assessment process must be factored into timelines for salvage logging.

Forest ecosystems can adapt to changes in climatic conditions by a gradual shift to different mixtures and distribution of species and genotypes, although there may be tradeoffs in productivity in some cases. With respect to social and policy influences, increased utilization of woody biomass can make fuels reduction and other silvicultural treatments more economically feasible, thus promoting healthier and more productive forests.

In some cases, increased wildfire and other disturbances may create a temporary increase in timber supply through salvage logging, but will reduce potential timber output in the long run. Disturbances and the manner in which postdisturbance tree mortality is managed will have implications for carbon dynamics. Thus, although the direct effects of climate change (temperature, precipitation) on timber are likely to be minor, the secondary effects through various disturbances may be significant for the timber industry.

Grazing Forage For Livestock and Wildlife

Broad-Scale Climate Change Effects

Warming temperatures, increased frequency of wildfires, and altered precipitation regimes will affect the health of the vegetation systems on which grazing depends (Chapters 7, 8). Productivity may increase in some grasslands, and decrease in others, and species distribution and abundance are likely to shift. Increased frequency of droughts will be especially influential, reducing the period of time during which cattle can use rangelands for forage.

Current Conditions and Existing Stressors

Livestock grazing is tied to cultural heritage in the West, existing alongside Spanish missions during the first periods of settlement, and playing an important role in the westward expansion of America. Today, livestock grazing is the most widespread use of land in western North America. Over two-thirds of all grazed land in the United States occurs in the Mountain and Southern Plains regions, and over two-thirds of all land in these two regions is grazed (Nickerson et al. 2011). According to the 2012 Census of Agriculture (USDA 2012b), grazing occurs on 76 percent of farmland in Idaho, Wyoming, Utah, and Arizona. Grazing is also the most widespread use of USFS and BLM lands, creating a footprint larger than roads, timber harvest, and wildfires combined (Beschta et al. 2013).

In the early 1900s, forest reserves were created in the IAP region to manage livestock grazing, decrease conflict in grazing areas, and promote scientific management of grazing. One of the first of these was the Manti Forest Reserve (now part of the Manti-La Sal National Forest), established in 1903. That history is still reflected in the Intermountain Region, and some National Forests contain large active livestock allotments.

Table 13.4—Change in log capacity and log capacity utilization (active and inactive mills) for the IAP region and subregions (from BBER 2016). Time periods (2006-2010, 2011-2014) refer to years over which survey data were collected across different states.

	Middle Rockies		S. Greater Yellowstone		Uintas and Wasatch Front		Plateaus		Great Basin and Desert		IAP region	
	2006-2010	2011-2014	2006-2010	2011-2014	2006-2010	2011-2014	2006-2010	2011-2014	2006-2010	2011-2014	2006-2010	2011-2014
	Thousand board-feet per year											
Log capacity	675,829	486,131	16,808	13,025	75,427	49,011	57,509	41,351	128,783	51,761	954,356	741,279
	Percent											
Log capacity utilization	69	75	94	38	37	38	24	14	83	70	66	67

Table 13.5—Livestock use on National Forests (NFS) and Grasslands in the USFS Intermountain Region (from USDA FS 2015b).

	Permittees	Cattle		Horses and burros		Sheep and goats		Total	
	Number	*Number*	*AUM*[a]	*Number*	*AUM*	*Number*	*AUM*	*Number*	*AUM*
NFS permitted commercial livestock	1,693	309,759	1,441,944	1,517	5,823	549,874	463,542	861,150	1,911,309
NFS authorized commercial livestock	1,670	294,476	1,236,510	1,221	4,583	512,649	329,521	808,346	1,570,614
NFS authorized livestock use	20	500	110	70	296	0	0	570	406
Total NFS authorized	1,690	294,976	1,236,620	1,291	4,879	512,649	329,521	808,916	1,571,020
Private lands	50	1,311	6,277	0	0	2,183	1,716	3,494	7,993

[a]Animal unit months.

Table 13.5 shows livestock use for the Intermountain Region in 2015. Permitted numbers are the head-months or animal unit months (AUMS) for which the lease is applicable. Authorized numbers are the numbers in a given year that the USFS or BLM will let the permittee actually run in an allotment. Authorized numbers may decrease during a drought. The number of goats and sheep exceeds that of cattle, horses, and burros, but cattle account for 78 percent of total AUMs.

Cattle, yearlings, and bison make up the majority of authorizations of AUMs in Idaho and Wyoming (table 13.6). Grazing statistics for BLM lands are from the Public Land Statistics for 2014 and are given by State, so they do not match up with the IAP region for these two States. Some permittees run more than one type of livestock and may be included in more than one column for type of grazing.

Despite the prevalence of grazed lands, some studies find the economic contribution of both livestock and public lands for grazing to these regions is modest (Mathews et al. 2002). Profitability has declined for most livestock producers, and total production across all land types is in decline. In Utah, beef production peaked in 1983 with 374,000 cattle, and lamb production peaked in 1930 with 107,000 lambs (McGinty et al. 2009). Mathews et al. (2002) found that only 6 percent of all livestock producers in the 17 States west of the Mississippi River maintain USFS or BLM grazing allotments, and 62 percent of counties in the western United States depend on Federally administered grazing allotments for 10 percent or less of their total livestock forage. Fewer than 10 percent of counties depend on Federal lands for more than 50 percent of the forage (Mathews et al. 2002).

Management of public lands for water, pollinators, threatened and endangered species, sensitive plant species, and cultural and historic objects is increasingly valued and often in conflict with current livestock grazing. These trends

Table 13.6—Authorizations and animal unit months (AUMs) on Bureau of Land Management lands (from BLM 2014).

	Cattle, yearlings, bison	Horses and burros	Sheep and goats	Authorization count
Authorizations	*Number*			
Idaho	1,549	93	99	1,632
Nevada	509	30	59	551
Utah	1,174	40	157	1,278
Wyoming	2,420	249	267	2,568
AUMs authorized	*AUMs*			
Idaho	806,580	3,945	69,778	880,303
Nevada	970,467	2,167	87,056	1,059,690
Utah	635,705	1,441	149,353	786,499
Wyoming	1,075,021	11,219	174,708	1,260,948

Box 13.2—Livestock Grazing Effects

- Summarized from "Initial Review of Livestock Grazing Effects on Select Ecosystems of the Dixie, Fishlake, and Manti-La Sal National Forests" (http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3810252.docx):
- Historic grazing rates have led to severe erosion in some allotments, and some allotments may have crossed thresholds that make returning to historic forage levels difficult.
- Monitoring records indicate that grazing standards are often being met. However, the majority of monitoring takes place in uplands, with little monitoring in sensitive riparian and wetland areas. Current standards and guidelines may also not be adequate to address particular resource concerns.
- In many riparian areas where monitoring has taken place, current and historic livestock use has impaired riparian areas and made them less resilient to catastrophic events. Approximately 36 percent of riparian vegetation sites measured in 2012 were not meeting objectives outlined for them.
- Springs and wetlands can receive heavy livestock use that results in trampling and hummocking. The effect of grazing on riparian vegetation has affected streambank integrity and damaged stream channels, which causes resource concerns such as erosion, sedimentation, and stream channel damage. However, where efforts have been made to protect riparian vegetation by exclosure or other methods, riparian vegetation improves quickly.
- Through 2013, long-term vegetation data suggests 60 percent of monitoring sites are meeting site-specific desired conditions, and 63 percent are meeting minimum ground cover values. However, current standards and guidelines may not be adequate in maintaining effective habitat for greater sage-grouse (*Centrocercus urophasianus*).
- Sagebrush communities generally have low diversity and cover of perennial plant species, especially perennial forbs. Managing livestock grazing to maintain residual cover of herbaceous vegetation may be an effective short-term action benefitting sage-grouse populations.
- Persistent browsing by livestock and wild ungulates contributes to long-term aspen decline.

reflect both the growth of the New West and the economic struggles of the Old West. The last few decades have seen a shift in public opinion about management priorities, and the sustainability of current grazing practices is increasingly being called into question. Public disagreement about management practices and existing and desired conditions in National Forests in southern Utah led the Dixie, Fishlake, and Manti-La Sal National Forests to assess the need for revisions to their forest plans, which date back to 1986 (box 13.2).

Federal lands are also grazed by wild native ungulates such as elk (*Cervus elaphus*) and deer. Populations of elk and deer have risen as a result of predator control and protection of game species. When concentrated, however, wild ungulates can overbrowse some vegetation, alter streambanks and riparian vegetation, and generally cause deterioration of land conditions (Beschta et al. 2013).

Foraging capacity is also adversely affected by the spread of invasive species (USFWS 2009). Overgrazing degrades native bunchgrasses and increases the likelihood of introduction and spread of nonnative annual species such as cheatgrass (*Bromus tectorum*). Proliferation of nonnative species also has adverse impacts on nutritional quality (McGinty et al. 2009).

Sensitivity to Climatic Variability and Change

Grazing occurs in some of the most sensitive vegetation regions (e.g., alpine, subalpine forblands, dry sagebrush shrublands, low-elevation riparian and wetland ecosystems), amplifying the effects of drought and other stressors. Temperature, seasonal aridity, and prolonged drought are expected to increase in a warmer climate, accelerating soil deflation and erosion. These impacts are intensified in areas where vegetation has been removed and divots have been created by cattle (Chapter 7). The effects will be heterogeneous across ecosystem types, and depending on their baseline adaptive capacity, some rangelands may have reduced resilience to climate change because of historical grazing.

Expected Effects of Climate Change

A recurring theme during workshops in the IAP region was the need for more flexibility associated with grazing permits. If weather becomes more variable, with more very wet years and more very dry years, expectations about on and off dates for grazing may need to be altered. This variability and user expectations are likely to be even harder to manage in areas that span elevations, where variability in timing of snowmelt also affects dates of the "muddy season." In addition, the direct effects of higher temperatures on cattle (Nardone et al. 2010) and lower forage productivity or quality may compound stresses in some locations.

Other important effects on forage areas include disturbances and social pressures on land use. Increased fire frequency and spread of invasive species have already altered areas formerly suitable for grazing. These impacts are expected to worsen with climate change, leading to both decreased lands available for forage and decreased productivity of some lands that remain open. Even without these changes, there is mounting social pressure for land management priorities to emphasize conservation and recreation over livestock. Decreased value of land for ranching, as well as increased population in the IAP region, has led to fragmentation of grazed lands through conversion of private rangeland to "ranchettes" and suburban developments (Holechek 2001; Resnik et al. 2006).

Municipal Drinking Water Quantity and Quality

Broad-Scale Climate Change Effects

Water temperature, yield, timing, and quality are important for municipal drinking water suppliers and are expected to be altered across the IAP region by a warmer climate. Stream temperatures are projected to increase 12 percent on average in the region by the end of the century (table 13.7) (Chapter 5), the result of increased temperatures and loss of vegetation along streambanks. Stream temperature affects water solubility and biogeochemical cycles, which determine the organisms that can survive in water. Increased number and severity of wildfires will also deposit more sediment and debris into streams, lakes, and reservoirs (Chapter 8), causing further concerns for water quality.

Current Condition and Existing Stressors

Many subwatersheds in the IAP region are already impaired or at risk (table 13.8). Both water quantity and quality are currently classified as impaired or at risk for most of Nevada, and generally as impaired in heavily populated parts of Utah. Urban and exurban development also exacerbates sediment and runoff of pollutants from roads and trails.

Sensitivity to Climatic Variability and Change

Sensitivity to climate change depends on current watershed conditions and future threats to those conditions. The most sensitive watersheds are those already impaired or at risk, based on vegetation and soil conditions. Watersheds that have high fuel loadings are also more sensitive to climate change, as are heavily developed areas. Developed land alters the shape of the landscape, influencing water flow, timing, and quality.

Expected Effects of Climate Change

Earlier stream runoff is expected over much of the region, and summer flows are expected to be significantly lower for most users (Chapter 4). By the end of the 21st century, the median flow date is expected to be over 19 days earlier, and summer flows are predicted to decline over 25 percent, on average (table 13.7). In extreme cases, the median flow date is over a month and a half earlier, and summer flows are projected to decline over 90 percent. Total water yield is expected to increase slightly in the northern portion of the IAP region, but decline over 10 percent in the warmer southern and western parts of the region (fig. 13.3).

Groundwater levels and recharge rates are also affected by climate change. During the summer, high water demand coupled with low water supply already forces many municipal water suppliers to utilize groundwater intakes in order

Table 13.7—Summary statistics of exposure projections for climate change, representing conditions for municipal water system intakes (521 total), characterized as the change relative to a 30-year historical average. Conditions near each water intake are weighted according to the total number of intakes within a system, then aggregated up to the water system scale. Exposure is increasing in temperature, and decreasing in flow and timing.

Variable	Average	Standard deviation	Median	Minimum	Maximum
2040 (2030-2059)					
Mean annual flow (% change)	2.04	5.34	3.62	-15.25	17.26
Mean summer flow (% change)	-20.85	22.08	-14.50	-90.37	21.11
Median flow date (no. days)	-11.34	6.27	-11.59	-28.14	2.21
Water temperature (% change)	6.71	1.70	6.95	2.56	14.00
2080 (2070-2099)					
Mean annual flow (% change)	-0.58	10.51	3.10	-31.24	17.44
Mean summer flow (% change)	-25.69	27.86	-18.27	-92.37	33.11
Median flow date (no. days)	-19.14	10.86	-19.52	-47.09	4.10
Water temperature (% change)	11.73	3.03	12.20	4.53	24.82

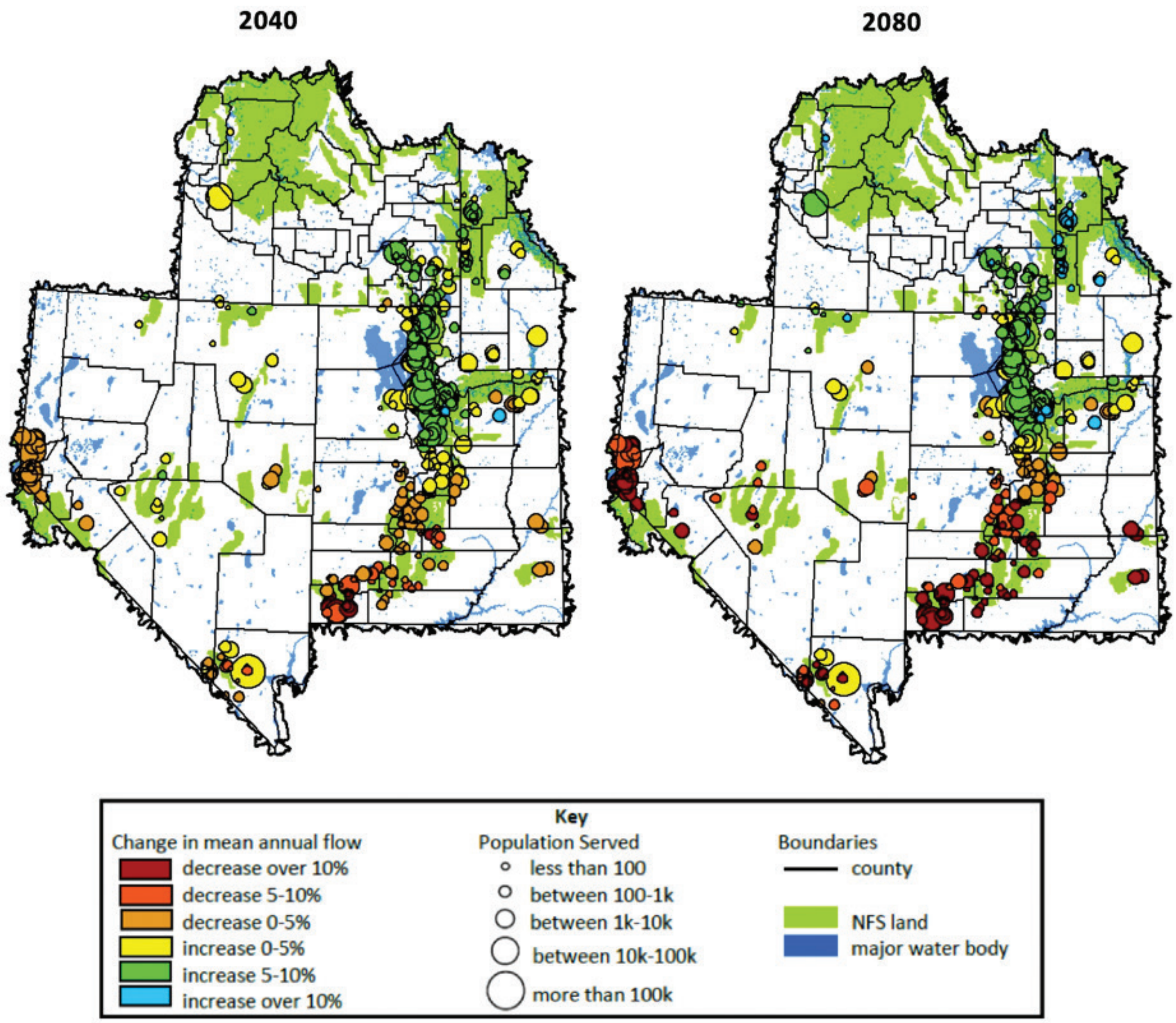

Figure 13.3—Projected changes in mean annual flow for municipal water systems. The center of each circle is the central location of each drinking water system relative to intake locations.

to meet water demand. Higher temperature and population growth will further increase the demand for water and stress water resources in the region, especially in Utah.

Riparian systems are a nexus for the interaction of vegetation and water, and climate change effects on these systems will reduce water quantity and quality in some portions of the landscape. In addition, lower and warmer surface water can affect the abundance and diversity of biota in riparian zones. Any associated reductions in water quality will lead to increased treatment costs for municipal users, as well as potential losses in biological function.

Increased fire frequency and severity would increase sediment delivery, leading to further degradation of water quality. Extreme weather and increased rain-to-snow ratios can also increase runoff from agricultural fields and add pesticides and fertilizers to streams. Changes in timing and summer flow are expected to cause shortages of surface water in some locations, especially during the summer, when demand is high. Many municipal systems are likely to incur increased treatment costs and to depend more heavily on groundwater intakes in order to meet demand. In addition, the effects of warmer water on algal blooms in lakes reduce dissolved oxygen, decrease clarity, and harm some aquatic species, humans, and pets (Moore et al. 2008).

Vulnerability Assessment for Municipal Water Users

We used municipal drinking water intake locations and nearby spatial characteristics to measure drinking water vulnerability for users who depend on National Forests in the Intermountain Region (table 13.9). A water system is defined as any unique supplier of municipal drinking water. Many small systems have only a single water intake, whereas larger systems sometimes have over 20 intakes. Municipal drinking water use is defined as serving the same population year-round (i.e., community water systems). Vulnerability measures are based on stream channel and subwatershed characteristics. We then map the final measures at the water system and National Forest levels. Each water system is analyzed based on the location of intakes and population served. Vulnerability is based on indicators of exposure, sensitivity, and adaptive capacity.

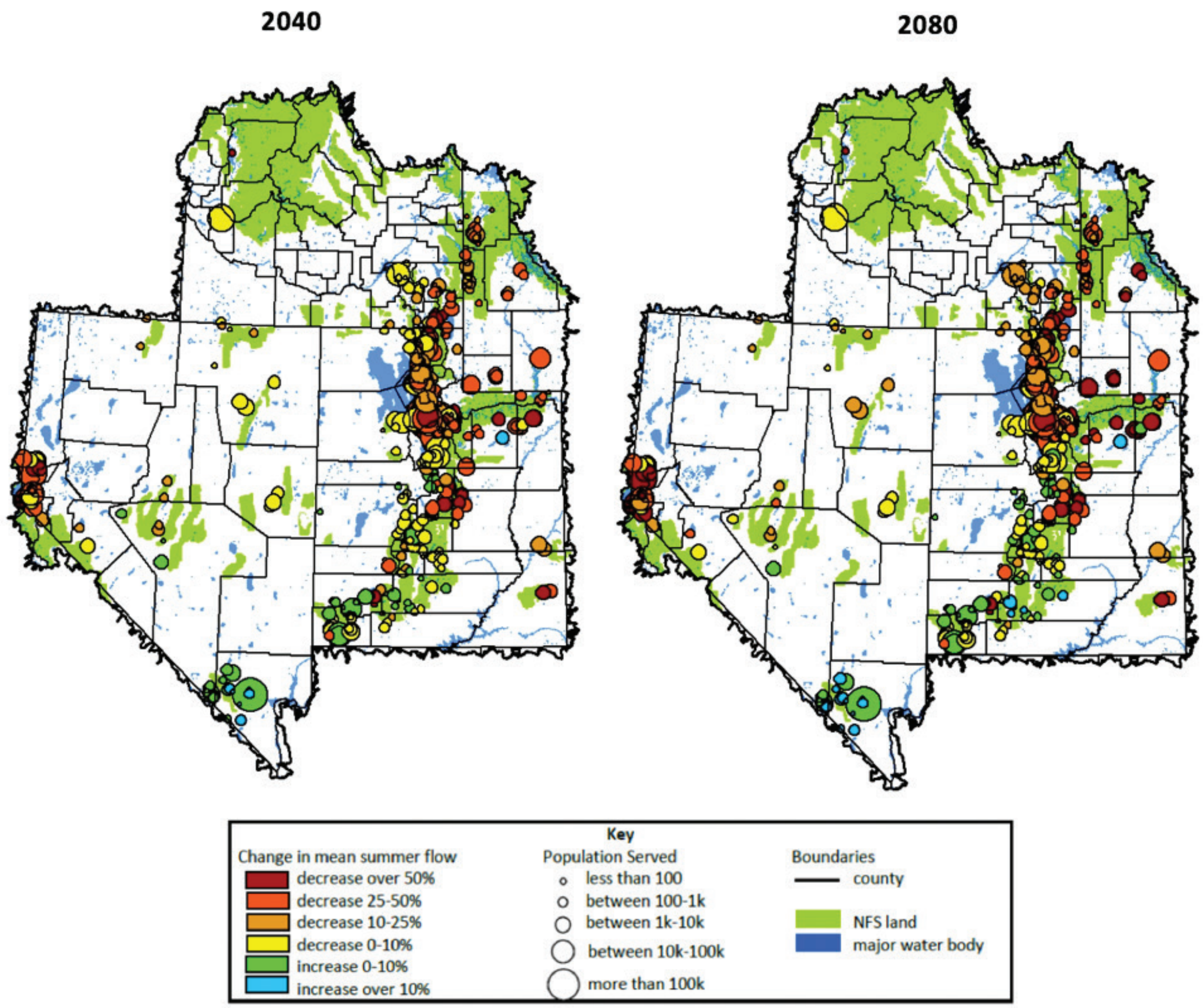

Figure 13.4—Projected changes in mean summer flow for municipal water systems. The center of each circle is the central location of each drinking water system relative to intake locations.

Exposure is measured according to projected changes in annual streamflow (fig. 13.3), summer streamflow (fig. 13.4), runoff timing (fig. 13.5), and stream temperature (fig. 13.6) from downscaled climate scenarios for the 2040s (2030–2059) and 2080s (2070–2099) (see chapters 3–5 for details). The most exposed users are those who experience declines in both mean annual and summer flows. Changes in summer flows are highly related to changes in runoff timing, with earlier runoff leading to lower summer flows. In many cases, however, this also appears to correspond with higher mean annual flows. Figure 13.7 shows total exposure values.

Water system sensitivity and adaptive capacity (SAC) are measured at the Hydrologic Unit Code 6 (10,000–40,000 acres) scale by using factor analysis to compare the variability of each water system to the average system within the Intermountain Region (fig. 13.8). The conditions are applied to any intakes in the subwatershed and then weighted according to the total number of intakes within each respective system. The final components for each system are standardized to a mean of zero and standard deviation of one, so they can be compared to other water systems in units of standard deviation from the mean.

Variables used to describe SAC together were narrowed to seven key factors, explaining over 97 percent of the variation among municipal water systems. Combining the final measures of exposure, sensitivity, and adaptive capacity provides the measure of vulnerability for each water system (fig. 13.9). System vulnerability measures are then averaged across nearby National Forests to map municipal drinking water vulnerability at the National Forest scale (table 13.10, fig. 13.10). Projections of water flows, timing, and temperature are described in chapters 4 and 5.

Summary

A large portion of the water used by human populations in the IAP region originates on National Forests and other public lands. Sensitivity of water supply to climate change depends on several factors, including current watershed conditions and future threats to those conditions. The most sensitive watersheds are those already impaired or at risk, based on vegetation and soil conditions. Increased temperature and reduced snowpack are expected to cause significant reductions in water supply by the 2040s and even higher

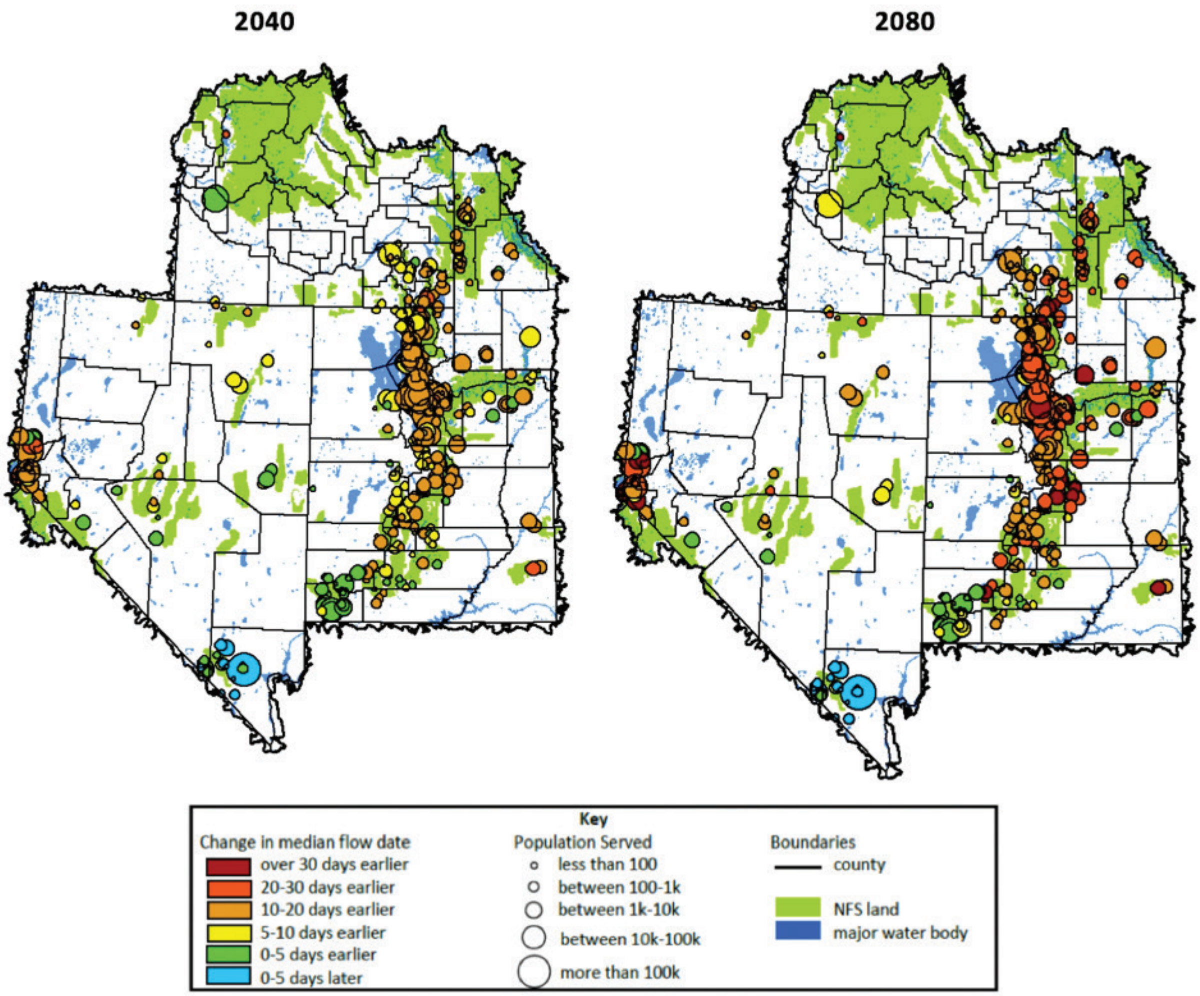

Figure 13.5—Projected changes in runoff timing (median flow date) for municipal water systems. The center of each circle is the central location of each drinking water system relative to intake locations.

reductions by the 2080s. Watershed response to climate change varies as a function of exposure to changing conditions. Geographic distribution of response in the IAP region depends on which variable is measured, specifically mean annual flow, mean summer flow, runoff timing, and stream temperature. Although spatial variability is generally high, watersheds in northern Utah tend to have greater sensitivity to climate change, as a result of lower water supply in areas with high populations (and thus high demand). In addition, watersheds that have high fuel loadings and are at risk for severe wildfires are sensitive to reduced water quality and supply.

Ecosystem Carbon

Ecosystems provide an important service in the form of carbon sequestration, the uptake and storage of carbon in vegetation and wood products. Carbon sequestration is often referred to as a regulating ecosystem service because it mitigates greenhouse gas emissions by offsetting losses through removal and storage of carbon. As such, carbon storage in ecosystems is becoming more valuable as the impacts of greenhouse gas emissions are becoming more fully understood and experienced (Janowiak et al. 2017; USDA FS 2015a).

The NFS constitutes 22 percent of the Nation's total forested land area and contains 24 percent of the total carbon stored in all U.S. forests, excluding interior Alaska (Heath et al. 2011). Management of these lands and disturbances can influence carbon dynamics. Rates of sequestration may be enhanced through management strategies that retain and protect forest land from conversion to nonforest uses, restore and maintain resilient forests that are better adapted to a changing climate and other stressors, and reforest lands affected by wildfires and other disturbances. Rates of forest carbon sequestration vary strongly across the United States, with eastern forests accounting for 80 percent of historical sequestration and as much as 90 percent of projected sequestration in future decades (USDA FS 2016b).

Carbon stewardship is an important aspect of sustainable land management. The USFS manages forests and grasslands by balancing the tradeoffs of carbon uptake and storage in a broad range of ecosystem services. The

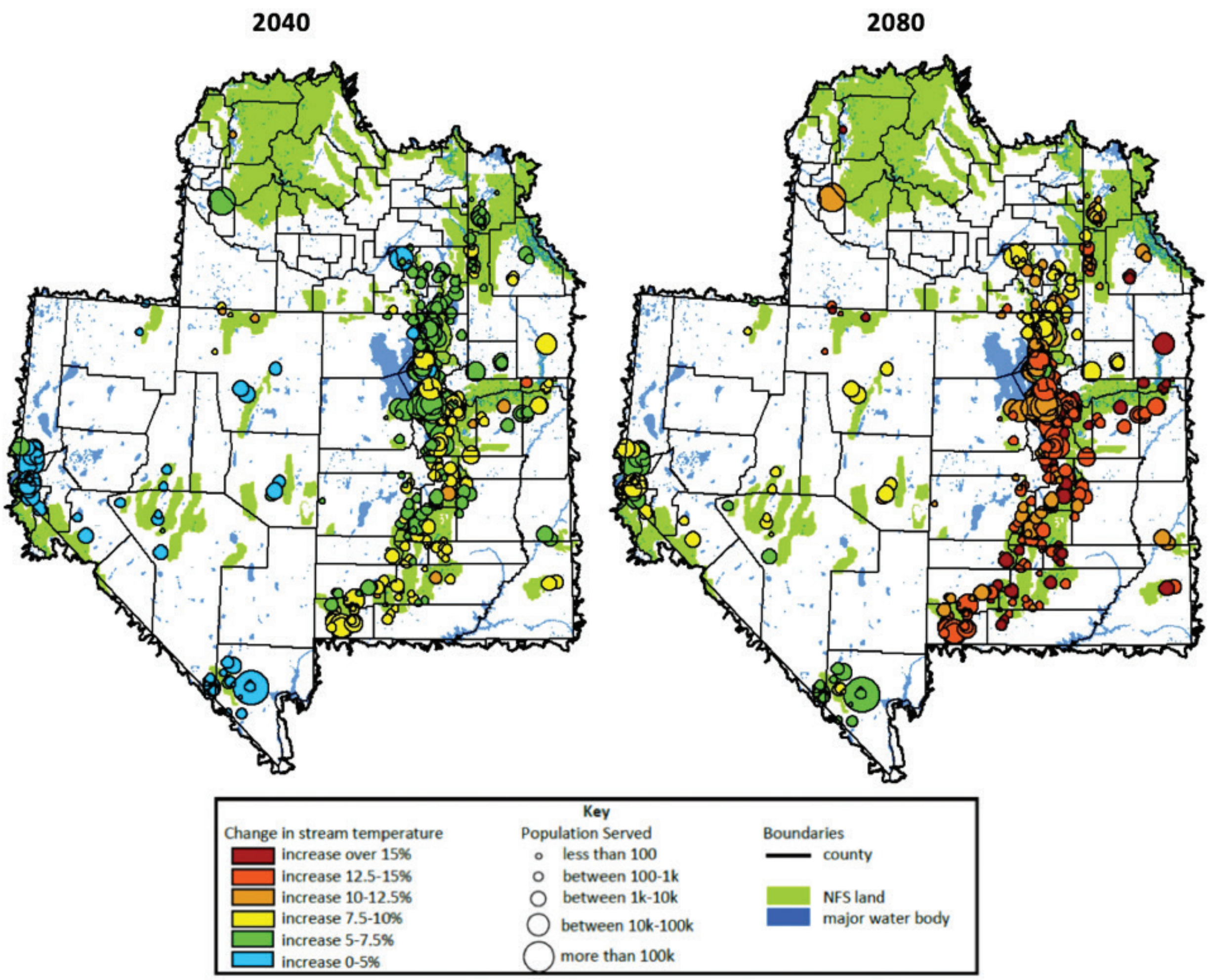

Figure 13.6—Projected changes in stream temperature for municipal water systems. The center of each circle is the central location of each drinking water system relative to intake locations.

goal is to maintain and enhance net storage (if possible) on Federal forests across all carbon pools and age classes. This is accomplished by protecting existing carbon stocks, and building resilience in carbon stocks through adaptation, restoration, and reforestation.

Carbon dynamics vary geographically and by vegetation type, as well as by disturbance regimes that alter vegetation structure and carbon at various spatial and temporal scales. For example, a severe wildfire may initially release carbon dioxide to the atmosphere and cause tree mortality, shifting carbon from living trees to dead wood and the soil. As the forest recovers, new trees establish and grow, absorbing carbon dioxide from the atmosphere. High-severity fires lead not only to a net loss of carbon storage, but also potentially to forest conversion to new landscapes that have lower sequestration rates. Although disturbances may be the predominant drivers of forest carbon dynamics (Pan et al. 2011), environmental factors such as the availability of forest nutrients and climatic variability influence forest growth rates and, consequently, carbon cycling (Pan et al. 2009). In addition, conversion of forests to other uses on private lands greatly reduces the potential for carbon sequestration and cycling processes.

In a warming climate, forests will be increasingly affected by factors such as multiyear droughts, insect outbreaks, and wildfires (e.g., Cohen et al. 2016). It is estimated that the amount of carbon dioxide emitted from fires annually in the United States is equivalent to 4 to 6 percent of anthropogenic emissions, and at the State level, the amount of carbon dioxide from large fires can occasionally exceed levels of carbon dioxide produced from burning fossil fuels (Wiedinmyer and Neff 2007). Maintaining healthy forest structure and composition may not eliminate disturbance, and may in fact entail additional low-magnitude disturbance, but is likely to reduce the risk of large and long-term carbon losses that would have been caused by large-scale disturbances (Millar and Stephenson 2015; Sorensen et al. 2011).

There is mixed evidence on the effect of fuel treatments and forest resilience on the long-term ability of forests to sequester carbon. Fuel treatments are generally effective both in reducing the amount of carbon lost in a fire and in increasing the amount of carbon stored in vegetation postfire (Dore et al. 2010; Finkral and Evans 2008; Meigs et al. 2009; Restaino and Peterson 2013; Stevens-Rumann et al. 2013). Fuel treatments themselves remove large amounts of carbon. Carbon removed during fuel treatments generally

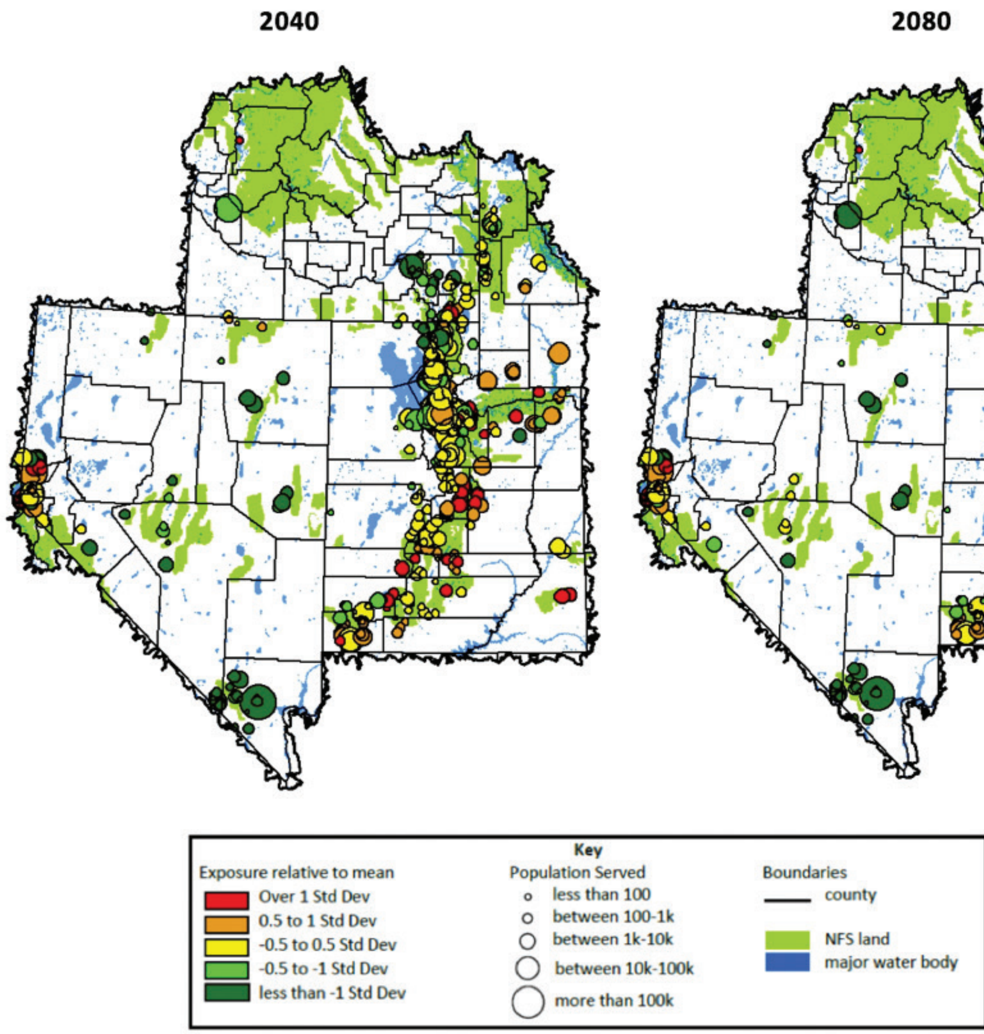

Figure 13.7—Municipal water system exposure. This is a standardized measure of the projected changes in mean annual flow, mean summer flow, runoff timing, and water temperature. Lower annual flow, lower summer flow, earlier median flow date, and higher temperature correspond with greater exposure. Each component is weighted equally. The center of each circle is the central location of each drinking water system relative to intake locations.

slightly exceeds that lost in wildfires over the long term, although the treatments prevent environmental damage associated with severe fires and reduce the size of periodic carbon pulses to the atmosphere (Campbell et al. 2012; Kent et al. 2015; Restaino and Peterson 2013).

Harvested wood products (HWP) (e.g., lumber, panels, paper) can account for a significant amount of offsite carbon storage, and estimates of this pool are important for national accounting and regional reporting (Skog 2008). Products and energy derived from harvest of timber from National Forests extend the storage of carbon or substitute for the use of fossil fuels. To date, few studies have looked at the long-term ability of these activities to sequester carbon, although they are an important component of forest management.

Baseline Estimates

The USFS 2012 Planning Rule and Climate Change Performance Scorecard element 9 (Carbon Assessment and Stewardship) require National Forests to identify baseline carbon stocks and consider that information in planning and management (USDA FS 2012a). The USFS has developed a nationally consistent assessment framework for reporting carbon components within each National Forest. Estimates of total ecosystem carbon and stock change (flux) have been produced at the forest level across the entire country, relying on consistent methodology and plot-level data from the Forest Inventory and Analysis program (USDA FS 2015a).

Carbon stocks reflect the amount of carbon stored in seven ecosystem carbon pools—aboveground live trees, belowground live trees, understory, standing dead trees, down dead wood, forest floor, and soil organic carbon—and in a pool comprising HWP in use and in solid waste disposal. These carbon pools are reported here for the Intermountain Region for the period 2005–2013. Carbon flux reflects year-to-year balance of carbon going into or being removed from the atmosphere (Woodall et al. 2013).

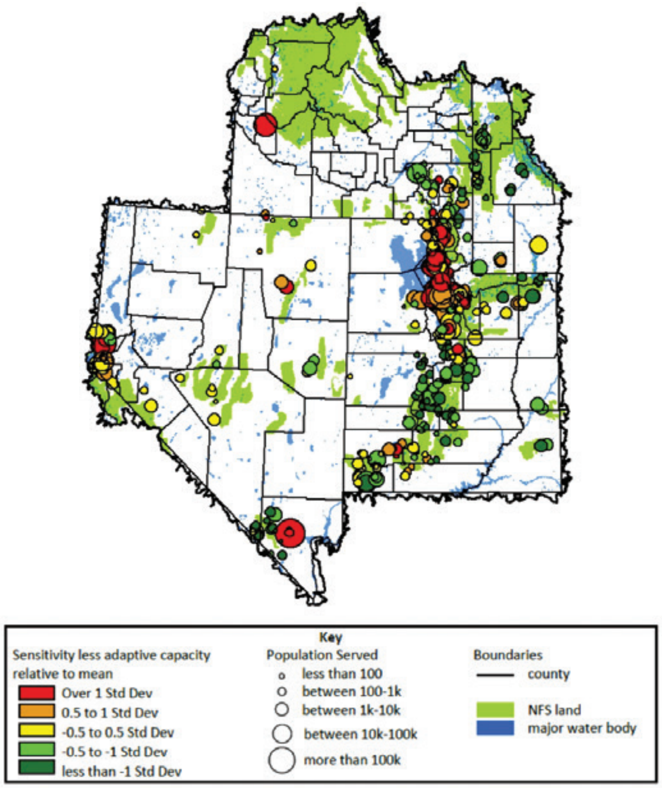

Figure 13.8—Municipal water system sensitivity less adaptive capacity. This is a standardized measure of sensitivity for each municipal system that also takes into account adaptive capacity. The measure is derived using factor analysis with the variables described in table 13.9. The center of each circle is the central location of each drinking water system relative to intake locations.

Salmon-Challis National Forest stored the largest amount of carbon among National Forests in the IAP region (181 million tons in 2005, 183 tons in 2013) (fig. 13.11). During this period, total forest ecosystem carbon in the Ashley, Bridger-Teton, Caribou-Targhee, Humboldt-Toiyabe, and Uinta-Wasatch-Cache National Forests generally increased, but decreased in the Boise, Dixie, and Sawtooth National Forests.

Carbon density is an estimate of forest carbon stocks per unit area. Carbon density barely changed from 2005 to 2013, going from 53.1 to 53.0 tons per acre. In 2013, Bridger-Teton National Forest had the highest carbon density (68.5 tons per acre) of all National Forests in the region, and the Desert Range Experiment Station had the lowest (22.9 tons per acre). Factors such as precipitation, growth rates (site quality), disturbances, and changes in land use, including timber harvest, may be responsible for these observed trends (USDA FS 2016b).

Regionwide, the amount of carbon stored in understory, standing dead, down dead, forest floor, and SOC pools increased between 2005 and 2013 but decreased in aboveground and belowground pools (fig. 13.12). Between these 2 years, the highest percentage change in carbon storage occurred in the standing dead pool (+7 percent), and the lowest in the forest floor pool (+0.9 percent). As of 2013, most of the carbon is concentrated in the aboveground, forest floor, and SOC pools.

Net ecosystem carbon sequestration in the IAP region is projected to remain stable until around 2020, then decrease gradually through around 2030 and level off at slightly less than zero through 2060 (USDA FS 2016b; Wear and Coulston 2015). Total ecosystem carbon stocks are expected to decrease steeply during the 2020–2030 period. If these trends hold (based on assumptions of the projections), the function of carbon retention will change significantly for the foreseeable future. Although these projections contain uncertainty, they appear reasonable in the IAP region, where more droughts and disturbances will make it difficult to retain carbon over the long term.

Cumulative carbon stored in Intermountain Region HWP accelerated around 1955 and increased until 2000, when it peaked at 10.5 million tons in storage. Since 2000, carbon stocks have been in a slow decline, and by 2013, the pool had fallen to 9.9 million tons (fig. 13.13). HWP stocks are decreasing because the amount of HWP carbon harvested and converted to products is less than the amount of carbon emitted through various pathways.

Carbon stocks are affected by disturbances such as wildfires, insect activity, timber harvesting, and weather events. Companion assessments are being completed to understand these influences. Although natural stand processes such as individual tree mortality and more widespread disturbances such as wildfire or droughts can greatly impact the status of forest carbon across NFS landscapes, the high levels of uncertainty associated with these carbon estimates prevent speculation as to the drivers of change. Research is currently underway to refine the spatial and temporal certainty associated with forest carbon baselines at the scale of an individual National Forest.

Pollinator Services and Native Vegetation

Broad-Scale Climate Change Effects

Human influences, such as introduction of invasive species, altered wildfire regimes, habitat modification, land use, and climate change, affect and stress native plant communities and species that depend on them, including both native and managed pollinator species (BLM 2015b). The geographic distribution and size of contemporary ecosystems are shifting, and novel ecosystems may develop in a warmer climate. These changes result in the loss, degradation, or fragmentation of pollinator habitat and other basic pollinator needs such as nesting sites and materials (GBNPP n.d.).

Warming temperatures, decreased snowpack, altered timing of snowmelt and runoff, invasive species, and changing fire behavior affect pollinators and their habitats in the IAP region. Among nonforest ecosystems, alpine, subalpine forblands, dry and dwarf sagebrush shrublands,

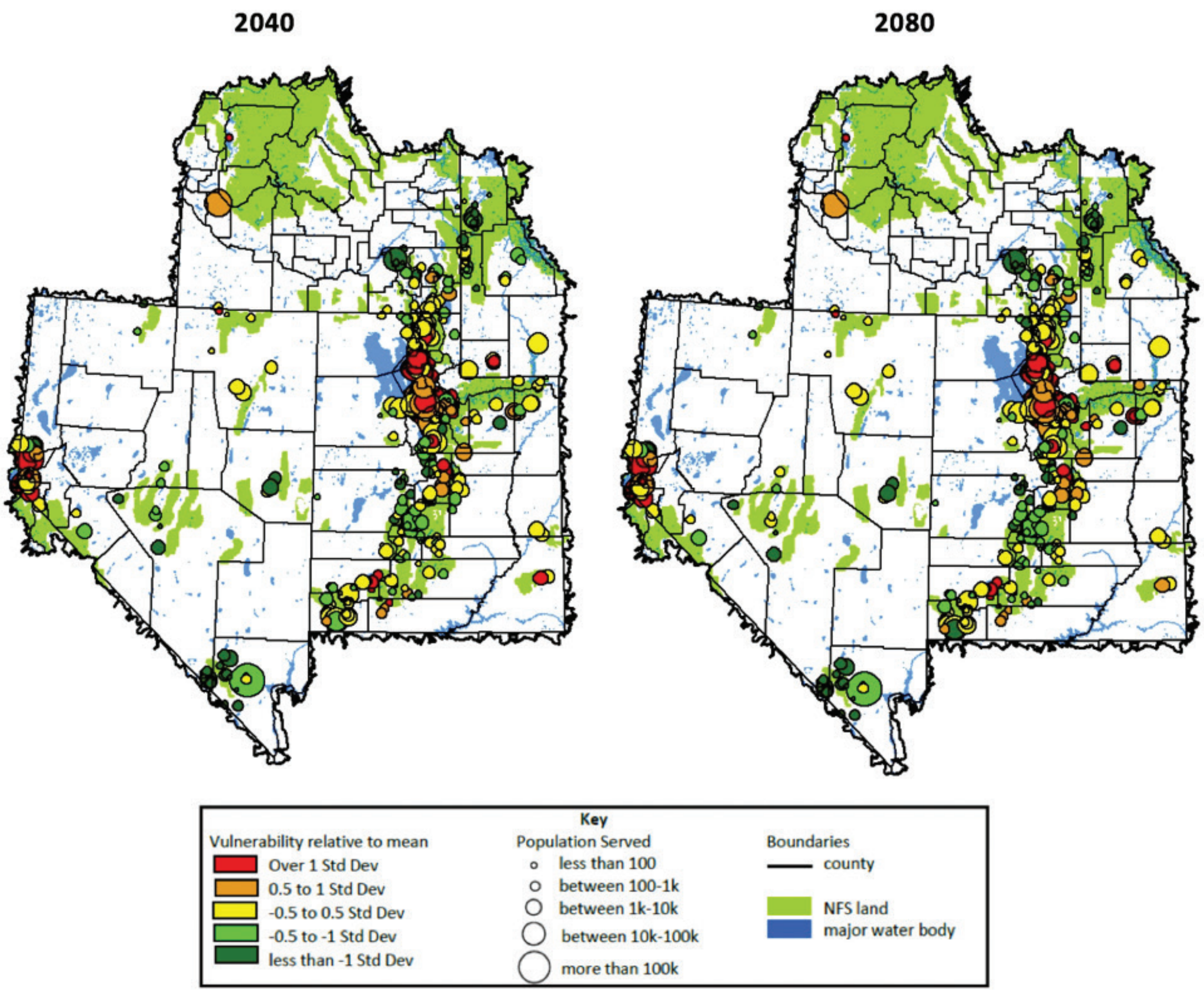

Figure 13.9—Municipal water system vulnerability. This is the final vulnerability measure for each water system. The measure is derived by summing the standardized measures of exposure and sensitivity less adaptive capacity for each system. The center of each circle is the central location of each drinking water system relative to intake locations.

and low-elevation riparian and wetland ecosystems are most at risk from climate change in the IAP region (Chapter 7).

Habitat, Ecosystem Function, or Species

Pollination by animals is a valuable ecosystem service provided to society by the western (or European) honey bee (*Apis mellifera*), native bees, other insect pollinators, birds, and bats (Pollinator Health Task Force 2015). Pollinators in systems ranging from wilderness to farmland serve a crucial role in the U.S. economy, food security, and environmental health. Honey bee pollination ensures crop production in fruits, nuts, and vegetables, adding $15 billion in value to U.S. agricultural crops annually. The value of pollinators in natural systems is more difficult to quantify because maintenance of natural plant communities through pollination contributes to a variety of ecosystem services (NRC 2007). The contribution of bees to ecosystems through pollination makes them a keystone species group in many terrestrial ecosystems (Hatfield et al. 2012).

Current Condition and Existing Stressors

Examples of local pollinator declines or disrupted pollination systems have been reported on every continent except Antarctica. Simultaneous declines in native and managed pollinator populations globally, with highly visible decreases in honey bees, bumble bees (*Bombus* spp.), and monarch butterflies (*Danaus plexippus*), have brought into focus the importance of pollinator conservation (Cameron et al. 2011; NRC 2007; Pettis and Delaplane 2010; van Engelsdorp and Meixner 2010; van Engelsdorp et al. 2010).

In 2014–2015, commercial beekeepers in the United States lost more than 40 percent of their honey bee colonies (Seitz et al. 2015). The parasitic *Varroa destructor* mite, introduced from Asia, has been attacking hives around the country (Traynor et al. 2016). Honey bees often suffer from poor nutrition because their usual diet of native flowers has been replaced in some areas by lawns and monoculture farmland. In addition, a class of pesticides known

Table 13.10—Municipal water system vulnerability in national forests.

National forest	Municipal systems	Population served	Exposure	Sensitivity less adaptive capacity	Vulnerability
Ashley	18	53,322	High	Low	Moderate
Boise	2	186,072	Very Low	Very High	High
Bridger	23	10,782	Moderate	Low	Low
Cache	83	398,296	Moderate	Very High	High
Caribou	22	66,615	Very Low	Moderate	Low
Curlew	2	449	Moderate	Moderate	Moderate
Dixie	50	148,365	Moderate	Moderate	Moderate
Fishlake	38	27,651	Moderate	Very Low	Low
Humboldt	15	21,718	Low	High	Moderate
Manti-La Sal	24	38,934	Very High	Low	Moderate
Payette	1	170	Very High	Moderate	Very High
Targhee	4	245	Moderate	Very Low	Very Low
Teton	22	13,452	Low	Very Low	Very Low
Toiyabe	99	2,070,860	Moderate	Moderate	Moderate
Uinta	54	463,766	Moderate	High	High
Wasatch	64	1,268,218	Moderate	Very High	Very High

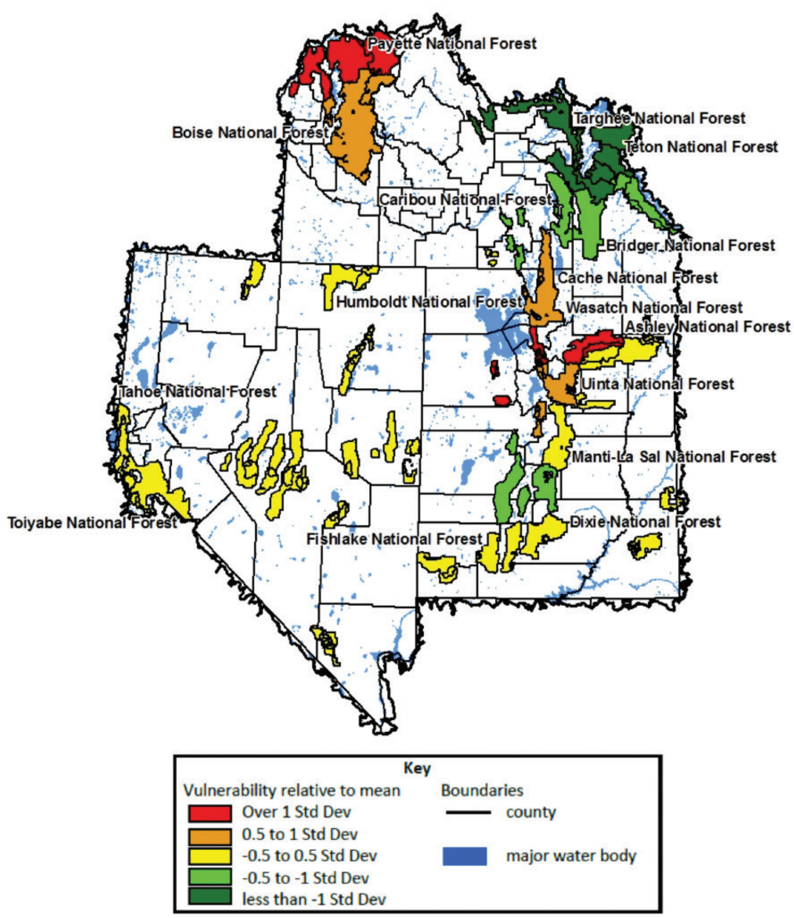

Figure 13.10—Water system vulnerability by national forest. Average vulnerability measure for each municipal water system is aggregated to the national forest level. Only water systems within one subwatershed (Hydrologic Unit Code 12) of national forest lands are included. Due to similarity after aggregation, this represents both 2040 and 2080 projections.

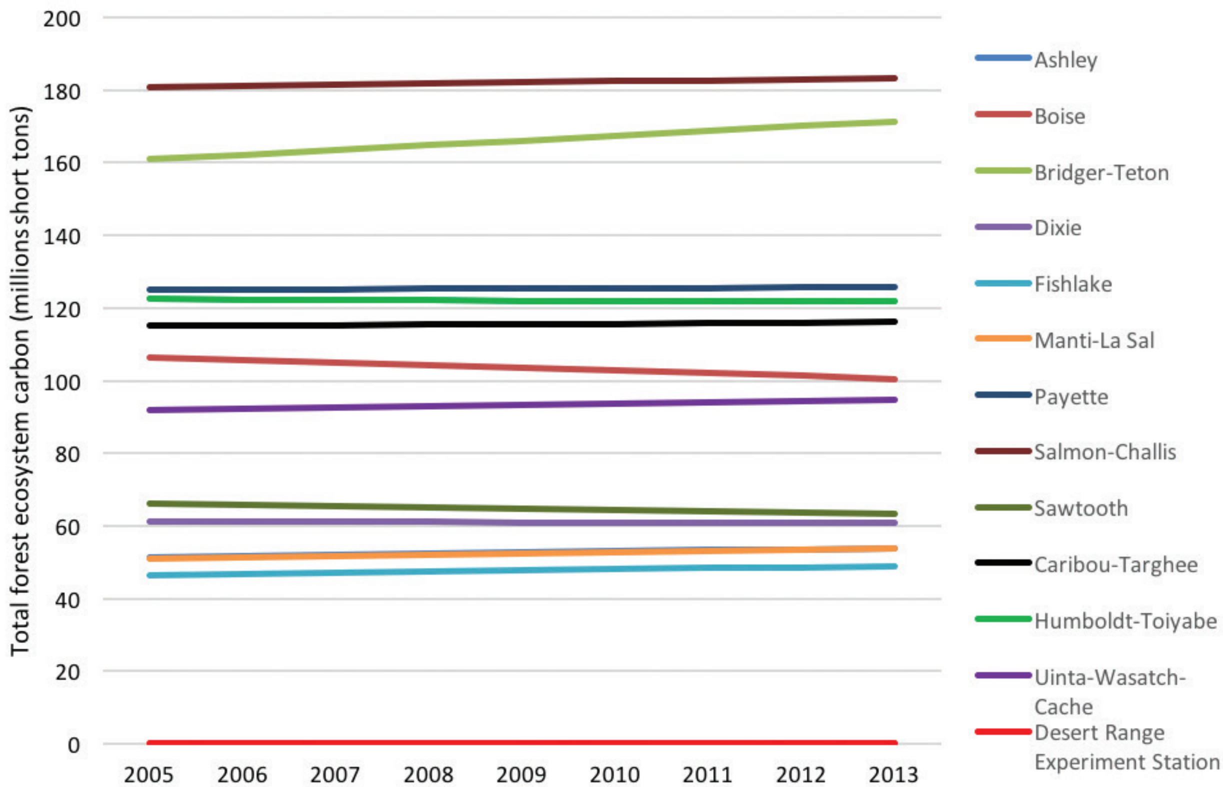

Figure 13.11—Total forest ecosystem carbon for national forests in the U.S. Forest Service Intermountain Region (2005–2013) (from O'Connell et al. [2016]).

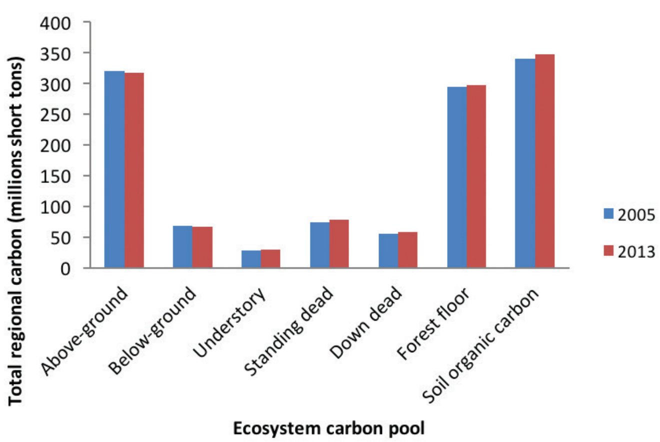

Figure 13.12—Carbon stocks in the seven forest ecosystem pools in national forest lands of the U.S. Forest Service Intermountain Region (2005 and 2013) (from O'Connell et al. [2016]).

as neonicotinoids may be affecting the nervous systems of insects, making them more susceptible to disease and pathogens.

Four species of bumble bees native to North America have declined by up to 96 percent and are estimated to no longer persist in up to 62 percent of ecoregions where they were historically present (Koch et al. 2012). These four historically abundant species are western bumble bee (*B. occidentalis*), *B. affinus, B. pennsylvanicus*, and *B. terricola*. Western bumble bee, native to the Pacific Northwest and Rocky Mountains (including Idaho), has decreased dramatically in abundance and range (Koch et al. 2012). Half of the bumble bee species found historically in the Midwest have declined or been extirpated, supporting observations of broader declines in North America (Grixti et al. 2009). The monarch butterfly population, which ranges throughout the IAP region, has declined to a small fraction of its previous size (Jepson et al. 2015). Monarchs that overwinter along the California coast lost 74 percent of their population in less than 20 years (Pelton et al. 2016).

Fifteen vertebrate pollinator species in the United States are listed as endangered by the U.S. Fish and Wildlife Service. The National Academy of Sciences noted that declines in many pollinator groups are associated with habitat loss, fragmentation, and deterioration; diseases and pathogens; and pesticides (NRC 2007). Availability of a variety of native plants is important because not all pollinators can gain access to the nectar found in introduced flowers. Pollinators also depend on availability of various flowering plants throughout a season. Habitat loss and degradation can negatively affect the timing and amount of food availability, thereby increasing competition for limited resources.

Increased fragmentation of habitats is particularly troublesome for pollinators that travel long distances. Migratory pollinators, such as the monarch butterfly, rufous

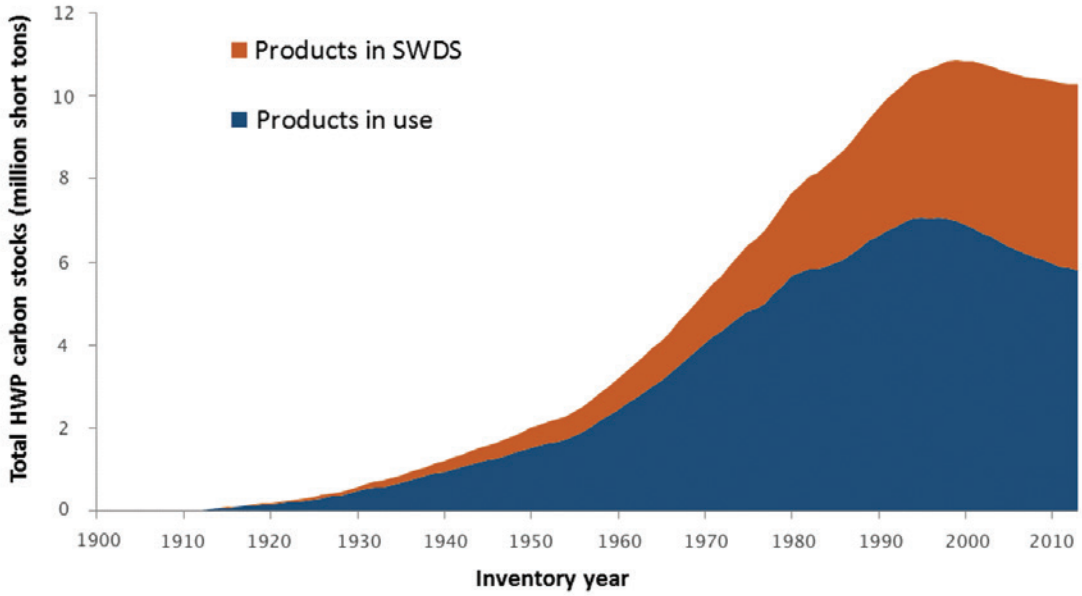

Figure 13.13—Cumulative total carbon stored in harvested wood products (HWP) manufactured from U.S. Forest Service Intermountain Region timber. Carbon in HWP includes products that are still in use and carbon stored at solid waste disposal sites (from Stockmann et al. [2014]).

hummingbird (*Selasphorus rufus*), and lesser long-nosed bat (*Leptonycteris yerbabuenae*), travel hundreds or thousands of miles each year as the seasons change. These trips require high levels of energy, and availability of food resources along the way is critical. Fragmentation of habitat increases the distance between suitable food and shelter sites along migratory routes, thereby disrupting the journey.

Agricultural and Grazing Practices

Monoculture farming and removal of buffer strips reduce suitable habitat for wild pollinators. Improper grazing practices may also adversely affect pollinators by removing pollinator food resources and by destroying underground nests and potential nesting sites, in some cases by trampling. Through allotment management planning, grazing systems can be managed to increase flowering plant diversity.

Pesticides

Insecticides affect pollinators directly through unintentional poisoning, and herbicides affect them indirectly through loss of insect forage and other wildflowers important in maintaining some insect populations. Increased dependence on pesticides is particularly problematic for managed honey bees because of their added exposure as crop pollinators. Overuse of pesticides occurs frequently, reaching unintended areas. In the case of aerial applicators, wind and human carelessness may extend actual coverage beyond the intended area, jeopardizing pollinators in areas within and adjacent to agricultural fields. This problem emphasizes the importance of buffer strips in agricultural areas, not only as habitat for pollinators, but as protection from overspraying of pesticide.

Introduced Species

Invasive plant species are considered by some to be the second most important threat to biodiversity, after habitat destruction (Westbrooks 1998). Introduced pathogens and parasites cause significant declines in both managed and native bee populations in North America. Honey bee colonies, both managed and feral, are being devastated by the parasitic *Varroa destructor* (Traynor et al. 2016). Similarly, the protozoan pathogen *Nosema bombi* causes problems for the western bumble bee and other bumble bees.

The most prevalent example of an introduced pollinator is the European honey bee, which has been imported to virtually every corner of the world. Despite its well-documented benefits to commercial agriculture, there is evidence that the honey bee has disrupted native pollination systems. Through competition for floral resources, honey bees reduce the abundance of native pollinators.

Unauthorized Bee Harvesting

Evidence of illegal harvesting of blue orchard (or mason) bees (*Osmia lignaria*) has been found on National Forests in the Intermountain Region. “Bee boxes” have been found on National Forests to encourage cocoon production in mobile boxes that are sold nationwide to orchard growers. These boxes have been placed long enough (several years) in the same places at high enough concentrations that an impact on sustainability and viability of the bees is probably occurring in multiple watersheds with suitable habitat.

Interactions and Compounded Effects of Stressors

The stressors discussed earlier are likely to interact with one another. For example, a lack of floral resources caused by intensive farming or ecosystem conversion from perennial native vegetation to nonnative annual grasses can lead to nutritional stress in insect pollinators, which, in turn, can make them more vulnerable to insect pests, diseases, and pesticides. The cumulative effects of these interactions are unclear, and more research is needed to identify the underlying causes of pollinator declines and interactions.

Current Management Strategies

Current management strategies focus on determining the status of pollinators and wildflower populations and the potential drivers of changes in these populations. In response to the global pollinator crisis, a 2014 presidential memorandum on pollinators directs Federal agencies to create a native seed reserve of pollinator friendly plants, create or enhance 7 million acres of pollinator habitat over the next 5 years, and incorporate pollinator health as a component of all future restoration and reclamation projects (The White House, Office of the Press Secretary 2014). The national strategy was implemented in May 2015 (box 13.3).

The Intermountain Region recently appointed pollinator coordinators on each of its National Forests, and these coordinators implement objectives of the national pollinator strategy and serve on teams to evaluate conditions and consequences of proposed management actions. If impacts to pollinators are expected, site-specific prescriptions are developed to prevent those impacts. Managing for pollinators involves providing basic habitat elements, including protecting, enhancing, or restoring wildflower-rich foraging habitat, providing hive site locations and nest sites for native bees, providing host plants for butterflies, and providing overwintering refuge for other insects (Mader et al. 2011).

The 2015 "Strategy to Promote the Health of Honey Bees and Other Pollinators" advances Federal commitments to increase and improve habitat for pollinators, directly through a variety of Federal facilities and lands, and indirectly through interactions with States, other organizations, and the public. Actions include planting pollinator gardens, improving land management practices at Federal facilities, and using pollinator friendly seed mixes in land management, restoration, and rehabilitation (box 13.4).

Demand is increasing for genetically appropriate seeds to restore plant communities on both public and private lands in the IAP region and elsewhere. The "National Seed Strategy for Rehabilitation and Restoration" (BLM 2015a) will foster collaboration among 300 non-Federal partners, 12 Federal agencies, private industry, and tribal, State, and local governments to guide the use of seed needed for timely and effective restoration.

The "Native Plant Materials Policy" (USDA FS 2012b) provides new direction on the use, growth, development, and storage of native plant materials. Objectives for the use of native plant materials in revegetation, rehabilitation, and restoration of aquatic and terrestrial ecosystems are to: (1) maintain, restore or rehabilitate native ecosystems so that they are self-sustaining, are resistant to invasion by nonnative species, or provide habitat for a broad range of species, or a combination thereof; (2) maintain adequate protection for soil and water resources through revegetation of disturbed sites that could not be restored naturally; (3) promote the use of native plant materials for the revegetation, rehabilitation, and restoration of native ecosystems; and (4) promote the appropriate use and availability of native and nonnative plant materials.

Box 13.3—Selected Excerpts from the 2014 Presidential Memorandum on Pollinators

Section 3A: Federal agencies will enhance pollinator habitat on managed lands and facilities through increased native vegetation (integrated vegetation and pest management) with application of pollinator friendly best management practices and pollinator friendly seed mixes (table 13.11).

Section 3B: Federal agencies will evaluate permit and management practices on power line, pipeline, utility, and other rights-of-way and easements, and consistent with applicable law, make necessary and appropriate changes to enhance pollinator habitat on federal lands through the use of integrated vegetation and pest management and pollinator friendly best management practices, and by supplementing existing agreements and memoranda of understanding with rights-of-way holders, where appropriate, to establish and improve pollinator habitat.

Section 3C: Federal agencies will incorporate pollinator health as a component of all future restoration and reclamation projects as appropriate, including all annual restoration plans.

Section 3F: Federal agencies will establish a reserve of native seed mixes, including pollinator friendly plants, for use on postfire rehabilitation projects and other restoration activities.

Section 3G: The U.S. Department of Agriculture will substantially increase both the acreage and forage value of pollinator habitat in the Department's conservation programs, including the Conservation Reserve Program, and provide technical assistance, through collaboration with the land-grant university-based cooperative extension services, to executive departments and agencies, state, local, and tribal governments, and other entities and individuals, including farmers and ranchers, in planting the most suitable pollinator friendly habitats.

Box 13.4—The 2015 National Strategy to Promote the Health of Honeybees and Other Pollinators

From Pollinator Health Task Force (2015):

Goals:

- Reduce honeybee colony losses to economically sustainable levels.
- Increase monarch butterfly numbers to protect the annual migration.
- Restore or enhance 7 million acres of land for pollinators over the next 5 years through Federal actions and public-private partnerships.

The Strategy addresses four themes central to the June 2014 Presidential Memorandum "Creating a Federal Strategy to Promote the Health of Honeybees and Other Pollinators":

- Conduct research to understand, prevent, and recover from pollinator losses.
- Expand public education programs and outreach.
- Increase and improve pollinator habitat.
- Develop public-private partnerships across all these activities.

The Intermountain Region Pollinator Friendly Plant Species

The Intermountain Region has identified 80 pollinator friendly plant species as a priority for seed production (table 13.11). This is a core list of native forbs and shrubs that are beneficial to pollinators and that have a high likelihood of being successfully propagated. The species are suitable for enhancing existing pollinator habitat and improving pollinator habitat in disturbed areas during revegetation activities (USDA FS 2015d).

Seed zones are areas within which plant materials can be transferred with little risk of being poorly adapted to their new location. There are typically two types of seed zones: (1) empirical seed zones determined by genetic studies and common gardens, and (2) provisional seed zones based on climatically similar areas. Seed zones help reduce failure of a seed source used in revegetation, reduce poor performance over time due to geographic and elevation effects, avoid contamination of native gene pools, and prevent seed sources from becoming overly competitive. This approach focuses on making available the most appropriate seed for a given location, providing genetically appropriate materials with a high likelihood of success when planted.

Sensitivity to Climatic Variability and Change

Altered disturbance regimes, habitat disruption from development, inappropriate livestock grazing, and spread of nonnative plant species interact to affect pollinator habitat in the IAP region. If the distribution and abundance of plant species shift significantly in a warmer climate, novel plant communities may develop, requiring an adaptive response by pollinators (Hegland et al. 2009).

Altered temperature and precipitation and their inherent variability have the potential to alter the vegetative landscape in the IAP region (BLM 2013). The timing and amount of precipitation will interact with temperature thresholds to potentially alter the structure and function of plant communities and ecosystems. Although the exact trajectory of this transition is uncertain, pollinator species will need to track changes in plant communities to ensure long-term survival of both the pollinators and plant-pollinator mutualisms.

Expected Effects of Climate Change

Bumble bees are vulnerable to climate change, especially at the edge of their range (Hatfield et al. 2012). Because bumble bees need flowering resources throughout their flight period, any changes in flowering phenology could have significant consequences. Altered temperature and precipitation could lead to unpredictable or unreliable flowering cues. At high elevation, earlier melting of snowpack is expected to reduce water availability in summer, resulting in low soil moisture and associated effects on vegetative productivity and flowering. Even a relatively small change in flowering phenology—a few days to a few weeks—could affect reproduction if flowering is asynchronous with pollinator activity. Pollinators will be most sensitive to altered plant phenology at the beginning and end of their flight seasons.

The ability of pollinators to move upward in elevation would facilitate adaptive response in some cases. In the Colorado Rocky Mountains, bumble bees have shown flexibility in altitudinal distribution in response to warmer temperatures, moving upwards as much as several hundred feet since the 1970s (Koch et al. 2012). In mountainous regions, upslope movement can result in reduced land area with suitable habitat and potentially "mountain top extinctions" (Dullinger et al. 2012). The ability of a plant or pollinator species to shift its range through propagule dispersal and the establishment of new populations will be critical (Dullinger and Hülber 2011; Dullinger et al. 2012),

Table 13.11—Pollinator friendly species designated by the USFS Intermountain Region.

Scientific name	Common name
Achillea millefolium ssp. *occidentalis*	yarrow
Agastache urticifolia	nettleleaf giant hyssop
Agoseris glauca	mountain dandelion
Agoseris grandiflora	big flower agoseris
Agoseris heterophylla	annual agoseris
Amelanchier alnifolia	Saskatoon serviceberry
Antennaria rosea	rosy pussytoes
Argemone munita	flatbud pricklypoppy
Astragalus calycosus	Torrey's milkvetch
Astragalus filipes	basalt milkvetch
Astragalus lonchocarpus	Rushy milkvetch
Asclepias speciose	showy milkweed
Balsamorhiza hookeri	arrowleaf balsamroot
Balsamorhiza sagittata	Hooker's balsamroot
Chaenactis douglasii	Douglas' dustymaiden
Cleome lutea	yellow spiderflower
Cleome serrulata	Rocky Mountain bee plant
Crepis acuminata	tapertip hawksbeard
Crepis intermedia	limestone hawksbeard
Cymopterus bulbosa	bulbous springparsely
Dalea ornata	blue mountain prairie clover
Dalea searlsiae	Searl's prairie
Dasiphora fruticosa	Shrubby cinquefoil
Erigeron clokeyi	Clokey's fleabane
Erigeron pumilus	shaggy fleabane
Erigeron speciosus	aspen/showy fleabane
Eriogonum heracleoides	parsnip flower buckwheat
Eriogonum umbellatum	sulfur-flower buckwheat
Eriogonum racemosum	redroot buckwheat
Erysimum capitatum	sanddune wallflower
Geranium viscossisimum	sticky purple geranium
Hedysarum boreale	Utah sweetvetch
Helianthus annuus	common sunflower
Heliomeris multiflora var. nevadensis	showy goldeneye
Heterothica villosa	hairy golden aster
Ipomopsis aggregata	scarlet gilia
Linum lewisii	Lewis flax
Lomatium grayi	Gray's biscuitroot

Table 13.11—*Continued*.

Scientific name	Common name
Lomatium triternatum	nineleaf biscuitroot
Lupinus argenteus	silvery lupine
Lupinus caudatus	Kellogg's spurred lupine
Lupinus prunophilus	hairy bigleaf lupine
Lupinus sericeus	hairy bigleaf lupine silky lupine
Machaeranthera canescens	tansyaster
Machaeranthera tanacetifolia	tanseyleaf tansyaster
Microseris nutans	nodding microseris
Packera multilobata	lobeleaf groundsel
Penstemon acuminatus	sharpleaf penstemon
Penstemon comarrhenus	dusty penstemon
Penstemon cyananthus	Wasatch beardtongue
Penstemon cyaneus	blue penstemon
Penstemon cyanocaulis	bluestem penstemon
Penstemon deustus	scabland penstemon
Penstemon eatonii	firecracker penstemon
Penstemon leiophyllus	smoothleaf beardtongue
Penstemon ophianthus	coiled anther penstemon
Penstemon pachyphyllus	thickleaf beardtongue
Penstemon palmeri	Palmer's penstemon
Pensetmeon procerus	little flower penstemon
Penstemon rostriflorus	bridge penstemon
Penstemon speciosus	royal penstemon
Penstemon strictus	Rocky Mountain penstemon
Phacelia hastata	silverleaf phacelia
Phlox hoodia	spiny phlox
Phlox longifolia	longleaf phlox
Polemonium foliosissimum	towering Jacob's-ladder
Potentilla crinita	bearded cinquefoil
Purshia tridentata	antelope bitterbrush
Solidago canadensis	Canada goldenrod
Sphaeralcea coccinea	scarlet globemallow
Sphaeralcea grossulariifolia	gooseberryleaf globemallow
Trifolium gymnocarpon	hollyleaf clover
Vicia americana	American vetch

especially for alpine endemics that may have limited life history options.

Nonnative plant species are already degrading and replacing native plant communities in the IAP region, thus reducing availability of floral resources. A warmer climate is expected to make nonnative species even more competitive in some locations, especially lower elevations dominated by shrubs and grasses. Floral resources in spring and fall migration corridors for monarch butterflies between over-wintering habitat (California, Oregon) and summer breeding locations (Nevada, Idaho, Utah) are already degraded, and additional habitat fragmentation in a warmer climate would cause further degradation.

Ecological Restoration

Landscapes that retain functionality in a warmer climate will have greater capacity to survive natural disturbances and extreme events in a warmer climate. Ecological restoration addresses composition, structure, pattern, and ecological processes in terrestrial and aquatic ecosystems, typically with a focus on long-term sustainability relative to desired social, economic, and ecological conditions. Including pollinators as a consideration in climate change adaptation will assist other restoration goals related to genetic conservation, biodiversity, and production of habitat for endemic species. Increasing the capacity of Federal agencies to mitigate current damage to pollinator populations and facilitate improvement of habitat will contribute to both restoration and climate change adaptation (box 13.5).

Box 13.5—Building Organizational Capacity to Improve Pollinator Habitat

Management of pollinator decline is based on avoiding or reducing the spread of new and existing diseases and pathogens, reducing pesticide use, and improving the resistance and resilience of native plant communities by encouraging or planting a wider variety of regionally appropriate pollinator friendly plant species. The following action items are encouraged:

- Assign a point of contact for pollinators and native plant materials development on each Intermountain Region unit.
- Plant pollinator gardens to raise awareness about pollinator decline for the public, decisionmakers, and resource specialists.
- Interpret/improve best management practices for pollinators.
- Assess pollinator issues of greatest need for different locations.
- Develop revegetation guidelines, including seed mixes by habitat type and seed transfer zones; include this document in updated plans.
- Assess the need for increased seed supply by species.
- Focus seed collection and material development on areas anticipated to have the greatest need.
- Actively engage in outreach and education about pollinator declines and climate change.
- Identify appropriate areas for apiary (honeybee colony) permits.
- Improve and maintain pollinator habitat through appropriate grazing management.

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