An AmeriFlux network perspective on urban and managed systems[1]

Prepared for the U.S. DOE BERAC Workshop on the potential Integrated Field Laboratory (IFL)[2]

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Summary

This white paper brought together expertise of the AmeriFlux community to identify gaps and offer recommendations to improve understanding of human-dominated and managed landscapes. It provides a brief review of socioeconomic, energy, water, ecological, and biogeochemical aspects of human-dominated ecosystems, and highlights the value of collecting observations from gradients that span urban/suburban, managed, and relatively unmanaged ecosystems, in different geographical areas and socioeconomic conditions. The white paper is divided into three sections: AmeriFlux Network Now, Research and Data Needs in Urban Ecosystem Studies and Research and Data Needs in Managed-to-natural landscapes.

Summary Table: Gaps, Uncertainties, and Recommendations

Gaps and uncertainties
• What is the influence of urban expansion on natural and managed terrestrial ecosystems? • What processes drive the changes in urban ecosystem structures? • How do urban ecosystem structures/patterns affect ecosystem functions? • How do land management practices exacerbate or improve adaptation of ecosystems to climate change? • Where are ecosystems most vulnerable to state changes? • To assess vulnerability of key forest species to climate-related stress and mortality, determine their physiological tolerances to climate parameters. • How do different management intensities affect biophysical properties such as microclimate, albedo and other feedbacks to climate? • How do changes in land use and management affect the carbon balance (years to decades)? • Geographic regions where earth system predictability is poorly understood, now under-sampled, and demonstrate climatic sensitivity and large source of uncertainty: Western US forests, North Central US forests bordering Canada, forests in mountainous terrain.

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[2] Prepared in response to a request by James Ehleringer and Anthony Janetos for a BERAC-led workshop to be held in Germantown, Maryland, January 29-30, 2015 that will explore science questions related to the potential development of an Integrated Field Laboratory (IFL) with a focus on urban and managed systems.

Recommendations

- Develop or support and expand existing flux sites and long-term plots along climatic gradients with nested land-use gradients within them. Establish several such gradients within U.S., with shared measurement and data protocols. Include urban-suburban-managed/wetland gradients.
- Develop sampling and observation approaches that account for spatial heterogeneity and advection across landscape components with different land use, disturbance levels and management history.
- Fill the cross-cutting gap in BER sciences (soils, vegetation) that limits understanding of Earth science predictability across geographic regions (e.g., assess vulnerability of terrestrial ecosystems to climate-related stress, biophysical and biogeochemistry processes affected by climate and land use interactions).
- Support development of integrated sensor systems and sensor system networks that are capable of measuring multiple variables of socioeconomic and environmental interests; for example, methane leaks, CO_2 emissions, urban heat island, cooling requirements.
- Support the training of urban ecosystem scientists at the IFL

The AmeriFlux Network Now

The AmeriFlux network consists of 210 sites located in 12 of the 17 IGBP land cover classes, with most sites in forests (30%) and Grasslands (14%) (Table 1). Urban areas make up a small percentage of the global land surface, though they have outsize importance, as discussed below. Although urban areas have outsized importance, as discussed below, currently, only 1% of AmeriFlux sites are urban.

Land management is not as easily observable as is land cover. Based on AmeriFlux metadata[3] and a January 2015 survey of U.S. AmeriFlux PIs, management information is available for 97 AmeriFlux sites (Table 2, Figure 1, Appendix 1). Half (51%) of these sites are managed in some way. Forestry is the most common management type (29%) and 21% undergo agriculture, grazing, hydrologic management or urban land use. For comparison, roughly 54% of earth's surface was used for agriculture, grazing, or urban land use, 1990-2000 (Sterling and Ducharne, 2008). This comparison should be repeated with U.S. (for the IFL) and Pan-American (for the whole AmeriFlux network) regions, to evaluate if urban, grazing, and agriculture are underrepresented land uses among AmeriFlux network sites. It appears the existing AmeriFlux network is more representative of natural ecoregions (Hargrove and Hoffman, 2005), while managed ecosystems are dynamic and high on the disturbance spectrum. There are some useful AmeriFlux sites (and site-clusters) that would contribute research on urban water, ecology, and health, and interactions along managed-to-natural gradients that an IFL could leverage, but development of an IFL may motivate new instrumentation to create a comprehensive and integrated 'Laboratory' in these landscapes.

Table 1. Land cover classes represented by AmeriFlux sites

IGBP Class	No. Sites	%	Description
ENF	62	30%	Evergreen needleleaf forests
GRA	30	14%	Grasslands
OSH	24	12%	Open shrublands
DBF	21	10%	Deciduous broadleaf forests
WET	21	10%	Wetlands
CRO	21	10%	Croplands
MF	9	4%	Mixed forests

[3] In AmeriFlux, site metadata, including land management, are gathered via a common protocol. AmeriFlux investigators report recent and historic disturbance and management events, and this information is stored in a common database, linked to the site flux data sets. To expand management data coverage beyond what was available from this database, a survey of U.S. AmeriFlux PIs was conducted in January 2015 for this white paper.

CSH	7	3%	Closed shrublands
EBF	6	3%	Evergreen broadleaf forests
WSA	3	1%	Woody savannas
URB	3	1%	Urban
BSV	1	0.5%	Barren or sparsely vegetated
Total	*208*	*100%*	

Table 2. Dominant management at North American AmeriFlux sites where management data are available (97 sites reporting)

Management	Count	Percentage
Not managed	48	49%
Forestry	28	29%
Agriculture	10	10%
Grazing	7	7%
Urban	3	3%
Hydrologic management	1	1%
Total	*97*	*100%*

Figure 1. AmeriFlux tower sites in North America for which land management data are available.

Research and Data Needs in Urban Ecosystem Studies

Urban areas are the most human-dominated systems on Earth. More than 50% of the world's population resides in urban areas, and is growing due to rapid urbanization in developing countries, and surbanization (urban sprawling) in developed countries (Grimm et al. 2008). Even though urban areas occupy less than 5% of total land area on Earth, their ecological footprints (the total land area needed to support an urban area) are hundreds of times larger (Rees and Wackernagel 1996). Fossil fuel CO_2 emissions related to direct (i.e., passenger vehicle use) and indirect (i.e., electricity use) energy use in urban areas often dominate regional and national anthropogenic greenhouse gas (GHG) emissions (McMahon et al. 2007).

The intersection of climate change, extreme events (e.g., droughts, heat waves) and a host of urban environmental issues (e.g., air quality, heat island effects) have profound implications for the health and well-being of urban residents. Furthermore, given their large role in GHG emissions and proportion of global population, key mitigation and adaptation activities must be operationalized in urban areas. Yet, historically urban systems have been developed and managed with essentially no input from the ecological sciences and with little consideration of climate change. To enable this capacity requires development of urban ecological theory, portable observation/attribution systems, and eco-biophysical socioeconomic modeling.

Development of urban ecological theory. Current ecological science concepts, theories, frameworks, and methodologies have been developed with little incorporation of humans and their engineered landscapes.. To understand and predict the evolution, structure and functioning of urban systems in our changing environment, a new urban, human-centric ecological theory is needed.

Distributed, integrated observation/attribution systems. Measurable variables that reflect and affect urban ecosystem functioning are diverse. These include variables obtained by instruments at fixed locations, for example, meteorological variables, concentrations and fluxes of greenhouse trace gas species (e.g., CO_2, CH_4, N_2O and ozone), and particulate matter (e.g., PM10 and PM2.5). For these measurements to be useful to policy makers, a capacity to detect, attribute (through tracers and dispersion modeling), locate and track gas and PM emissions and airborne concentrations is also needed. Such measurement systems should be massively distributed to capture spatial variability over a range of time scales to understand the evolution of urban ecosystems with socioeconomic change. Further, urban measurement systems should have integrative capabilities to provide links across urban, weather and climate scales. In addition, portable and mobile systems can provide useful information regarding the highly heterogeneous urban areas and provide improved understanding of emerging gaps in knowledge and understand of urban systems.

Eco-biophysical socioeconomic modeling. Although there have some efforts in modeling urban systems, such efforts are, in general, disciplinary and have not been supported by observations. Even some disciplinary questions are not clearly understood. For example, it has been generally believed that urban heat island effect is caused by reduced evaporative cooling, but a recent modeling study suggests that heat convection and local background climate are largely responsible for this effect (Zhao et al. 2014). Multidisciplinary approaches that cut across natural and social sciences are needed to develop models of mass and energy flows within and across urban ecosystems to model urban dynamics in a changing environment.

Earth System Modeling. An important consideration for urban areas is climate change mitigation and impact assessment. Many of the GHG emission mitigation activities identified by the IPCC reviews could be enacted in urban areas, which represent concentrations of economic and social activity. Yet, there is limited knowledge regarding the controls, drivers, and quantitative flows of GHG emitting activities. Furthermore, existing information is often of limited use to local stakeholders and decision-makers due to lack of standardization, space/time detail and functional attribution.

Large-scale changes in climate and locally driven changes such as urban heat islands are expected to cause increases in urban temperatures in some regions. Urban warming has direct effects on human welfare through heat stress and heat-related mortality during heat waves. In combination with changing economic factors, it also has indirect effects on the amount of GHG emissions through increased building energy use (Sivak 2009, 2013). Urban development and changes in urban land management, such as planting practices, plant functional type composition, and irrigation, could mitigate or enhance large-scale temperature changes, resulting in significant uncertainty for urban climate outcomes.

The lack of sufficient spatial and temporal observations (atmospheric, ecological and social/economic variables) in highly heterogeneous urban systems presents challenges in upscaling and downscaling urban fluxes for linking local scale changes to climate scales. This requires modeling systems that capture detailed urban fluxes at the meter scale, where decisions are made.

However, land-atmosphere fluxes of energy, water, and CO_2 in cities, suburbs, and other developed landscapes are poorly represented in the flux observation database for the U.S. And, while fundamental characteristics of urban "canyon" radiative exchange have recently been included in the urban module of land-surface models such as CLM (Oleson et al. 2010), they currently do not include a parameterization of vegetation, which is significant in most urban, suburban, and other developed areas of the U.S. (Chen et al. 2012). There is a pressing need for flux observations and mechanistic studies that quantify how the surface energy budget changes along gradients of urban density and morphology, as well as urban vegetation cover and composition.

Research and Data Needs in Managed-to-natural landscapes

The expanding and intensifying land use for food and fiber production and urban development (FAO 2009; FAO 2010), and a concomitant degradation or conversion of natural ecosystems (especially wetlands and old-growth forests) imply that a growing fraction of beneficial ecosystem services, such as clean water supply and buffering environmental extremes and disease outbreaks, must be met by managed lands (Millenium Ecosystem Assessment 2005). However, our understanding of the dynamics of the carbon, water, nutrient, and energy cycles in managed ecosystems is limited compared to natural and more slowly changing systems. While some of the structural changes associated with human land use intensification—from changes in vegetation structure to those affecting environment quality (such as drainage, soil disturbance, fertilization (NRC 2013))—are well recognized, their impact on the biogeochemical cycling, energy balance and land-atmosphere feedbacks are poorly constrained.

Human land use change is implicated in the intensification of the hydrologic cycle (van der Ent et al. 2010), which is likely to contribute to climatic and environmental extremes (Durack et al. 2012). Better understanding of shifts in carbon dynamics along gradients of land use intensification would answer whether the same effect is occurring with the carbon cycle (Noormets et al. 2015; Piao et al. 2009; Hansen et al. 2013). In addition, a number of studies report declining soil C stocks over recent decades across the world (Bellamy et al. 2005; Xie et al. 2007) and primarily attribute these to land use intensification (Yan et al. 2011; Maia et al. 2010; Don et al. 2011); Thus it is imperative that intensification processes be explicitly treated in the next generation Earth System Models (ESMs). Closing this knowledge gap requires cross-cutting efforts by different disciplines, e.g., ecological, biogeochemical, and atmospheric, and coordination through modeling efforts in the "predictive understanding" (MODEX) framework.

Managed ecosystem gradients. Managed ecosystems exist at a broad range of scales and the gradient of land-use intensification can be defined along two axes: intensity and frequency. The intensity or severity of the management, for example, would characterize management of a tallgrass prairie at the continuum between the natural undisturbed state, through mild managed disturbances such as prescribed grazing or periodic prescribed fire. An irrigated corn field represents the result of activities at the extreme end of the management intensity scale. Similarly, forest ecosystems can vary from undisturbed, through mild activities for removal of invasive species, prescribed understory fire or selective logging, to complete stand-removal by logging and urban development. Another axis along which to characterize land management intensity it temporal. Management activities such as selective logging and prescribed fire can be rare and prescribed at a very long return period and low frequency, be repeated annually (e.g., grass harvest, grazing), or become permanent (e.g., suburban development).

Also needed are gradient studies of land use effects on biogeochemistry and biophysical processes, including the interaction of land use and climate. Abrupt state changes can occur for ecosystems, triggered by climate and/or land use changes (NRC 2013), such as conversion of native forests to intensive management, and urban expansion into natural systems. Changes in microclimates due to management (e.g., forest thinning in dry environments) can shift ecotones or edge effects, which then can influence functioning of natural ecosystems. Tipping points, such as wind erosion in deforested landscapes, need observation to improve prediction of vulnerability of terrestrial ecosystems to state changes.

Gradient studies combining observations and modeling can address these issues. For example, gradient studies are needed to examine the influence of urban expansion on natural and managed terrestrial ecosystems, and the effects of land use change or change in management intensity on forests and woodlands (e.g. impacts of change from native forests to short rotations for bioenergy production). Impacts might include loss of soil carbon, switching from a long-term sink to a source, and degradation and loss of ecosystem function (e.g., SW U.S., N Great Basin). Feedbacks might include changes in albedo or microclimate suitable for growth. Clusters of flux sites could be established along climate and land use gradients in different regions of the US. They could be supplemented with landscape analysis of carbon stocks and fluxes across gradient and ecotones, and ancillary measurements at plots across the gradients (physiological, soil processes, microclimate conditions) to determine sensitivities and vulnerability to state changes. This should be conducted in conjunction with model development and applications to determine importance of different forcings and integrated responses.

Disturbance effects. The increasing frequency and intensity of disturbance, resulting in heterogeneous age and canopy structure in forests, is the main source of spatial variability in landscape-level and regional carbon exchange (Desa et al. 2008; Pregitzer and Euskirchen 2004; Birdsey et al. 2006). The structural and functional traits that change with forest age (Noormets et al. 2007; Noormets et al. 2006; Law et al. 2001a; Law et al. 2001b) exert greater control on biogeochemical cycling than climate (Pregitzer and Euskirchen 2004; King et a.l 1999; Magnani et al. 2007). Importantly, the structural changes in ecosystem structure and redistribution of biomass between live and dead, and above- and belowground pools, affect microbial activity and new productivity through changes in nutrient cycling. As these effects are not included in the current global land surface models, model estimates of allometric proportions between different C pools are often inconsistent with observations (Wolf et al. 2011), particularly in young forest stands, and the allocation patterns may be outside the spread of data (Malhi et al. 2011). Recent years have also shed light on the interactive effects of multiple environmental factors. For example, the role of nutrient status can predispose plants to drought stress (Ward et al. submitted), which in turn predisposes them to pest attacks (McDowell et al. 2008), which may increase the likelihood of wildfire, which may alter the energy balance of entire landscapes with potential effects on land-atmosphere feedbacks. Incorporating such tipping points in regional and global models requires thorough understanding of interactions between ecosystem components. Expectations for realistic outcomes will result only if models account for all key feedbacks. While some of these feedbacks are being incorporated and tested in the latest ecosystem models, additional ones continue to be discovered.

Scale in managed land use. Land use and management activities cover a range of spatial domains. In some cases the managed plot is small, while in other cases different activities, application methods, or application times are implemented in a patchwork of small-subsets in a larger managed landscape. Special attention should be given to the spatial structure of the management activities and how it relates to the scale of the observation footprint. Temporal scales are also important, particularly for belowground carbon. Advances in better understanding of belowground processes require observations over longer timescales (years to decades) to integrate the typical disturbance cycle for a given ecosystem. Recognition of the scale dependence should guide both delineation of key land use change gradients and necessary improvements in ESM-s.

Land management policy and practice. As the type and intensity of the management activity stem from anthropogenic processes of land management policy and practices, physical models cannot address these processes but should prescribe the consequences of implementing practices. This defines a particular challenge to observations in managed lands, which include the characterization of the type, intensity, period, frequency and immediate consequences of management activities. Improving understanding of how the current state of the ecosystem, climate, and societal parameters and processes interact and contribute to land-management practices will allow models to address these anthropogenic processes, and include their effects in future climate and ecosystem predictions.

Land use intensification and climate-related stress. Additional quantitative and process-level information is needed on the interactions of land use intensification with climate-related stress, and their effect on ecosystem biogeochemistry, and vulnerabilities to environmental extremes. Understanding the changes in key ecosystem properties during the land use intensification, including local and regional feedbacks, and then providing observation continuity through changes in land cover classification will fill important knowledge gaps in current ESM-s and allow improved forecasting capability under evolving environmental and land use scenarios.

Belowground carbon. Many key uncertainties in current understanding deal with belowground carbon pools. Some key processes currently lacking in detail include belowground carbon allocation, stabilization of carbon in soils, and the role of rhizosphere processes.

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Appendix 1: Management, Disturbance, and Land Cover categories for AmeriFlux sites. Includes the 97 sites for which data on management/disturbance were available.

AmeriFlux Site ID	Land Cover type, using IGBP classification[4]	Management and Dominant Disturbance[5]	Source
CA-Ca1	Evergreen Needleleaf Forests	Forestry	BADM
CA-Ca2	Evergreen Needleleaf Forests	Forestry	BADM
CA-Ca3	Evergreen Needleleaf Forests	Forestry	BADM
CA-DL1	Open Shrublands	Undisturbed	BADM
CA-DL2	Permanent Wetlands	Undisturbed	BADM
CA-Gro	Mixed Forests	Forestry	BADM
CA-Let	Grasslands	Grazing	BADM
CA-Man	Evergreen Needleleaf Forests	Fire	BADM
CA-Oas	Deciduous Broadleaf Forests	Fire	BADM
CA-Obs	Evergreen Needleleaf Forests	Fire	BADM
CA-Ojp	Evergreen Needleleaf Forests	Fire	BADM
CA-Qfo	Evergreen Needleleaf Forests	Fire	BADM
CA-SJ1	Evergreen Needleleaf Forests	Fire, Forestry	BADM
CA-SJ2	Evergreen Needleleaf Forests	Fire, Forestry	BADM
CA-SJ3	Evergreen Needleleaf Forests	Fire, Forestry	BADM
CA-TP1	Evergreen Needleleaf Forests	Forestry, Pests and disease	BADM
CA-TP2	Evergreen Needleleaf Forests	Forestry	BADM
CA-TP3	Evergreen Needleleaf Forests	Forestry	BADM
CA-TP4	Evergreen Needleleaf Forests	Forestry	BADM
CA-TPD	Deciduous Broadleaf Forests	Forestry	BADM
CR-SoC	Evergreen Broadleaf Forest	Forestry	BADM
MX-LPA	Open Shrublands	Not managed or lightly managed, Extreme Event	Survey
US-An1	Open Shrublands	Fire, Extreme event	Survey
US-An2	Open Shrublands	Fire, Extreme event	Survey
US-An3	Open Shrublands	Not managed or lightly managed	Survey
US-ARM	Cropland	Agriculture	BADM
US-ATQ	Permanent Wetlands	Not managed or lightly managed	Survey
US-Bar	Deciduous Broadleaf Forests	Forestry	BADM
US-BRW	Permanent Wetlands	Not managed or lightly managed	Survey
US-Ced	Evergreen Needleleaf Forests (BADM: Closed Shrublands	Fire, Pests and Disease	Survey
US-Cpk	Evergreen Needleleaf Forests	Forestry, Pests and Disease	Survey
US-Dea	Cropland	Agriculture	BADM

[4] IGBP classes: Barren Sparse Vegetation, Croplands, Closed Shrublands, Deciduous Broadleaf Forests, Deciduous Needleleaf Forests, Evergreen Broadleaf Forests, Evergreen Needleleaf Forests, Grasslands, Mixed Forests, Open Shrublands, Savannas, Snow and Ice, Urban and Built-Up Lands, Permanent Wetlands, Woody Savannas, Cropland/Natural Vegetation Mosaics, Water bodies

[5] The survey, implemented January 2015, focused on U.S. sites per BERAC workshop focus. Survey options for Management and dominant disturbance: Agriculture, Fire, Forestry, Grazing/rangeland management, Hydrologic management (drainage, flooding, irrigation), Not managed or lightly managed ,Land cover change, Encroachment (e.g., woody), Pests and Disease, Extreme event (e.g., drought, heat wave), Other (comment field)

US-Dia	Grasslands	Not managed or lightly managed	Survey
US-Dix	Mixed forests	Fire, Pests and Disease	Survey
US-DK1	Grasslands	Agriculture, Other (mowed annually for hay)	Survey
US-DK2	Deciduous Broadleaf Forests	Not managed or lightly managed	Survey
US-DK3	Evergreen Needleleaf Forests	Forestry (BADM: Storm or wind)	Survey
US-EML	Open Shrublands	Temperature extreme	BADM
US-Fmf	Evergreen Needleleaf Forests	Forestry	BADM
US-Fuf	Evergreen Needleleaf Forests	Undisturbed	BADM
US-Fwf	Grasslands	Fire	BADM
US-GLE	Evergreen Needleleaf Forests	Forestry, Not managed or lightly managed	Survey
US-Ha2	Evergreen Needleleaf Forests	Pests and disease	BADM
US-Ho1	Evergreen Needleleaf Forests	Fire	BADM
US-Ho2	Evergreen Needleleaf Forests	Fire	BADM
US-Ho3	Evergreen Needleleaf Forests	Forestry	BADM
US-IB1	Cropland	Agriculture	BADM
US-IB2	Grasslands	Agriculture, Fire	BADM
US-ICh	Open Shrublands	Not managed or lightly managed	Survey
US-ICs	Permanent Wetlands	Not managed or lightly managed	Survey
US-ICt	Open Shrublands	Not managed or lightly managed	Survey
US-IVO	Permanent Wetlands	Not managed or lightly managed	Survey
US-KFS	Grasslands	Fire, Temperature extreme	BADM
US-Kon	Grasslands	Fire, Temperature extreme	BADM
US-KUO	Urban and Built-up Lands	Land cover change	BADM
US-KUT	Grasslands	Land cover change	BADM
US-Los	Permanent Wetlands	Hydrologic management	Survey
US-Me1	Evergreen Needleleaf Forests	Fire	BADM
US-Me3	Evergreen Needleleaf Forests	Forestry	BADM
US-Me5	Evergreen Needleleaf Forests	Forestry	BADM
US-MMS	Deciduous Broadleaf Forests	Forestry	Survey
US-MOz	Deciduous Broadleaf Forests	Not managed or lightly managed, Extreme event	Survey
US-NC1	Evergreen Needleleaf Forests	Forestry, Hydrologic management, Land cover change, Extreme event	Survey
US-NC2	Evergreen Needleleaf Forests	Forestry, Hydrologic management, Land cover change, Extreme event	Survey
US-NC3	Evergreen Needleleaf Forests	Forestry, Hydrologic management, Land cover change, Extreme event	Survey
US-NC4	Permanent Wetlands	Not managed or lightly managed, Land cover change, Extreme event, Other(sea	Survey
US-Ne1	Cropland	Agriculture	BADM
US-Ne2	Cropland	Agriculture	BADM
US-Ne3	Cropland	Agriculture	BADM
US-NR1	Evergreen Needleleaf Forests	Forestry	BADM
US-ORv	Water Bodies	Hydrologic management, Urban	Survey
US-PFa	Mixed forests	Agriculture, Forestry, Land cover change, Pests and Disease	Survey

US-Prr	Evergreen Needleleaf Forests	Not managed or lightly managed	Survey
US-RO1	Croplands	Agriculture	Survey
US-Ro3	Croplands	Agriculture	Survey
US-SdH	Grasslands	Grazing	BADM
US-SDU	Urban and Built-up Lands	Land cover change	Survey
US-Shd	Grasslands	Fire	BADM
US-Skr	Evergreen Broadleaf Forest	Storm or wind	BADM
US-Slt	Deciduous Broadleaf Forests	Fire, Pests and Disease	Survey
US-SO2	Open Shrublands	Fire, Not managed or lightly managed	Survey
US-SO3	Open Shrublands	Fire, Not managed or lightly managed	Survey
US-SO4	Open Shrublands	Fire, Not managed or lightly managed	Survey
US-SP1	Evergreen Needleleaf Forests	Fire, Forestry	Survey
US-SP2	Evergreen Needleleaf Forests	Forestry	Survey
US-SP3	Evergreen Needleleaf Forests	Forestry	Survey
US-SP4	Evergreen Needleleaf Forests	Forestry	Survey
US-SRG	Grasslands	Grazing	BADM
US-SRM	Savannas	Grazing/rangeland, Encroachment	Survey
US-Sta	Open Shrublands	Undisturbed	BADM
US-Syv	Mixed forests	Not managed or lightly managed	Survey
US-Ton	WSA	Grazing	BADM
US-ULM	Deciduous Broadleaf Forests	Not managed or lightly managed	Survey
US-UMB	Deciduous Broadleaf Forests	Not managed or lightly managed (BADM: Fire, Forestry)	Survey
US-UMd	Deciduous Broadleaf Forests	Forestry, Other (disturbance, accelerated succession)	Survey
US-Var	Grasslands	Grazing	BADM
US-WCr	Deciduous Broadleaf Forests	Forestry	Survey
US-Wdn	Open Shrublands	Undisturbed	BADM
US-Wkg	Grasslands	Grazing/rangeland, Extreme event	Survey
US-Wrc	Evergreen Needleleaf Forests	Not managed or lightly managed	Survey
US-Wsh	Open Shrublands	Not managed or lightly managed	Survey