Major Land-Management Activities and Natural Disturbances Considered in This Assessment

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Chapter 4 of
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Chapter 4. Major Land-Management Activities and Natural Disturbances Considered in This Assessment

By Shuguang Liu[1], Jennifer Oeding[2], Zhengxi Tan[3], Gail L. Schmidt[2], and Devendra Dahal[2]

4.1. Introduction

Carbon stocks and fluxes of ecosystems are strongly influenced by, among other factors, land-management activities and natural disturbances. The U.S. Forest Service (USFS) estimated that approximately 4.05 million hectares (or 1.3 percent) of forested land is harvested each year (W.B. Smith and Darr, 2004), which may significantly affect the carbon cycle at local to national levels (Cohen and others, 1996; Pan, Birdsey, and others, 2011). Although the effects of natural disturbances and land management on carbon dynamics are significant, few datasets exist that adequately describe the spatial and temporal characteristics of various land-management activities. This chapter provides a brief review of major natural disturbances and land-management activities in the Western United States in relation to carbon sequestration, describes the status of data availability for the activities, and introduces those activities that were included in the assessment and their data-processing steps. Wildland fires are the most significant natural disturbances in the Western United States. Chapters 3 and 8 of this report provide extensive treatment of wildland fires; therefore, the primary focus of this chapter is on the land-management activities that were considered in the modeling process for this assessment.

4.2. Review of Major Land-Management Activities and Natural Disturbances

Major land-management activities and natural disturbances, their impacts on carbon dynamics, and the status of the geospatial data layers characterizing their spatial and temporal changes in the Western United States are briefly reviewed below.

4.2.1. Forest Harvesting

There are many examples of forest harvesting data at a local scale, but they are rarely available at a national or regional scale in a spatial format. The USFS Forest Inventory and Analysis (FIA) Program (USDA Forest Service, 2012b) provides nationwide information on the extent, condition, volume, growth, and removal of trees. The FIA is the best available resource for information on forest-management activities and its database was extensively used in support of this assessment. On the other hand, the FIA is a site-specific characterization of forest conditions, which was both an advantage and a limitation. The lack of wall-to-wall geospatial information from the FIA often made it difficult to identify the real clearcutting patterns for modeling efforts over a large area. Current approaches that merge remotely sensed land-cover-change information with FIA inventories have shown promising results (for example, Hicke and others, 2007; Goward and others, 2008; Cho-ying Huang and others, 2010; D.P. Turner, Gockede, and others, 2011; Williams and others, 2012).

4.2.2. Wildland Fires

Wildland-fire combustion releases carbon into the atmosphere and resets the pathways for carbon-sequestration across the landscape (Running, 2008). For this assessment, the treatment of both the baseline and the projected future potential fire emissions is covered in chapters 3 and 8; the fire-extent and fire-severity data layers were used to support the biogeochemical modeling (see chapters 5 and 9).

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4.2.3. Insects and Disease

Insects and disease, such as the western pine bark beetle, cause extensive defoliation, mortality, and reduced carbon stocks in forests across the Western United States (Fellin and Dewey, 1992; Man, 2010; Pfeifer and others, 2011). The carbon-cycle processes that are affected by insects or disease depend on the type of disturbance and whether it causes defoliation or tree mortality (S. Liu and others, 2011). The USFS FIA database (USDA Forest Service, 2012b) contained information related to the types and severity of insects and disease and related information on defoliation and mortalities; however, the database was limited by a lack of repeated inventories, which limited the analysis for insects and disease.

4.2.4. Grazing on Grasslands and Shrublands

Grazing on grasslands and shrublands in the Western United States, particularly in the Great Basin and the Colorado Plateau, is a leading land-use activity and has had a major effect on the carbon cycle and other qualities of the landscape (Wagner, 1978; Crumpacker, 1984; Fleischner, 1994). Many studies have documented the effects of grazing on carbon cycles (for example, Lal, 2004; Derner and Schuman, 2007; Schuman and others, 2009), but often at the local scale. The USGS carbon-sequestration assessment for the Great Plains (Zhu and others, 2011) relied on assumed relationships between the animal unit month (AUM, the amount of forage required by an animal unit for one month; Ruyle and Ogden, 1993) and carbon removal, but the uncertainty was very high. Ultimately, any regional or national assessment of the effects of grazing is limited by the absence of synthesized data or a georeferenced database.

4.2.5. Crop Rotation and Tillage

Tillage is one of the major land-management activites that could substantially affect carbon storage in and GHG fluxes from the soil (Ogle and others, 2005; Alluvione and others 2009). Crop rotation, residue management, and tillage practices are exercised in all agricultural areas of the Western United States. In practice, both residue management and tillage practices (either no tillage, conventional tillage, or reduced tillage) are commonly coupled to form a cropping system. The data by acreage for both practices are usually reported as county-based statistics by the Conservation Technology Information Center (CTIC, 2012). For this assessment, although the CTIC data were not georeferenced, they were allocated to each crop type using a method by Schmidt and others (2011).

4.2.6. Irrigation and Drainage

The Snake River Plain and Columbia River Basin support agriculture production (row crops, hay and pasture) with large-scale irrigation projects. Irrigation can increase soil moisture, improve crop yields, and potentially enhance carbon sequestration in soil (Lal and others, 1998). The drainage of wet soils may increase crop and animal productivity and reduce methane emissions, but it may also lead to a loss of soil organic carbon (SOC) stock by increasing the decomposition of soil organic matter and the leaching of dissolved organic carbon (Watson and others, 2000); however, data about irrigation are limited (Wu and others, 2008). A nationwide MODIS-derived dataset about irrigated agriculture (MIrAD-US) was developed by the USGS for 2002 (USGS, 2010) and 2007 (Pervez and Brown, 2010) at both 1,000-m and 250-m resolution. They are available at USGS (2010).

4.2.7. Manure Application

Manure is widely used in agricultural fields to supply nutrients because of the high price of fertilizers (Lentz and Lehrsch, 2010). According to MacDonald and others (2009), about 15.8 million acres of cropland, equivalent to about 5 percent of all cropland in the United States, are fertilized with livestock manure. Data on manure production and application are usually estimated through the USDA's Agricultural Resource Management Survey (ARMS; USDA Economic Research Service, 2011a). The EPA estimated the annual manure-related GHG emissions at both State and national levels on the basis of annual yields of animal products and determined that manure application was one of the major contributors to the total GHG emissions from agricultural lands, amounting to up to 19.88 $TgCO_{2-eq}$ in 2010 over the Western United States, of which California made the greatest contribution (52 percent), followed by Idaho (about 20 percent) (EPA, 2012).

4.3. Data Processing for Major Land-Management Activities and Natural Disturbances Included in the Assessment

As with the Great Plains assessment conducted by the USGS (Zhu and others, 2011), this assessment relied on nationwide geospatial data layers in order to characterize the spatial and temporal dynamics of land-management activities and natural disturbances (Schmidt and others, 2011). Table 4.1 lists the data layers used for major land-management activities and natural disturbances for this assessment and figure 4.1 depicts the spatial patterns of some data layers for 2005.

The spatial resolution of some of the data layers in table 4.1, especially those derived from censuses and inventories, was at the county, State, or FIA-unit level. These data layers were further downscaled to pixels to generate spatially explicit map layers using a Monte Carlo procedure, land cover, and other information (Schmidt and others, 2011). The most common pixel resolution among all the map layers was 250 meters. The data covered the time period from 1992 to 2050 on an annual basis. Annual maps showing areas of forest clearcutting were produced as part of the LULC-change modeling detailed in chapter 2 of this report. Annual maps of wildland-fire disturbances were modeled using an approach described in chapter 3 of this report.

Table 4.1. Summary of data for the major land-management activities and natural disturbances that were considered as part of this assessment.

[CFS, Canadian Forest Service; CTIC, Conservation Technology Information Center; m, meter; NA, not applicable; PRISM, parameter-elevation regressions on independent slopes model; USDA, U.S. Department of Agriculture; USDA ERS, USDA Economic Research Service; USDA FIA RPA, USDA Forest Inventory Analysis Resource Planning Act; TPO, timber product output; USGS, U.S. Geological Survey]

| Type	Source	Spatial resolution	Time period	Reference
Crop management				
Crop yield	USDA crop yield table	County	1992–2050	USDA National Agricultural Statistics Service (2011).
Fertilization	USDA ERS fertilization table	County	1992–2050	USDA Economic Research Service (2011b).
Manure	USDA manure table	County	1996–2050	USDA Economic Research Service (2011a).
Tillage	CTIC tillage table	County	1992–2050	CTIC (2011); USDA Economic Research Service (2011a).
Irrigation	USGS	250 m	NA	USGS (2010).
Derived crop management				
Derived crop type, manure, tillage, and fertilizer	Derived grids for this assessment	250 m	1992–2050	Schmidt and others (2011).
Fire				
Extent, severity, frequency	This assessment	250 m	1992–2050	Chapters 3 and 8 of this report.
Forest clearcuts				
Forest-stand age	USGS Land Cover Trends Project	250 m	1992–2050	USGS (2012a).
Timber product output	TPO from USDA FIA RPA	State	2002	USDA Forest Service (2011)
Drought				
Precipitation	PRISM and CFS	250 m	1992–2050	Canadian Forest Service (2012); PRISM Climate Group (2012).

A. Land cover, 2005
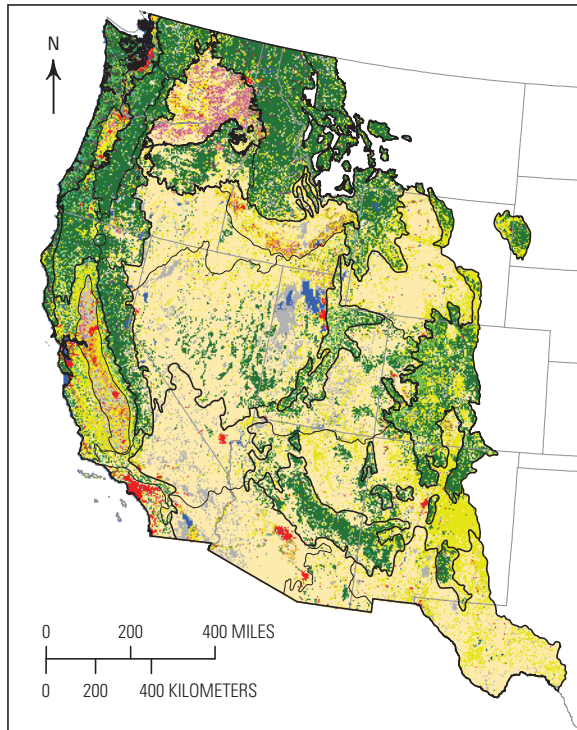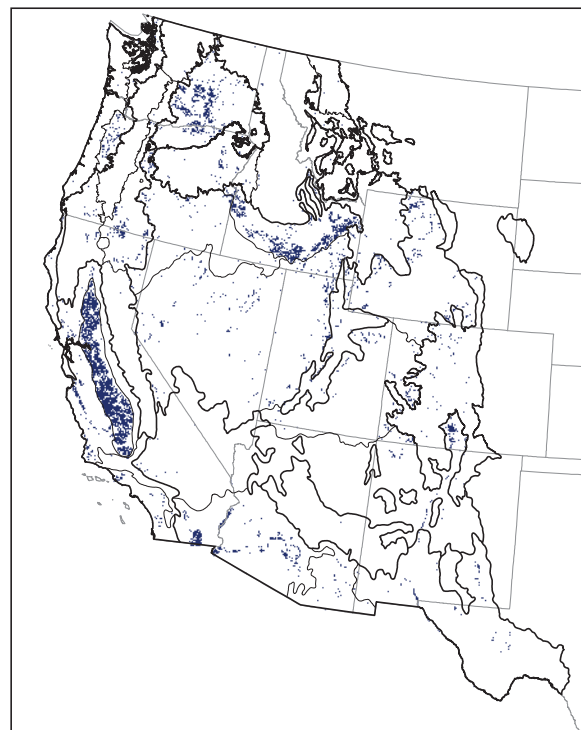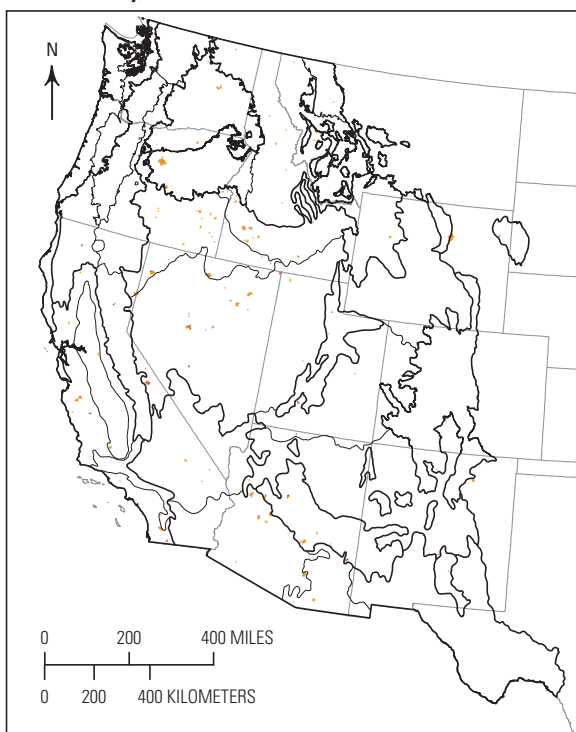
B. Manure, 2005
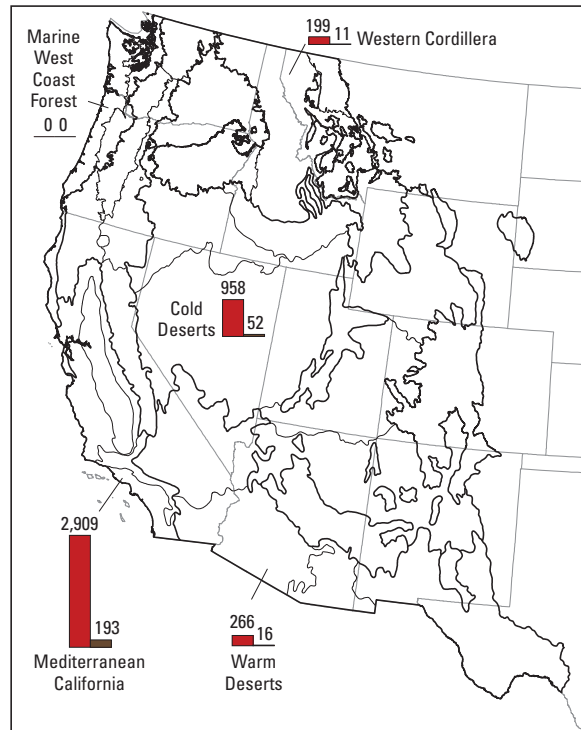
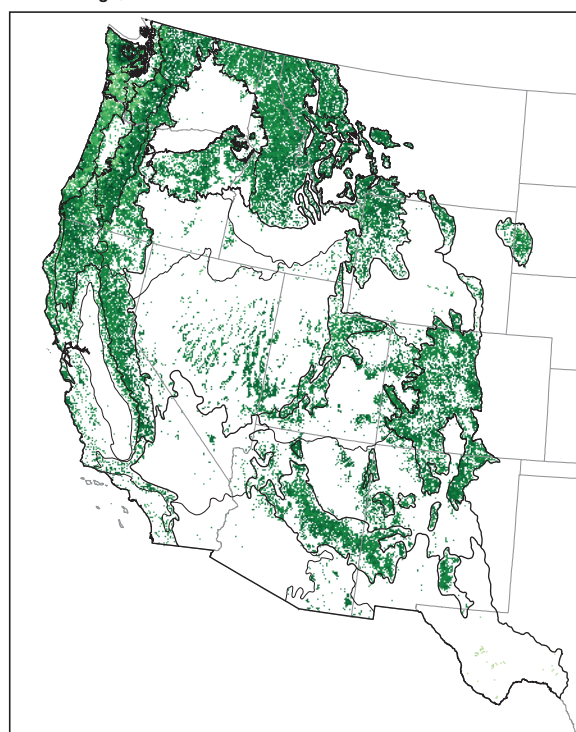*C.* Tillage, 2005
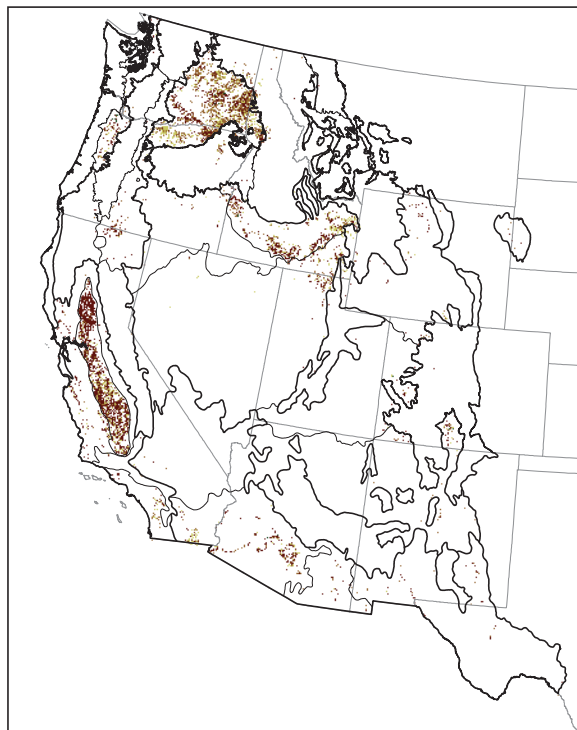
D. Irrigation, 2005

Figure 4.1.   Maps showing examples of the data layers for land-management activities and natural disturbances in the Western United States for 2005. *A*, Land cover. *B*, Manure. *C*, Tillage. *D*, Irrigation. *E*, Fire severity. *F*, Stand age. See figure 1.1 in chapter 1 for ecoregion names.

E. Fire severity, 2005

F. Stand age, 2005

EXPLANATION

Land use and land cover

- Water
- Developed
- Mechanically disturbed national forest
- Mechanically disturbed other public land
- Mechanically disturbed private land
- Mining
- Barren
- Deciduous forest
- Evergreen forest
- Mixed forest
- Grassland
- Shrubland
- Hay/pasture
- Woody wetlands
- Herbaceous wetlands
- Perennial ice/snow

- Barley
- Beans
- Corn grain
- Corn silage
- Cotton
- Flaxseed
- Lentils
- Sorghum silage
- Oats
- Peanuts
- Peas
- Potatoes
- Rice
- Rye
- Safflower
- Sorghum
- Soybeans
- Sugarbeets
- Sunflowers
- Tomatoes
- Wheat durum
- Wheat spring
- Wheat winter

Total manure application per level II ecoregion—In kilograms

1,500
750
Carbon
Nitrogen

Tillage
- None
- Ridge
- Mulch
- Reduced
- Conventional

Irrigation
- Non-irrigated
- Irrigated

Fire severity
- Low
- Moderate
- High

Stand age—In years
- 0
- 1 to 5
- 6 to 10
- 11 to 15
- 16 to 30
- 31 to 50
- 51 to 100
- 101 to 250
- >250

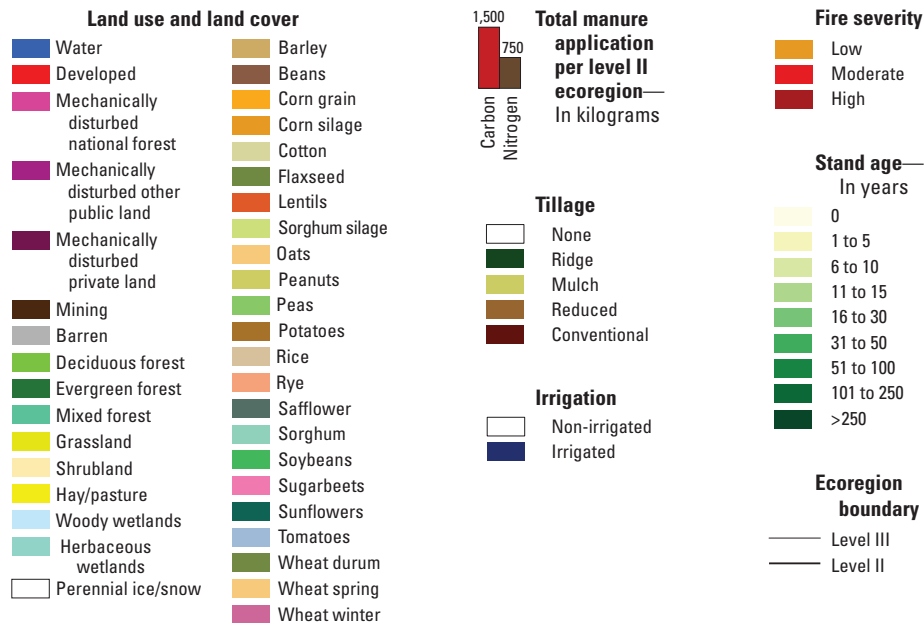**Ecoregion boundary**
- Level III
- Level II

Figure 4.1.—Continued

The crop-management information used in this assessment includes crop type, crop rotation, fertilization, manure addition, tillage practices, irrigation, and harvesting practices. All of the crop-management activities were specific to various crops and locations. All of the pixels representing agricultural lands in the land-cover data layers, generated in the LULC mapping and modeling process described in chapter 2 of this report, were downscaled (using a probability-based Monte Carlo approach) to crop types according to the crop-composition information derived from the USDA agricultural census data (USDA National Agricultural Statistics Service, 2011). All of the crop-management data layers (except irrigation) were subsequently generated from these land-cover data layers and more than 20 major crops were presented consistently for the United States (Schmidt and others, 2011). The tabular data about manure application were derived from the USDA census (USDA, Economic Research Service, 2011a), which included, for each crop type in each State, the following information: the State Federal Information Processing Standard (FIPS) code, the year, the total planted area, the percentage of the planted area that was treated with manure, the amount of manure that was applied, the rate at which the manure was applied, the rate at which the nitrogen in the manure was applied, and rate at which the carbon in the manure was applied. A gridded manure dataset for all agricultural lands in the region was generated from this tabular data along with the land-cover maps using a Monte Carlo procedure.

The information about tillage practices was acquired from the CTIC in tabular format. The tabular data include the following information: the State FIPS code, the year, the total planted area that was tilled, the total percentage of residue on all tilled areas, the planted area for each tillage type, and the percentage of residue for each tillage type by crop type within the State. The tillage practices included in the database included conventional, mulch, no-till, reduced, and ridge tillage. A gridded dataset showing the spatial and temporal changes of tillage practices for all agricultural lands was generated from this tabular data along with the land-cover maps using a Monte Carlo procedure. Figure 4.1 shows the spatial distribution of tillage practices in the Western United States in 2005. An irrigation map derived from the MODIS for the United States (USGS, 2010) was used to characterize the locations of irrigated land. Because of the lack of data showing the temporal changes in irrigation across the Western United States, this assessment assumed that the locations of irrigated land did not change over time during the assessment period.

Only nitrogen fertilization was considered in this assessment. A nationally consistent procedure was put in place to generate crop- and location-specific nitrogen-fertilization data for all croplands (see Schmidt and others, 2011). The tabular dataset included the State FIPS code, year, the total planted area where nitrogen fertilizer was applied, the percentage of total area that was fertilized with nitrogen, the rate of application for nitrogen fertilizer, and the total amount of nitrogen fertilizer applied for each crop type within each State. Because several States in the Western United States did not report this information, this assessment assumed that croplands were automatically fertilized every year in order to satisfy growth requirements.

4.4. Land-Management Activities or Natural Disturbances Not Included in the Assessment

Because of the lack of input data and constraints on resources, this assessment did not explicitly consider the following activities:

- Selective or partial forest cutting. One of major factors driving carbon dynamics in forest ecosystems is selective or partial forest cutting, which should have been considered for the modeling steps in this assessment. Unfortunately, there were no spatial datasets available that characterized the spatial and temporal changes of selective or partial forest cutting in the Western United States.

- Insects and diseases. Various studies and inventories of natural disturbances by insects and diseases have been conducted at a broad regional scale. For example, Raffa and others (2008) provided an estimate of forest mortality caused by bark beetle eruptions in western North American forests. These types of data were not included in this assessment because their spatial and temporal extents and resolution were usually limited.

- Grazing. Grazing on grasslands and shrublands is extensive and varies in both time and space; however, there are no geospatial datasets available that characterize grazing in the Western United States.