Final Report

Detailed fuelbed characterization, mapping and future fire hazard assessment for Eglin Air Force Base, FL

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Abstract

We have developed a suite of tools associated with Fuels Characteristic Classification System (FCCS) to help Eglin Air Force Base address short and long-term fire management challenges. Eglin encompasses 187,555 hectares and is the largest forested military reservation in the United States. Fire-dependent vegetation with a historic mean fire return interval of three years comprises 78 percent of Eglin's area so frequent application of prescribed fire is necessary to maintain the ecosystem health and manage hazardous fuels. Given the increase in military activities on the base and increasing residential development in surrounding areas, more accurate assessments of the impacts of prescribed fire are required to justify and adequately plan burning operations. The FCCS is a comprehensive system that can address many of the needs faced by fire managers who must accurately quantify the effects of prescribed burning programs including emissions predictions, mapping hazardous fuels, and assessing potential fire behavior. Another challenge faced by fire managers is the evaluation of long term fuel treatment scenarios. Landscape-fire-succession-models are a class of computer programs that can incorporate relevant natural processes into a modeling framework to simulate how various human and natural disturbance regimes will affect patterns of vegetation over time periods relevant to long-term planning horizons (i.e., 50-100 years). These simulations can help management staff identify and communicate the benefits and risks associated with different fuels and fire management strategies such as increasing or decreasing the amount of prescribed burning.

We created 181 custom FCCS fuelbeds that represent fuel types based on five drivers of fuels: topographic position, dominant overstory species, silvicultural history, fire history, and stand age. Fuelbeds were mapped throughout Eglin and surrounding areas by associating them with vegetation classes from the Florida Cooperative Land Cover Map and where needed, a rule-based system was used to assign fuelbeds based on other spatial data layers. These included soil type, dominant overstory species, silvicultural history, mean fire return interval, and stand age. Four state and transition models were created to link these drivers to fuelbeds and provide the framework for fuel transitions in a landscape fire succession model, the Fuelbed Dynamics Model (FDM), which was modified to realistically model natural and human processes in the southeastern US. Upgrades to FDM were made to explicitly incorporate processes important to wildfire ignition and growth, implement treatments based on management strategies and unit boundaries, increase spatial resolution, improve efficiency of calculations, and to run ensemble simulations. This suite of tools should bolster the ability of the Eglin Natural Resources Management Branch to successfully achieve management goals using prescribed fire and other forest management treatments given challenges from competing land uses on the base and increasing urbanization in surrounding municipalities.

I. Overview

Prescribed fire is an important land management tool used to reduce wildfire hazard and improve habitat in the southeastern US, but several challenges limit its application. Historically, low intensity fires burned every 1-3 years in the longleaf pine (*Pinus palustris*) ecosystem. These forests were once widespread (Henderson 2006, Huffman 2006, Bale 2009, Stambaugh et al. 2011), but after nearly 200 years of intensive land use, the longleaf pine ecosystem has become fragmented and wildfire has been excluded from many remnant stands (Stanturf et al. 2002, Frost 2006). Remaining stands have high biological diversity of plant species (Glitzenstein et al. 2012), and provide habitat for many rare and endangered species including the gopher tortoise (*Gopherus polyphemus*; Cox et al. 1987) and the red cockaded woodpecker (*Picoides borealis*; Van Balen and Doerr 1978, James et al. 1997). Fire exclusion in remnant longleaf pine forest diminishes ecosystem functions and changes vegetation structure and composition (Figure 1) in ways that increase fire hazard (Hough and Albini 1978, Brose and Wade 2002) restrict longleaf pine regeneration, and reduce biological diversity (Gilliam and Platt 1999). These changes often run counter to natural resource management objectives in these ecosystems (Marshall et al. 2008, Keddy 2009, O'Brien et al. 2010). In lieu of historic fires, which would burn large areas on a landscape with continuous forest cover (Duncan et al. 2011), natural areas are often managed with a combination of prescribed fire, mechanical vegetation removal, and herbicide application to restore the historical fire regime and desired vegetation characteristics (Stanturf et al. 2002).

Figure 1. Prescribed burn demonstration plot at St. Marks National Wildlife Refuge, Florida, USA showing biennially burned (left) and unburned (right) fuels in mesic longleaf pine flatwoods.

Over recent decades there has been less public tolerance for prescribed burning in the southeastern US (Loomis et al. 2001) and land managers have noted multiple barriers to burning operations including: smoke and air quality regulations, public opposition, lack of resources, liability associated with burning, and narrow prescription windows (Haines et al. 2001). These barriers are often interconnected making them difficult to address individually. For instance, negative smoke impacts exacerbate public opposition which can spur more restrictive permitting and clean air regulations which in turn narrow prescription windows.

The cumulative effect of these barriers and legacy of fire suppression (Frost 2006) has left a large deficit in prescribed burning needed to maintain the natural fire regime and accomplish management goals. For instance, fire is excluded from 52 to 85 percent of private forest lands in southeastern states (Outcalt 2000), and along the northern range of longleaf pine forests only 19 percent of remnant stands were being maintained with fire (Frost 2006). Given the ecological value of regularly-burned longleaf pine forest and potential for high wildfire hazard when fire is excluded it is imperative to continue frequent application of prescribed fire to manage biodiversity and rare species in remaining natural areas (Keddy 2009). Avoiding or reversing deficits in prescribed fire is important because otherwise important land management objectives directed at reducing fire hazard and improving wildlife habitat are unlikely to be achieved.

Accurate classification of fuels is critical to managing fire-adapted ecosystems in the southeastern US because fuels data are important inputs for many fire management software applications and fuels are an important bottom up control on fires. Factors including topographic position, overstory species, disturbance history and structural stage can have substantial consequences for fire behavior, smoke emissions, and burn severity. For example, a shift in topographic position of just a few feet can encompass a soil moisture gradient from perennially wet bottomlands to moisture-limited uplands. At the ends of this gradient fire ignition and growth can be inhibited; by high fuel moisture in bottomlands and lack of fuel in uplands. Across much of the soil moisture gradient well-drained sandy soils and low bulk density of litter and grass fuels create conditions for rapid drying and site productivity is high enough to support the rapid accumulation of a continuous fine fuel layer. This arrangement acts as a flammable carrying fuel that readily ignites when dry. Classification of these fuel types based on these factors, accurate mapping at fine spatial scales, and the ability to annually update mapping products are a key component to successfully integrating fuel models into fire management software applications.

Fuel models are a quantitative description of fuel characteristics for a homogenous arrangement and composition of live and dead vegetation, and are often formatted as input files specific to one or more fire management software applications. Among the most widely used fuel model classification schemes in the US are stylized fire behavior fuel models (e.g., Anderson 1982, Scott and Burgan 2005) used in fire prediction models like BehavePlus (Andrews et al. 2005) and FARSITE (Finney 2004), the 20 fuel models used with the National Fire Danger Rating System (Deeming et al. 1977), and the Fuelbed Characteristics Classification System (FCCS; Riccardi et al. 2007) fuelbeds, which are used for several purposes including as a data source for the smoke emissions and fire effects models Consume (Prichard et al. 2007), BlueSky (Pouliot et al. 2005) and FOFEM (Reinhardt et al. 1997). The selection of one system over the other is dependent on their intended use. For example, the standard fuel models (Anderson 1982) are widely known among fire management personnel and can be used to effectively and simply communicate fuels and associated fire behavior. FCCS, on the other hand, is better suited to situations where accurate fuel parameters and differences among local fuel types are important such as predicting smoke emissions in a given area with high fuel heterogeneity among stands or mapping hazardous fuels.

Landscape fire succession models (LFSMs) are a class of computer models used for long-term planning for large areas (i.e. tens of thousands to millions of hectares). In their review of LFSMs Keane et al. (2004) state that at a minimum they must simulate the linked processes of fire and succession in a spatial domain. These models can be used to simulate the landscape-scale effects of different management scenarios on fuels. For example, simulations can quantify how the rate of prescribed burning affects the area of the landscape with high crown fire potential. For many LFSMs that produce fuels data, the base maps are either vegetation classification systems or relatively simple fuel model sets. Both have drawbacks from a fire management perspective. LFSMs are not always suited to addressing fire management questions. For instance, for LFSMs linked to vegetation classes simulation output maps must be cross-walked to fuel models. This can lead to mischaracterizations of fuels if vegetation classes do not encompass the range of relevant fuels types. Other LFSMs operate on a small number of fuelbeds and cannot adequately model the interactions important disturbance events or succession have on fuel development. One way to address these problems is to create a LFSM that operates on a fuel model classification system with custom fuelbeds that reflect local fuel conditions and responses of fuels to the linked processes of fire, succession, and other dominant disturbance regimes. LFSMs with this capability provides simulation results with more utility to fire managers because output maps more accurately display patterns of disturbance and succession, fuelbeds are recognizable and relevant to the area, and human and natural disturbance regimes can be customized to reflect local conditions.

The goal of this project is to develop a catalogue of FCCS fuelbeds and a LFSM capable of simulating fuelbeds over medium to long-term time frames for Eglin Air Force Base, a 187,555-ha military installation in northwestern Florida (Figure 2). We choose to work with Eglin because the Natural Resources Management Branch of the base (i.e., Jackson Guard) operates an ambitious, nationally recognized, prescribed fire program (New York Times 2011) to maintain 146,000 ha of ecosystems with high frequency-low severity fire regimes (Henderson 2006). Increasingly, more accurate assessments of the impacts of prescribed fire are necessary to justify and adequately plan burning operations because of barriers to prescribed burning at the base including increased military activities on the base and urbanization in the areas surrounding the base. Doing so is important because their ability to restore and maintain elements of the natural fire regime is necessary to successfully achieve fuel hazard and ecological management goals. Deliverables associated with this project will help Jackson Guard continue to use prescribed fire to restore and maintain biological diversity and ecosystem resilience, and reduce fire hazard (Science Applications International Corporation 2010). Specific project objectives include:

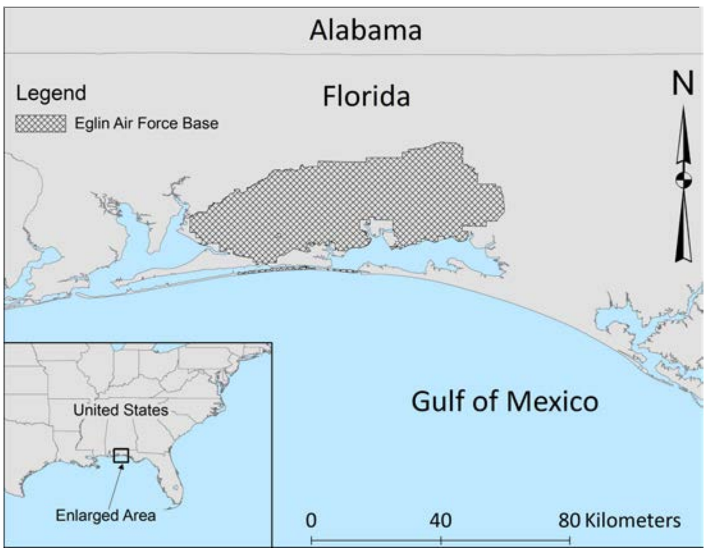

Figure 2. Location of Eglin Air Force Base in the southeastern US.

- Comprehensively describe fuelbeds that occur at Eglin using the FCCS.
- Linked fuelbeds temporally with a State and-Transition Models (STMs).
- Map their current spatial distribution.
- Update an existing prototype LFSM

Specifically we address limitations on the use of prescribed fire by focusing on two fire management concerns: more accurate prescribed fire emissions assessments which will be possible with the FCCS fuelbeds and associated map, and quantification of reduced rates of prescribed burning on fuel characteristics and wildfire hazard through the development of STMs and an updated version of a LFSM, the Fuelbed Dynamics Mode (FDM) developed to work with FCCS fuelbeds, which, along with the aforementioned tools, can be used to simulate the long-term effects of various management scenarios. The FCCS is a fire management decision support tool that includes a surface fire behavior prediction model based on a reformulation of the Rothermel quasi-steady-state fire spread model (Rothermel 1972, Sandberg et al. 2007). FCCS fuelbeds are divided into six strata that represent unique combustion environments and include tree canopies, shrubs, herbs, woody fuels, litter, and duff (Riccardi et al. 2007). FDM (Cronan and Wright *in preparation*) is an LFSM that simulates the effects of natural and human-caused disturbances on FCCS fuelbed development over time by using STMs as a framework to evaluate the effect of succession and stochastically modeled disturbance.

II. Methods

2.1 Study Area

The study area includes Eglin (excluding Cape Blas Island) in Santa Rosa, Okaloosa, and Walton Counties in northwest Florida plus 10 kilometers of surrounding land area. The climate is humid-subtropical (Kottek et al. 2006) and temperatures range from an average minimum of 5°C in January to an average maximum of 33°C in July. Average annual precipitation is 1525-1650 mm with peak rainfall in July associated with convective thunderstorm activity. Dry periods occur in October-November and April-May. Eglin encompasses two physiographic regions: the northern two thirds fall within the Western Highlands with broad plateaus dissected by dendritic streams while the southern third is part of the Gulf Coastal Lowlands which are lower in elevation and have little topographical relief (Puri and Vernon 1964). Soil texture is generally sandy or sandy with a loamy subsoil and drainage ranges from excessively well drained and well drained in the Western Highlands to moderately well drained through very poorly drained in the Gulf Coastal Lowlands (Overing and Watts 1989, Overing et al. 1995). Plant communities at Eglin are divided into four ecological associations: sandhill, flatwoods, barrier island, and wetlands/riparian (Eglin Air Force Base, 2011). The sandhill and flatwoods ecosystems account for 85 percent (Chafin et al. 1997) of Eglin's area and when possible, are burned every 1-4 years with prescribed fire to mimic the local (Henderson 2006), and regional (Frost 1995, Huffman et al. 2004, Bale 2009, Stambaugh et al. 2011) mean fire return interval (mFRI). In addition to prescribed fire, other disturbances at Eglin includes wildfires, wind damage, timber harvesting, sand pine (*Pinus clausa*) removal, herbicide application, and land clearing.

2.2 FCCS Fuelbeds

We developed FCCS fuelbeds to provide staff at Jackson Guard with a spatially explicit method of calculating emissions from prescribed burns and wildfires, and to provide the base fuel input map for FDM simulations. Vegetation types were categorized into fuelbeds according to differences in fuel characteristics, potential fire behavior, smoke emissions, and vegetation structure or composition. While the last criterion is not necessarily an important consideration for fuel models we felt that this could provide alternate uses for fuelbed maps such as more accurate crosswalks to vegetation classes or use of fuelbed variables for other important management consideration such as habitat suitability and carbon accounting. To account for the large number of fuelbeds that would likely be developed, we employed a modular naming and numbering scheme where each fuelbed component represents a major driver of fuels and fire behavior. These fuelbed components were also used in the development of the fuelbed STMs and mapping methodology. To quantify fuels, fields within each of the six strata were initially populated with values from existing fuelbeds that closely resembled vegetation types at Eglin (Andreu et al. 2012, Ryan and Opperman 2013). Parameters were then adjusted with multiple existing datasets that were prioritized based on their relevance to the fuelbed and applicability of the data field. Datasets used included fuel loading, depth, and cover values based on measurements collected for the Photo Series (Ottmar and Vihnanek 2000, Ottmar et al. 2003), a fuel succession study (Cronan et al. 2015), and species composition data from a permanent monitoring plot database maintained by Eglin (Science Applications International Corporation 2010). Once fuelbeds were parameterized, we reviewed values with staff at Eglin to identify inconsistencies and errors. After these were corrected values were plotted among different combinations of fuelbeds to further identify errors or inconsistencies.

2.3 Fuelbed Pathways

A series of STMs were developed to describe the response of fuelbeds to time and dominant disturbance types. STMs provide the framework for the fuel transition sub-model in FDM and are necessary to automatically update the FCCS fuelbed map and run model simulations. STMs were designed to incorporate multiple natural and human processes that are primary drivers of fuels and potential fire behavior at Eglin Air Force Base including wildfire, natural succession, soil properties, multiple stable states, historical timber management practices, forest restoration treatments, and prescribed fire. These pathways were initially based on existing publications describing succession and disturbance ecology in the southeastern United States and modified based on discussions with staff at Jackson Guard during workshops.

2.4 FCCS Fuelbed Map Development

A FCCS fuelbed map was created for Eglin and a 10 km wide strip of land surrounding the base. This map is used in the fire hazard simulation modeling and can be used by Eglin to more accurately estimate emissions from prescribed fire management units by spatially representing the range of fuels present. To map fuelbeds we used multiple remotely sensed vegetation maps augmented with biophysical datasets to inform surface fuel conditions. FCCS fuelbeds were initially associated with the Florida Natural Area Inventory Assessment (FNAI) Cooperative Land Cover map. A rule-based assignment criteria was then used to assign fuelbeds to cells within the mapping area based on information from additional spatial data layers. Additional data layers included a vegetation cover map derived from Normalized Difference Vegetation Index data, soil survey map, and prescribed fire, silvilcultural treatment, and timber management spatial datasets maintained by Jackson Guard. All spatial layers used to inform fuelbed components were converted to 30 m resolution raster files and georectified. The fuelbed map has a resolution of 30 m and was ground-truthed with two independent datasets to assess accuracy.

2.5 Updates to FDM

FDM is a stochastic, cellular automata computer program in the R language (R Development Core Team 2009) that simulates the effects of disturbance and succession on a raster FCCS fuelbed map. Successional changes in the fuelbeds are controlled by the STMs described above and are implemented at annual time steps for each grid cell. Disturbance is implemented by cellular automata sub-models that spread disturbances from a single point based on probabilities associated with each cell. In the case of prescribed fire or wildfire these probabilities are based on rate of spread generated by the FCCS fire behavior model under pre-defined fire weather scenarios. Disturbance regime characteristics, including area, size, shape, and frequency are generated with probability distribution functions parameterized with historic data and inherently incorporate the effect of weather on annual fire frequency and area burned. The effect of weather on fire ignition and growth is modeled by decreasing the bottom up control of fuels on probability of ignition and rate of spread as fire weather severity (defined by individual fire size) increases. That is to say, as fire size increases differences in probability of ignition and rate of spread among fuelbeds (with some exceptions such as non-vegetated areas and wetlands) approaches zero. The model has the capacity to incorporate anthropogenic boundaries by overlaying management decision criteria onto the fuelbed raster map to generate realistic patterns of disturbance over time (e.g. prescribed fire units and variable suppression strategies). Updates to FDM will focus on four major upgrades that will incorporate relevant drivers of fire ignition and spread, and human influences on the fire regime, which are more prevalent in the southeastern US than remote areas of the Pacific Northwest which FDM was developed for.

2.6 Data Management

FCCS fuelbeds are stored in XML format, a durable file format for data storage and archiving. The fuelbed map and all spatial data layers used to generate the fuelbed map are stored as 30 m raster files with associated metadata. Fuelbed pathways are stored as graphical representations of state and transition models and as lookup table stored in CSV files. All FCCS fuelbeds, FDM computer code and related products created as part of this project are stored locally with Eglin Air Force Base and remotely through a cloud computing service (Table 2). All spatial data products are stored on a University of Washington ArcGIS server and are web accessible (Table 2). Copies of the fuelbeds, successional pathways, fuelbed map, and supporting documentation have been delivered to Jackson Guard. Staff involved with this project will provide continued technical support.

III. Key Findings

This section describes various products of this project including the FCCS fuelbeds, STMs, the fuelbed map, and improvements to FDM. These products have utility for Jackson Guard and represent an integration of concepts relevant to fuels and fire management that can simulate the long-term effects of management actions on fuels and fire hazard.

3.1 FCCS Fuelbeds

FCCS fuelbeds were created to represent unique combinations of fuel characteristics, potential fire behavior, smoke emissions, and vegetation composition and structure. The numbering system uses a five digit code for each fuelbed where each digit describes a drive of fuel characteristics (Table 1). Fuelbeds are broadly divided into five categories: wet flatlands, mesic flatlands, mesic uplands, xeric uplands, and static fuels. The first four are the topographic positions used in the development of the STMs, while the last represents fuelbeds that do not change in response to time or disturbance. These are primarily non-burnable fuelbeds such as water, bare land, and urban areas, or intensively managed vegetation such as the frequently mowed military ranges.

Table 1: Factors representing each digit in the FCCS fuelbed numbers. Each factor is a major driver of fuels and fire behavior in the southeastern US.

1st Digit Topographic Position		**2nd Digit** Dominant Overstory Species		**3rd Digit** Silvicultural History		**4th Digit** Fire Return Interval		**5th Digit** Stand Age	
Value	Description	Value	Description	Value	Description	Value	Description	Value	Description
1	Wet Flatlands	1	Long-needle Pine	1	Natural	1	1-3 years	1	0-10 years
2	Mesic Fatlands	2	Mixed Broadleaf-Pine	2	Sand pine removal (0-10 years post-treatment)	2	4-8 years	2	11-20 years
3	Mesic Uplands	3	Broadleaf	3	Herbicide (no understory; 0-1 years post-treatment)	3	8-20 years	3	21-40 years
4	Xeric Uplands	4	Short-needle Pine	4	Herbicide (grass understory; 2-4 years post-treatment)	4	> 20 years	4	41-60 years
5	Modified	5	Tall shrub	5	Plantation			5	60-100 years
		6	Short shrub	6	Plantation + san pine removal			6	> 100 years
		7	Mixed shrub/herb	7	Plantation + herbicide (no no understory)				
		8	Herbaceous	8	Plantation + herbicide (grass understory)				
		9	Non-vegetated	9	Vegetation cleared				

For each topographic position, natural fuelbeds describe structure and composition of fuels based on differences in overstory composition, mFRI, and stand age (Appendix A). There are 36 natural fuelbeds for wet flatlands with 18 representing longleaf pine-dominated wet flatwoods, six representing broadleaf-dominated wet bottomland forest, and 12 representing baygall swamps. For mesic flatlands there are 24 natural fuelbeds that reflect the same distribution among longleaf pine (mesic flatlands; n = 18) and broadleaf (mesic bottomland forest; n = 6) overstory types as wet flatlands. There are 30 natural fuelbeds that describe mesic uplands with 18 for longleaf pine-dominated upland pine, six for mixed pine-oak overstory forest, and six for oak-dominated forest. For xeric uplands there are 36 natural fuelbeds, half represent longleaf pine-dominated sandhills, and the other half divided evenly among three types of overstory composition: mixed oak and pine, oak, and sand pine. For silvicultural treatments, mesic flatlands, mesic uplands, and xeric uplands each have 11 fuelbeds that describe long-needle pine plantations, i.e., longleaf, loblolly (*P. taeda*), and slash (*P. elliottii*) pine, and four fuelbeds describing sand pine plantations in mesic and xeric uplands. We created 11 fuelbeds to describe post-treatment fuels characteristics following mechanical removal of sand pine and herbicide application to reduce oak density. To describe static conditions we developed seven fuelbeds. Three describe non-burnable fuels including water, developed land (includes bare ground and urbanized areas), cleared wetlands, and agriculture. Burnable static fuelbeds include mowed rangeland, saltwater marsh, and shrub swamps.

3.2 FCCS State and Transition Models

The STMs account for effects of factors that drive fuel characteristics and fuel-mediated fire behavior. There are 467 fuel states within five STMs. Where fuel and vegetation characteristics are similar multiple fuel states are represented by a single fuelbed. Here we describe each driver and its influence on fuel characteristics.

Topographic position is a top down control on vegetation structure and composition on the coastal plain ecoregions in the southeastern US, including Eglin Air Force Base. Based on existing vegetation classification used by Eglin (Chafin et al. 1997) STMs were developed for four topographic positions: wet flatlands, mesic flatlands, mesic uplands, and xeric uplands). STMs are not linked, that is fuelbeds cannot transition among topographic positions, and static fuelbeds do not interact with fuelbeds in the STMs.

Overstory species composition directly affects fire behavior based on differences in canopy structure such as canopy base height, canopy bulk density, and flammability of foliage, and indirectly through litter accumulation and light availability for understory growth. This factor also indirectly represents the concept of multiple stable states because potential vegetation in the absence of fire can be dominated by oaks or sand pine at upland sites. Overstory composition in stands managed with fire is characterized by high relative cover of longleaf pine and surface fuels have continuous cover of fine dead and live fuels that will support low to medium intensity surface fires. When fire is excluded from upland longleaf pine forest the overstory is slowly replaced by sand pine or fire-inhibiting oak species (Kane et al. 2008) such as laurel oak (*Quercus hemisphaerica*) and bluejack oak (*Q. incana*). Initially, accumulation of fine surface fuels causes an increase in potential fireline intensity and decrease in probability of ignition. As fire inhibiting overstory trees replace longleaf pine and shade out understory vegetation, both potential fireline intensity and probability of ignition decrease to the point where fire is unlikely to occur, and when it does, is characterized by low-intensity creeping surface fires. Similarly, when fire is excluded from flatland longleaf pine forest, broadleaf tree species (bottomland forest) or tall evergreen shrubs (baygall swamps) replace longleaf pine. Potential fire behavior in fire-excluded vegetation is similar to upland sites for broadleaf forest, but in baygall swamps, vegetation can be flammable during dry periods, especially in the spring, and can support high-intensity stand replacing fire.

The silvicultural history component describes the impact of historical timber management and current ecological restoration techniques on fuel characteristics. Pine plantations occupy 35 percent of the land area at Eglin and fuel states represent them through 60 years old. In older plantations fuel characteristics are indistinguishable from natural stands. In newly established pine plantations ruderal understory species become established and are less flammable than bunch grasses and resinous shrubs in undisturbed natural longleaf pine forests managed with fire. Plantations less than 60 years old have higher stem density than comparable natural stands that reduces wind speed sufficiently enough to reduce potential rate of spread. Current forest management operations are designed to restore the longleaf pine ecosystem by reversing the effects of fire exclusion. These treatments include mechanical removal of sand pine and herbicide application to reduce density of fire-inhibiting oaks. Treatments are applied in mesic and xeric upland sites and post-treatment fuel states characterize unique fuel conditions in the years following each type of treatment. Herbicide application in upland oak fuel types generates dense growth of herbaceous vegetation that along with abundant dead shrubs can support fast moving fires of moderate intensity. Sand pine removal treatments generate longer-lasting slash fuels that can burn intensely, but take longer to dry and lack a continuous fine fuel source which reduces rate of spread and probability of ignition.

The fire regime is incorporated into STMs based on a binary response to burn severity where low-intensity surface fires generate low burn severity and high-intensity surface fires or crown fires generate high burn severity. Low-intensity surface fires have no immediate effect on fuels. Changes in fuel occur when the cumulative effect of past fires cause cross any of the thresholds between the five fire regime categories: 1-3 year mFRI, 4-8 year mFRI, 9-20 year mFRI, 20-50 year time-since-last-fire (TSLF), and TSLF greater than 50 years. Fuel states within the three mFRI brackets they can shift in both directions between categories, but once a fuel state transitions into the TSLF categories fire is unlikely to occur because probability of ignition is low, and if it does, the fuel state cannot shift back into the mFRI categories. This resistance to conversion does not occur in the opposite direction; less frequent fire will always shift fuel states towards fuels composition and structure characteristic of fire-excluded vegetation. For fuel states in the two TSLF categories a shift to a more frequent fire regime can only occur after a stand-replacing wildfire or restoration treatments. High-intensity surface fires or crown fires are assumed to cause near 100 percent overstory mortality and reset the stand age to zero. Succesional trajectories, either towards fire-adapted longleaf pine or less fire-adapted overstory species is determined by any additional fires that occur in the first 10 years of stand development.

Stand age is represented by six sequential fuel states. In the absence of disturbance, vegetation proceeds through expected forest succession (i.e. stand initiation, stem exclusion, understory re-initiation, and old-growth). The amount of time represented by fuel state increases with stand age because changes in fuel composition and structure occur most rapidly in the years following a stand initiating event. Time ranges for each successional stage are standardized to simplify STMs and their interactions with each other.

3.3 FCCS Fuelbed Map

The FCCS fuelbed map is a 30 m resolution raster file that describes fuelbeds for a 424,110 hectare area including Eglin and land within 10 km of the base boundary (Figure 3). Accuracy assessments using a set of 119 systematically arranged ground truth points and vegetation classification data from 200 permanent monitoring plots maintained by Eglin showed the map is 77.8 percent and 75.6 percent accurate, respectively.

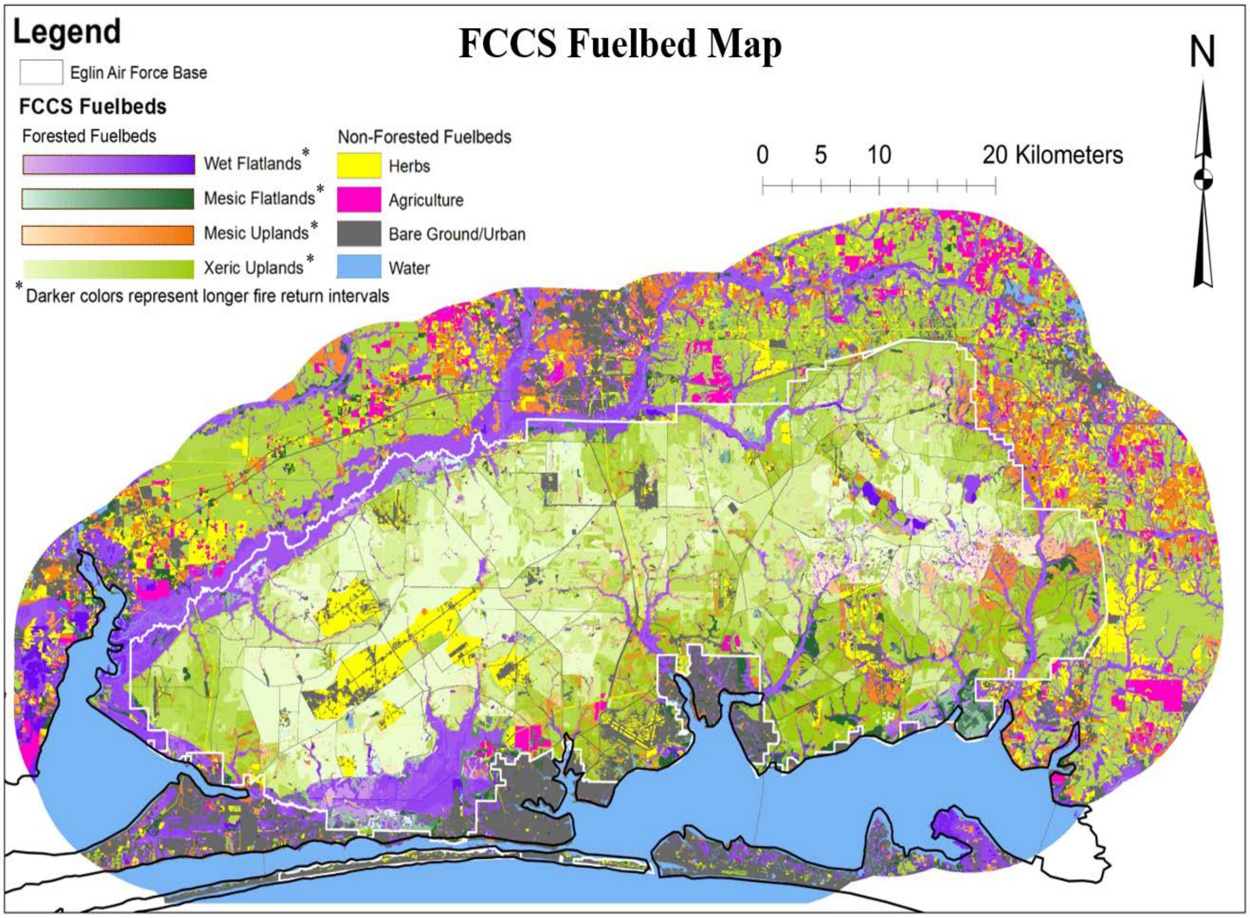

Figure 3: A 30 m resolution Fuel Characteristics Classification System fuelbed map for Eglin Air Force base and the surrounding landscape at a distance of 10 km from the base.

At the final workshop in December 2015, the fuelbed map was reviewed for accuracy by Jackson Guard and no major errors or mischaracterization of fuels were identified. The simplified map shows patterns of fuels within and around Eglin Air Force Base. Between the Gulf of Mexico and the southern boundary of the base fuelbeds are mostly bare ground/urban (12.8 percent of buffer landscape) because this area is densely populated and includes the communities of Fort Walton Beach, Niceville, and Destin. Areas to the north of the base are mostly fire-excluded forests (47.9 percent of buffer landscape) and agriculture (11.2 percent of buffer landscape). Wet flatlands (purple) occupy 13.4 percent of the base are concentrated along the north end and southwest corner of the base. These fuelbeds are part of the flatlands along the Yellow and East Bay Rivers, respectively. Narrow strands shaded purple show flatland fuelbeds along the smaller dendritic streams that drain outwards from uplands in the northern two thirds of the base. Areas shaded orange depict mesic upland fuelbeds which and are resitricted to the eastern edge of the base. Fuelbeds classified as xeric uplands (shaded yellow-green) are most common and comprise 62.4 percent of Eglin's land area. The lighter shades of colors describing forested fuelbeds show two areas of higher fire frequency (i.e., mFRI is less than 8 years): around the large range (shaded yellow) in the western half of the base and another large area on the eastern half of the base. All together, fire-maintained fuels account for 45.7 percent of Eglin and show the fraction of the base that is burned frequently. Fuelbeds indicating long fire return intervals (greater than 20 years) occupy 33.7 percent of the base; mainly along the perimeter of the base where wetlands are prevalent and along the two highways that bisect the base. Areas along the these roads are burned less frequently because of smoke impacts on traffic.

3.4 Improvements to FDM

Upgrades to FDM improve the realistic representation of natural processes that drive fuel dynamics at the stand scale or increase modeling efficiency. Incorporation of sub-models that explicitly simulate natural processes should increase the accuracy of model output maps while improved efficiency enables FDM to run at a higher spatial resolution that captures fine-scale stand-level patterns in fuel distribution and run simulations in parallel to produce ensemble maps to account for variability among simulations.

To generate more realistic patterns of disturbance we replaced the cellular automata sub-model with two versions. One designed to simulate treatments including thinning, herbicide application, and prescribed fire, and the other designed to simulate wildfires. The treatment sub-model contains a hierarchical priority algorithm that can sequentially choose and treat units based on annual treated area targets, relevance of management areas, and fuelbed composition of individual units. A mass start function initiates treatments in receptive fuelbeds at multiple locations. This mimics both the ignition patterns for prescribed fires and the manual application of sand pine removal and herbicide treatments. Additional improvements to the treatment sub-model include a cut-off function that will stop prescribed fire growth when iterative rates of growth fall below a threshold and a cut-off stand size that will prevent restoration activities from occuring in small stands work crews would not ordinarily visit. Improvements to the wildfire cellular automata sub-model include the addition of a wind field, a 6x larger search area around burning cells that allows for spotting and rapid growth, a call to the treatment cellular automata sub-model under certain conditions to implement "block and burn" suppression tactics where firefighters burn out along the unit boundaries of an actively burning wildfire, a burnout function that extinguishes burning cells after a given period of time, and a crown fire algorithm that evaluates the potential for involvement of crown fuels on a cell by cell basis using fuel characteristics and inferred weather.

Cumulative tracking of non-fire disturbance history was added to expand the potential interaction within and among the human and natural processes explicitly modeled in FDM. While the original version used deterministic fuelbed pathways that could only shift along a single direction in response to a disturbance or stand age, the revised version tracks four metrics and uses them along with random probability to guide fuelbed transitions. Tracked disturbance regime metrics include the 20-year mFRI, TSLF, TSLT (for thinning and herbicide application), and stand age. In instances where disturbance does not reset stand age (i.e, is not stand replacing) annual assessments of these metrics direct fuelbed trajectories along pathways in each STM.

IV. Management Implications

The FCCS products improve accuracy of emissions predictions for prescribed burns and wildfires and can quantify other important natural resource factors including wildfire hazard, fuel treatment effectiveness, stored carbon, and wildlife habitat. Updates to FDM strengthen the capability of the model to simulate the effects of wildfire and fuels treatment actions at large spatial and temporal scales relevant to long-term planning of fuels and fire management strategy. While this project was specific to Eglin, many components such as the fuelbeds and FDM can be applied to other locations with similar fuels and natural processes.

The FCCS fuelbed map will replace current aspatial techniques for emissions predictions employed at Eglin that assume homogenous fuels across an entire prescribed fire unit and produces conservative estimates. Overestimates often occur because prescribed fire units contain substantial areas of fire-resistant fuel types such as deciduous bottomland forests and upland sand pine. With the FCCS fuelbed map, fire managers can query fuelbed composition of burn units and either run each fuelbed through the emissions model or stratify them into flammable and non-flammable fuelbeds and apply a standard loading and emissions factor to only the area expected to burn. The FCCS fuelbed map is preferable to existing fuel mapping products such as LANDFIRE because the FCCS map has been ground-truthed for accuracy, contains fuelbeds created using local data, and was created with input from land managers at Eglin. If emissions quotas are implemented by regulatory agencies Jackson Guard should be able avoid restrictions on prescribed burning activities that may have been imposed because of overestimated emissions that are a product of current methods.

Wildfire hazard maps are useful for a number of fire management applications and can be generated from the FCCS fuelbed map. Individual fuel parameters and potential fire behavior predicted with the FCCS fire behavior model can be mapped to show the spatial distribution of variables important to assessing wildfire hazard. For instance, mapping the total available fuel loading, an important determinant of flame length, can help determine appropriate strategies for fire suppression or holding along prescribed burn perimeters. Maps of expected fire behavior under different weather scenarios can also be generated by running the FCCS fire behavior model on each fuelbed and mapping the outputs. This allows managers to identify areas with potential for high rate of spread, fireline intensity, and crown fire risk. However, it should be noted that mapping predicted fire behavior carries increased uncertainty because variables that are important to fire behavior including fuel moisture and mid-flame windspeed will vary among fuelbeds and using standard or values that are otherwise incorrect could generate erroneous fire behavior values. Mapping hazardous fuels or predicted fire behavior can be used to identify areas with high wildfire hazard, prioritize fuel treatments, and communicate risk. If the FCCS fuelbed map is updated regularly, maps can be compared over time to assess trends and quantify progress relative to management goals. Regular updates would require little effort because of the six data layers used to generate the fuelbed map, two are updated on a sub-annual bases (fire history and forest management actions), two are updated annually (NDVI land cover map and FNAI vegetation map), and the last two contain static information (soil map and timber plantation map).

FDM can assess the effect of different management strategies on wildfire hazard over multiple decades. This will help managers determine which type of management strategies are best suited to long-term management goals and communicate their effects to base administrators and other stakeholders. FDM was developed to simulate natural and human disturbance regimes in the southeastern US and is uniquely suited for modeling scenarios at Eglin where prescribed fires and silvicultural treatments are the dominant form of disturbance. By deriving fuel and potential fire behavior variables described above from output maps produced at specified intervals during the simulations, fire managers can provide summary statistics to show how these variables change over time. For example, the area of land with high potential fireline intensity. By running simulations under different management scenarios managers can use the model outputs to help identify strategies that optimize trade-offs between wildfire risk, cost, and smoke emissions. For example, how cost savings and decreased smoke emissions associated with a 50 percent reduction in annual prescribed burning compares with changes in wildfire hazard. However, a limitation of the FDM model is that wildfire ignitions and growth are static and do not respond to changes in fuels. Thus a changing wildfire regime and associated emissions would have to be either estimated separately or explicitly incorporated in the model (i.e. specify changes in the annual wildfire statistics). The FDM is an excellent tool for understanding how fuel treatments including prescribed fire, thinning, and herbicide application affect fuels across Eglin and surrounding lands over multiple decades.

The FCCS fuelbeds and FDM can also be used to examine properties of vegetation relevant to other management objectives. For instance, fuelbeds were created with actual data that describes important elements of red cockaded woodpecker (RCW) habitat such as dominant overstory species, tree height and density, height between the ground and the canopy, and species composition and height of the understory. These parameters can be used to simulate how distribution of RCW habitat at Eglin changes under different management scenarios. As with wildfire hazard, managers can evaluate the effect of multiple management scenarios on the amount and quality of RCW habitat. This application could be extended to model habitat changes for other important terrestrial species including: bobwhite quail, white-tailed deer, turkey, black bear, flatwoods salamander, and gopher tortoise.

These deliverables have potential applications to other areas of the southeast with similar management challenges, fuels, and natural processes. Existing fuelbeds can be applied to other areas or mixed with fuelbeds developed for LANDFIRE or other FCCS projects such as Fort Gordon in South Carolina (Andreu et al. 2012). The methods for developing the FCCS fuelbed map can be applied at other locations with fire-adapted vegetation in the southeastern US, provided necessary spatial data layers are available, and be used in combination with management boundaries and decision criteria to analyze the effect of different management scenarios.

V. Relationship to Recent Findings

Characterizing fuels is a complex process because the continuous distribution of a large number of fuel parameters across the landscape varies at multiple spatial scales and each change at different rates over time and in response to disturbance. As such there are a wide variety of fuel characterization schemes and protocols for classifying fuels. Fuel classification schemes are often oriented towards a specific purpose to simplify the process. For instance, fire behavior fuel models (Anderson 1982, Scott and Burgan 2005) are developed exclusively for fire behavior prediction models and inputs are stylized, that is they don't necessarily reflect values in the actual fuel types being modeled, but they fuel parameters are adjusted to fire behavior prediction models produce expected results. Smoke emissions models, such as Consume (Prichard et al. 2007) and FOFEM (Reinhardt et al. 1997), on the other hand require actual fuel quantifications, such as those contained in FCCS fuelbeds, for the sites the models are applied to, and if fire behavior fuel models are used for this purpose they will produce erroneous estimates. Aside from inputs for emissions prediction models, FCCS has a wide variety of applications, including fire behavior predictions and carbon accounting. Relative to other classification schemes and is best suited for this project because fuelbeds can be used for emissions predictions, wildfire hazard assessments, and as a LFSM input. Other fuel mapping projects have also used the FCCS to classify fuelbeds. For example, Andreu et al. (2012) used the FCCS to classify fuels across a 71,224 ha area at the Savanna River Site in South Carolina. As with this project, the purpose of the fuelbed development was to use fuel characteristics to prioritize fuels treatments and assess wildfire hazard. Keane et al. (2013)outline three processes for characterizing fuels including association, linking fuelbeds to existing vegetation classes; classification, the process of clustering items such as fuelbeds into like groups based on some attribute such as fuel characteristics or modeled fire behavior; and abstraction, or stylized fuelbeds created to represent the possible range of fire behavior. We choose the association approach for several reasons. Linking FCCS fuelbeds to a widely used vegetation classification scheme in Florida (FNAI) makes it easier for managers to relate to the fuelbeds, that is, there is no need to teach users a new classification scheme for fuels. The FNAI vegetation classes are already mapped to high resolution and are updated annually so this reduced problems creating an accurate fuelbed map that could be updated as conditions changed. We modified this approach by supplementing the FNAI vegetation class data with other spatial data layers such as overstory composition, silvicultural history and fire perimeter datasets. A rule-based system was applied to FNAI-based fuel categories and these additional datasets to assign fuelbeds to each cell that accounts for the influence of disturbance history on fuels within vegetation classes (Brown and Bevins 1986). This is especially relevant in the southeastern US were small changes in mFRI can have large changes on surface fuels within a vegetation class such as flatwoods (Figure 1).

Many fuel modeling projects use the association approach described by Keane et al. (2013)to predict future fuel characteristics by crosswalking fuel types with predicted vegetation maps simulated with landscape vegetation succession models (Cary et al. 2006, Davis et al. 2009). To avoid mischaracterization of fuels un the crosswalk we excluded it and created STMs that directly model fuelbeds. STMs have been developed with FCCS fuelbeds at other locations including the eastern Cascades in Washington State (McKenzie et al. 2007) and large areas across Washington, Oregon, Arizona, and New Mexico (Burscu et al. 2014, Halofsky et al. 2014).

The first known fuels map in the US was created in the early 1900s by employing 90 Civilian Conservation Corps employees to survey potential fire behavior conditions across 6 million acres of the northern Rocky Mountains (Hornby 1936). While field reconnaissance data is still important for parameterizing fuelbeds and assessing accuracy, fuels are generally mapped with remotely sensed data and biophysical settings (Keane et al. 2001). Remotely sensed data includes imagery with resolutions that ranges from meters to kilometers (Arroyo et al. 2008) and is an important tool. A major limitation is the inability to detect surface fuels that can change independently of the overstory vegetation that obscures them. Biophysical settings such as moisture availability, stand structure, and disturbance history can also be drivers of understory vegetation (Keane et al. 2001), which is more important that canopy fuels in surface fire regimes like the southeastern US. For example, (McKenzie et al. 2007) created a 25 m resolution FCCS fuelbed map for the 890,000 ha Okanogan-Wenatchee National Forest in Washington State using rule-based decision criteria to classify cells into fuelbeds based on existing spatial data layers including ecoregion type, potential vegetation, cover type, structural stage, and fire regime. Other fuel mapping projects used more sophisticated classification procedures. For instance, Poulos et al. (2009) used classification trees (Breiman et al. 1984) to predict fuel models based on 13 biophysical properties and 11 spectral characteristics from Landsat ETM+ images to map fuels in the Sierra Madre Oriental in northern Coahuila, Mexico and western Texas, US. Many fuel mapping studies verify the accuracy of mapping projects with independent datasets. A comparison of the Eglin fuelbed map accuracy of 77.8 percent and 75.6 percent with two independently collected datasets was near the high end for range of values (54-84 percent) reported in the literature (Miller et al. 2003, Falkowski et al. 2005, Poulos 2009).

FDM is part of a large family of LFSMs (Keane et al. 2004) and is at the lower end of the spectrum in terms of complexity. FireBGCv2 (Keane et al. 2011) is one of the more sophisticated LFSMs, and while it shares some commonalities with FDM, it contains several mechanistic models to simulate a large number of natural processes whereas FDM uses deterministic and stochastic models to simulate a small number of processes. While the approach used in the development of FDM increases the potential for accuracy within the range of data used to develop the model, accuracy of predictions will likely decline as simulations fall outside of this range. Thus, it will not perform accurately in simulations that extend beyond the range of age classes (approximately 150 years) or incorporate disturbance regime characteristics not used to develop the model. For instance, scenarios that assume defoliating insect outbreaks or a climate-mediated shift in the fire regime. Processes modeled by FDM include succession, fire, fire effects, understory dynamics, and silvicultural treatments whereas fireBGCv2 simulates these and climate, hydrology, seed dispersal, insect and disease outbreaks, smoke emissions, soil and fuel moisture, carbon cycling, evapotranspiration, photosynthesis and respiration, and decomposition. Furthermore, some processes in fireBGCv2 are modeled at the individual plant level whereas processes in FDM are modeled at 30m resolution or the stand-level. The tradeoff between these two levels of model complexity is that FireBGCv2 has large input requirements and is difficult to parametrize whereas FDM can be parameterized easily and inputs, except for the state and transition models are generally available spatial datasets at most natural areas. LANDIS PRO 6.0 (Yang et al. 2011) is also more complex than FDM because insect and disease outbreaks, windthrow, species competition, vegetative reproduction, and seed dispersal are explicitly modeled (He et al. 2005). Other LFSMs that have a similar level of complexity to FDM include BFOLDS which is designed to operate in the forested areas of Ontario, Canada (Perera et al. 2008), LADS designed for coastal Oregon (Wimberly 2002), and SIMPLLE which is used to assess the interaction between vegetation and disturbance in the northern Rocky Mountains (Chew et al. 2004). The EMBYR model is an example of a more simplistic LFSM (Hargrove et al. 2000).

VI. Future Work Needed

As these fuelbeds are put into use, a list of improvements to their utility, simplicity, and accuracy should be developed and items should be prioritized. Anticipated improvements are listed below.

FCCS Fuelbeds and Map

- Merge fuelbeds into a smaller set to reduce the amount of time required for emissions calculations. Doing so would be helpful because emissions must be calculated frequently for the hundreds of prescribed burns and wildfires at Eglin every year. Once created this smaller set of fuelbeds should be mapped by croswalking them with the original fuelbeds and establishing field plots to measure and verify the accuracy of fuelbed parameters relevant to emissions.
- Identify additional uses of these fuelbeds to expand the number of benefits gained from this project. For instance, at the Savanna River Site in South Caralina Parresol et al. (2012) used hierarchical cluster analysis to merge FCCS fuelbeds (Andreu et al. 2012) based on common fire behavior parameters to create a small number of fire behavior fuel.
- Develop fuelbeds to represent damage from hurricanes; a major component of the disturbance regime in the southeastern US that affects fuel characteristics. This project did not develop post-hurricane fuelbeds because these events are infrequent and these fuelbeds are not widespread at Eglin. Fuelbeds to represent this disturbance would be useful to show how widespread damage from hurricanes could change hazardous fuel disturbution.
- Increase the useability of these products. The FCCS fuelbed map is currently being hosted on a University of Washington ArcGIS server and there is limited ability for users to interact with fuels data. We currently have permission to host the map permanently on a US Forest Service ArcGIS servers and discussions with staff at Eglin have identified online tools that would help them calculate emissions. Principal among them is a tool that would report a list of fuelbeds and their areas for each burn block, or management unit.
- Identify applicability to other nearby areas with similar fuel types. Methods developed to characterize, map, and simulate fuels on the southeastern US could be transferred to many other locations in the region with similar resource objectives and management challenges.

FDM Landscape Fire Succession Model

- Conduct sensitivity analysis on FDM to determine how each parameter affects model performance. There 49 parameters that determine how FDM simulates disturbance. An assessment of the sensitivity to and effects of each parameter on simulated disturbance could be used to improve model accuracy and understand the appropriate range for each parameter.
- Test accuracy of FDM predictions by conducted a two stage model evluation. The purpose of the first evaluation would be to test how well FDM can replicate individual disturbances. For instance, comparing progression and attributes of an actual wildfire to a wildfire simulated in FDM under the same conditions. Deviations from actual wildfire attributes could be used to adjust FDM parameters

to create more realistically simulate wildfires. The second stage would be a full-scale comparison of a simulated landscape to an actual landscape by backcasting, that is using historic data to parameterize the model and simulating forward to a more recent time where model outputs can be compared with actual data.

VII. Deliverables and Science Delivery

Deliverables and their status are listed in the table below.

Table 2. Deliverables crosswalk table.

Project Milestone	Description	Completion Dates
Seminar	Conduct seminar at Eglin with fire managers to present fuelbed map and explain potential uses and limitations.	November 12th, 2014
Conference presentation	Poster presentation at the Association for Fire Ecology 6th Fire Ecology and Management Congress in San Antonio, TX	November 17th, 2015
Presentation	Presentation of fuelbed map and preliminary results for fire hazard modeling simulation to Eglin Air Force Base	December 9th, 2015
FCCS Fuelbeds*	181 Custom fuelbeds for Eglin Air Force Base	March 23rd, 2015
Fuelbed Pathways*	State and Transition model for FCCS fuelbeds.	April 30th, 2015
Fuelbed Map	30 meter resolution Fuel Characteristic Classification System fuelbed map for Eglin Air Force Base and surrounding landscape.	September 28th, 2015
FCCS Eglin Fuelbed Map Website*	Beta-version of website to display and interact with fuelbed map.	September 28th, 2015
Update to Fuelbed Dynamics Model*	Update landscape-fire succession model	December 31st, 2015
Peer-reviewed manuscript*	Overview of updates to Fuelbed Dynamics Model	In progress
Peer-reviewed manuscript	Results from simulations examining the effect of different rates of prescribed burning on fuel hazards.	In progress
JFSP final report	Submit final report to JFSP	August 11st, 2016

*Indicates additional deliverable

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Appendix A: Selected parameters for FCCS fuelbeds developed for Eglin Air Force Base

Table A-1: Selected parameters for natural fuelbeds in wet flatlands

	Litter				Herbs			Shrubs			Woody Fuel Loading[4]				Overstory	
Fuelbed No.[1]	Cover[2]	Depth[3]	Loading[4]	Type[5]	Cover[2]	Height[3]	Loading[4]	Cover[2]	Height[3]	Loading[4]	1-hr	10-hr	100-hr	1000-hr	Cover[2]	Height[3]
11111	20	0.1	0.1	gr	80	0.5	1.8	5	0.3	1.7	0.1	0.1	0.1	--	--	--
11112	40	0.3	0.2	grln	75	0.5	1.8	10	0.5	6.7	0.2	0.2	0.2	0.7	5	6
11113	60	0.5	0.4	ln	65	0.5	1.6	15	0.5	6.7	0.4	0.4	0.4	1.6	10	14
11114	95	1.8	1.1	ln	65	0.5	1.6	15	0.6	6.7	0.5	0.8	0.8	2.2	20	23
11115	95	2.5	1.6	ln	65	0.5	1.3	15	0.6	6.7	0.7	0.8	0.8	2.2	20	35
11116	95	3.0	1.7	ln	65	0.5	1.1	15	0.6	6.7	0.8	0.8	0.8	2.2	20	35
11121	20	0.3	0.6	gr	65	0.3	1.6	10	0.6	7.8	0.2	0.1	0.1	0.7	--	--
11122	40	0.5	1.1	gr	55	0.3	1.6	30	0.9	7.8	0.2	0.2	0.2	1.8	25	6
11123	60	0.8	1.7	lnbe	45	0.3	1.3	45	1.1	7.8	0.7	0.4	0.5	2.9	50	14
11124	95	2.0	2.2	be	35	0.3	1.3	45	1.2	5.6	0.8	0.8	0.9	3.8	50	23
11125	95	2.8	2.8	be	35	0.3	1.1	45	1.2	6.7	0.8	0.8	0.9	5.6	50	35
11126	95	3.3	3.4	be	35	0.3	0.9	45	1.2	7.8	0.9	0.8	0.9	7.4	50	35
11131	20	1.0	2.2	gr	45	0.3	1.3	20	1.2	9.0	0.2	0.2	0.4	1.1	--	--
11132	40	1.3	3.9	grbe	35	0.3	1.3	40	1.8	15.7	0.4	0.5	0.9	2.9	50	6
11133	60	1.9	4.5	be	25	0.3	1.1	70	1.8	17.9	1.1	1.0	1.0	3.8	70	14
11134	95	2.5	5.0	be	15	0.3	1.1	70	1.8	17.9	1.2	2.0	1.1	5.6	70	23
11135	95	3.2	5.6	be	10	0.3	0.9	70	1.8	17.9	1.2	2.0	1.2	7.4	70	35
11136	95	3.8	6.7	be	10	0.3	0.7	70	1.8	17.9	1.3	2.0	1.3	9.4	70	35
13141	20	0.1	0.1	bd	25	0.3	1.1	65	1.3	10.1	0.7	1.6	0.8	1.8	--	--
13142	30	0.2	0.2	bd	21	0.3	1.1	75	2.6	13.5	1.1	2.0	0.9	2.8	80	27
13143	40	0.5	0.4	bd	18	0.3	1.1	85	2.6	17.9	1.6	2.2	1.0	3.8	80	27
13144	60	1.8	1.1	bd	12	0.3	0.9	45	2.6	15.7	1.7	2.7	1.2	7.4	80	27
13145	95	2.5	1.6	bd	10	0.3	0.7	20	2.6	11.2	1.7	3.2	1.5	9.4	80	27
13146	95	3.0	1.7	bd	7	0.3	0.4	10	2.6	4.5	1.8	3.2	1.7	11.2	80	27
15131	20	2.5	4.0	be	--	--	--	70	1.8	9.0	8.9	3.2	3.1	7.9	3	4
15132	40	3.2	4.5	be	--	--	--	75	2.1	13.5	8.9	3.2	3.1	7.9	5	6
15133	60	4.4	5.6	be	--	--	--	75	2.4	26.9	8.9	3.2	3.1	7.9	10	6
15134	95	5.1	6.7	be	--	--	--	75	2.4	44.8	8.9	3.2	3.1	7.9	20	8
15135	95	5.1	7.8	be	--	--	--	75	3.0	44.8	8.9	3.2	3.1	7.9	20	9
15136	95	5.1	8.5	be	--	--	--	75	3.0	44.8	8.9	3.2	3.1	7.9	20	9
15141	60	4.4	5.6	be	--	--	--	75	2.4	26.9	1.1	0.4	0.4	-	10	6
15142	20	2.5	4.0	be	--	--	--	70	1.8	9.0	2.2	0.8	0.8	-	3	4
15143	40	3.2	4.5	be	--	--	--	75	2.1	13.5	4.4	1.6	1.5	2.2	5	6
15144	95	5.1	6.7	be	--	--	--	75	2.4	44.8	8.9	3.2	3.1	4.5	20	8
15145	95	5.1	7.8	be	--	--	--	75	3.0	44.8	8.9	3.2	3.1	9.0	20	9
15146	95	5.1	8.5	be	--	--	--	75	3.0	44.8	8.9	3.2	3.1	9.0	20	9

See table A-7 for subscript explanations and descriptions of litter type codes

Table A-2: Selected parameters for natural fuelbeds in mesic flatlands

	Litter				Herbs			Shrubs			Woody Fuel Loading[4]				Overstory	
Fuelbed No.[1]	Cover[2]	Depth[3]	Loading[4]	Type[5]	Cover[2]	Height[3]	Loading[4]	Cover[2]	Height[3]	Loading[4]	1-hr	10-hr	100-hr	1000-hr	Cover[2]	Height[3]
21111	20	0.1	0.1	gr	75	0.5	1.3	5	0.3	1.1	0.2	0.2	0.2	0.4	--	2
21112	40	0.2	0.1	grln	65	0.5	1.3	8	0.5	2.2	0.2	0.2	0.2	1.1	5	8
21113	60	0.5	0.2	ln	55	0.5	1.1	10	0.5	2.2	0.3	0.4	0.4	2.2	10	14
21114	95	1.5	0.6	ln	55	0.5	1.1	10	0.6	2.2	0.3	0.8	0.8	2.8	20	23
21115	95	1.9	1.0	ln	55	0.5	0.9	10	0.6	2.2	0.3	0.8	0.8	3.8	20	32
21116	95	2.8	1.5	ln	55	0.5	0.9	10	0.6	2.2	0.4	0.8	0.8	5.6	20	32
21121	20	0.1	0.6	gr	60	0.3	1.1	10	0.6	2.2	0.2	0.4	0.3	1.8	--	2
21122	40	0.3	1.0	gr	50	0.3	1.1	20	0.9	4.5	0.4	0.6	0.4	3.8	25	8
21123	60	0.5	1.5	grln	40	0.3	0.9	25	1.1	6.7	0.5	0.7	0.5	4.6	50	14
21124	95	1.8	1.9	grln	30	0.3	0.9	25	1.2	6.7	0.7	0.8	0.7	5.6	50	23
21125	95	2.5	2.4	grln	30	0.3	0.7	25	1.2	6.7	0.7	1.0	0.8	6.6	50	32
21126	95	3.0	2.8	grln	30	0.3	0.7	25	1.2	6.7	0.7	1.0	0.9	7.4	50	32
21131	20	0.8	2.1	gr	45	0.3	1.0	20	1.0	4.5	0.3	0.3	0.6	0.7	--	2
21132	40	1.3	3.4	grbe	35	0.3	1.0	40	1.9	11.2	0.4	0.4	0.7	2.9	50	8
21133	60	1.4	4.4	mix	25	0.3	0.9	60	1.9	15.7	0.6	0.7	0.8	3.8	70	14
21134	95	1.9	4.8	mix	20	0.3	0.7	60	2.2	15.7	0.8	1.5	0.9	5.6	70	23
21135	95	3.0	5.3	mix	15	0.3	0.4	55	2.3	15.7	0.9	1.5	1.0	7.4	70	32
21136	95	3.6	6.2	mix	10	0.3	0.2	50	2.3	13.5	1.1	1.5	1.1	8.4	70	32
23141	25	0.3	0.1	be	25	0.2	0.9	30	1.3	4.5	0.2	1.6	0.5	1.8	--	3
23142	35	0.5	0.2	be	20	0.2	0.7	55	2.6	11.2	0.5	2.0	0.8	3.8	80	8
23143	65	0.8	0.4	be	10	0.2	0.4	65	2.6	15.7	0.7	2.2	1.0	4.6	80	14
23144	95	2.0	1.1	be	5	0.2	0.2	65	2.6	15.7	0.9	2.7	1.2	6.6	80	18
23145	95	2.8	1.6	be	1	0.2	0.2	45	2.6	11.2	1.2	3.2	1.3	7.4	80	24
23146	95	3.3	1.7	be	1	0.2	0.2	20	2.6	9.0	1.4	3.2	1.5	9.4	80	27

See table A-7 for subscript explanations and descriptions of litter type codes

Table A-3: Selected parameters for natural fuelbeds in mesic uplands

	Litter				Herbs			Shrubs			Woody Fuel Loading[4]				Overstory	
Fuelbed No.[1]	Cover[2]	Depth[3]	Loading[4]	Type[5]	Cover[2]	Height[3]	Loading[4]	Cover[2]	Height[3]	Loading[4]	1-hr	10-hr	100-hr	1000-hr	Cover[2]	Height[3]
31111	15	0.1	0.1	gr	55	0.3	1.1	5	0.3	1.1	--	0.2	0.2	--	10	1
31112	35	0.5	0.1	grln	45	0.3	1.1	10	0.5	2.2	0.1	0.2	0.2	0.1	10	5
31113	55	1.0	0.2	ln	35	0.3	0.9	15	0.5	5.6	0.1	0.4	0.4	1.0	30	10
31114	90	1.5	0.6	ln	25	0.3	0.9	15	0.6	5.6	0.2	0.7	0.7	1.8	30	16
31115	90	2.0	1.0	ln	25	0.3	0.7	15	0.6	5.6	0.2	0.7	0.8	2.8	30	22
31116	90	2.5	1.5	ln	25	0.3	0.7	15	0.6	5.6	0.2	0.7	0.8	3.8	30	22
31121	15	0.3	0.6	gr	40	0.2	0.9	30	0.6	4.5	0.1	0.2	0.2	0.4	10	1
31122	35	0.8	1.0	gr	30	0.2	0.9	45	0.9	6.7	0.2	0.4	0.5	1.7	30	5
31123	55	1.3	1.5	grln	25	0.2	0.7	60	1.1	7.8	0.2	0.6	0.8	2.8	60	10
31124	90	1.8	1.9	ln	15	0.2	0.7	60	1.2	7.8	0.3	0.7	0.9	3.8	60	16
31125	90	2.3	2.4	ln	10	0.2	0.4	60	1.2	7.8	0.4	0.8	0.9	4.6	60	22
31126	90	2.8	2.8	ln	10	0.2	0.2	50	1.2	6.7	0.5	0.8	0.8	5.6	60	22
31131	15	0.5	2.1	be	30	0.2	0.8	50	0.9	9.0	0.3	0.4	0.4	0.4	--	--
31132	35	1.0	3.4	be	25	0.2	0.7	75	1.7	13.5	0.2	0.5	0.7	2.8	40	5
31133	55	1.5	4.4	be	20	0.2	0.4	90	1.7	17.9	0.4	0.7	0.8	3.8	60	10
31134	90	2.0	4.8	be	15	0.2	0.2	90	1.7	17.9	0.5	1.0	0.9	4.6	60	16
31135	90	2.5	5.3	be	10	0.2	0.2	80	1.7	16.8	0.6	1.1	1.0	5.6	60	22
31136	90	3.0	6.2	be	5	0.2	0.2	70	1.7	15.7	0.7	1.2	1.1	6.6	60	22
32141	15	2.0	1.1	be	10	0.2	1.1	30	0.6	3.4	2.9	0.4	0.3	0.4	--	--
32142	35	3.4	5.6	beln	5	0.2	0.7	60	0.9	5.6	2.9	0.4	0.3	2.8	50	5
32143	55	3.4	5.6	ln	2	0.2	0.2	80	1.2	7.8	5.8	0.9	0.7	5.6	85	10
32144	90	5.1	11.2	ln	2	0.2	0.2	80	1.2	7.8	9.0	1.3	1.1	9.0	85	16
32145	90	5.1	11.2	ln	2	0.2	0.2	80	1.5	7.8	11.7	1.8	1.3	11.8	85	22
32146	90	5.1	11.2	ln	2	0.2	0.2	80	1.5	7.8	11.7	1.8	1.3	12.3	85	22
33141	15	0.3	0.1	be	20	0.2	0.7	20	0.9	4.5	0.2	0.4	0.6	0.7	50	1
33142	35	0.5	0.2	be	15	0.2	0.4	45	1.4	9.0	0.3	0.5	0.8	1.8	50	5
33143	55	1.0	0.4	be	10	0.2	0.2	55	1.5	10.1	0.5	0.8	0.9	3.8	85	10
33144	90	1.5	1.1	be	5	0.2	0.1	55	1.5	10.1	0.6	1.1	1.0	5.6	85	16
33145	90	2.0	1.6	be	2	0.2	0.1	35	1.8	9.0	0.8	1.2	1.1	6.6	85	22
33146	90	2.5	1.7	be	1	0.2	0.1	20	1.8	6.7	0.9	1.3	1.2	7.4	85	22

See table A-7 for subscript explanations and descriptions of litter type codes

Table A-4: Selected parameters for natural fuelbeds in xeric uplands

	Litter				Herbs			Shrubs			Woody Fuel Loading[4]				Overstory	
Fuelbed No.[1]	Cover[2]	Depth[3]	Loading[4]	Type[5]	Cover[2]	Height[3]	Loading[4]	Cover[2]	Height[3]	Loading[4]	1-hr	10-hr	100-hr	1000-hr	Cover[2]	Height[3]
41111	10	1.3	0.1	gr	26.4	0.3	0.6	2	0.3	0.6	--	0.2	0.1	0.1	10	2
41112	30	1.9	0.1	grln	23.1	0.3	0.4	5	0.6	1.1	--	0.2	0.1	0.4	22	5
41113	50	1.9	0.2	ln	19.8	0.3	0.3	5	0.6	1.1	0.1	0.4	0.2	0.6	45	10
41114	85	2.2	0.6	ln	19.8	0.3	0.2	5	0.6	1.1	0.1	0.7	0.4	1.1	45	12
41115	85	2.2	1.0	ln	19.8	0.3	0.1	5	0.6	1.1	0.1	0.9	0.4	2.2	45	15
41116	85	2.3	1.5	ln	19.8	0.3	0.1	5	0.6	1.1	0.1	0.9	0.4	2.8	45	18
41121	10	1.3	0.6	gr	21.45	0.2	0.4	5	0.6	1.1	--	0.2	0.2	0.4	10	2
41122	30	2.0	1.0	gr	18.15	0.2	0.3	10	0.9	1.5	0.1	0.2	0.2	0.7	33	5
41123	50	2.3	1.5	grln	14.85	0.2	0.2	10	0.9	1.5	0.1	0.4	0.4	1.0	65	10
41124	85	2.5	1.9	ln	11.55	0.2	0.1	10	0.9	1.5	0.2	0.8	0.4	1.8	65	12
41125	85	2.5	2.4	ln	9.9	0.2	0.1	10	0.9	1.5	0.2	1.0	0.6	2.8	65	15
41126	85	2.5	2.8	ln	8.25	0.2	--	10	0.9	1.5	0.2	1.0	0.6	3.8	65	18
41131	10	1.3	2.1	bd	14.85	0.2	0.3	5	1.2	1.3	0.1	0.2	0.2	0.4	10	2
41132	30	2.0	3.4	bd	11.55	0.2	0.2	10	1.8	1.8	0.1	0.6	0.3	1.0	33	5
41133	50	2.3	4.4	bd	8.25	0.2	0.1	15	1.8	2.2	0.2	1.1	0.5	1.8	65	10
41134	85	2.5	4.8	bd	3.3	0.2	0.1	15	1.8	2.2	0.2	1.3	0.6	2.8	90	12
41135	85	2.5	5.3	bd	3.3	0.2	--	15	1.8	2.2	0.3	1.7	0.8	3.8	90	15
41136	85	2.5	6.2	bd	1.65	0.2	--	15	1.8	2.2	0.4	2.2	0.9	4.6	90	18
42141	10	0.5	1.1	be	10	0.6	1.1	15	1.4	3.4	1.3	0.3	0.5	0.4	10	1
42142	30	1.0	5.6	be	5	0.6	0.7	15	2.4	4.5	1.3	0.3	0.5	2.8	30	4
42143	50	1.5	5.6	be	2	0.6	0.2	25	3.0	6.7	1.6	0.7	0.9	5.0	50	6
42144	85	2.0	11.2	be	2	0.6	0.2	25	3.0	6.7	1.6	1.1	1.7	7.8	60	8
42145	85	2.3	11.2	be	2	0.6	0.2	20	2.4	4.5	1.8	1.6	2.2	10.6	85	9
42146	85	2.3	11.2	be	2	0.6	0.2	20	2.4	4.5	1.8	1.6	2.2	11.2	85	9
43141	10	0.5	0.1	bd	8.25	0.2	0.1	10	0.9	1.5	0.1	0.6	0.3	0.7	10	1
43142	30	1.0	0.2	bd	4.95	0.2	0.1	35	1.5	2.8	0.2	0.8	0.4	1.8	30	4
43143	50	1.5	0.4	bd	3.3	0.2	--	45	1.5	6.7	0.2	1.1	0.6	2.8	40	6
43144	85	2.0	1.1	bd	2.64	0.2	--	45	1.5	6.7	0.3	1.3	0.7	3.8	50	8
43145	85	2.3	1.6	bd	1.65	0.2	--	30	1.5	4.5	0.4	1.7	0.8	4.6	60	9
43146	85	2.3	1.7	bd	1.65	0.2	--	25	1.5	4.5	0.5	2.2	1.0	5.6	60	9
44141	10	0.5	0.1	sn	10	0.3	1.6	15	0.9	1.5	1.3	0.9	0.4	2.2	10	2
44142	30	1.0	0.2	sn	5	0.3	0.4	25	1.1	2.8	1.3	0.9	0.4	4.5	35	6
44143	50	1.5	0.4	sn	5	0.3	0.2	15	1.1	2.2	1.6	0.9	0.4	5.0	70	10
44144	85	2.0	1.1	sn	5	0.3	0.2	10	0.9	1.3	1.6	0.9	0.4	5.6	75	14
44145	70	5.1	7.8	sn	--	--	--	--	--	--	1.8	0.9	0.4	2.2	75	15
44146	70	8.9	10.1	sn	--	--	--	--	--	--	1.8	0.9	0.4	2.2	75	17

See table A-7 for subscript explanations and descriptions of litter type codes

Table A-5: Selected parameters for plantation fuelbeds

	Litter				Herbs			Shrubs			Woody Fuel Loading[4]				Overstory	
Fuelbed No.[1]	Cover[2]	Depth[3]	Loading[4]	Type[5]	Cover[2]	Height[3]	Loading[4]	Cover[2]	Height[3]	Loading[4]	1-hr	10-hr	100-hr	1000-hr	Cover[2]	Height[3]
21513	60	0.5	0.2	ln	50	0.5	0.9	30	0.5	4.5	0.3	0.4	0.4	2.7	30	14
21514	95	1.5	0.6	ln	50	0.5	0.9	30	0.6	4.5	0.3	0.8	0.8	3.9	30	23
21523	60	0.5	1.5	grln	40	0.3	0.9	50	1.1	9.0	0.5	0.3	0.5	6.2	60	14
21524	95	1.8	1.9	grln	30	0.3	0.7	50	1.2	9.0	0.7	0.6	0.7	10.1	60	23
21532	40	1.3	3.4	grbe	35	0.3	1.0	70	2.1	17.9	0.4	0.4	0.7	3.5	40	8
21533	60	1.4	4.4	mix	25	0.3	0.9	70	3.0	17.9	0.6	0.7	0.8	5.6	60	14
21534	95	1.9	4.8	mix	20	0.3	0.7	60	4.6	17.9	0.8	1.5	0.9	11.2	60	23
21541	25	0.3	2.1	be	25	0.2	0.9	50	1.2	7.8	0.2	3.7	0.5	7.8	80	3
21542	35	0.5	3.4	be	20	0.2	0.7	40	3.0	12.3	0.5	0.5	0.8	9.0	80	8
21543	65	0.8	4.4	be	10	0.2	0.4	15	3.7	12.3	0.7	1.0	1.0	7.3	80	14
21544	95	2.0	4.8	be	5	0.2	0.2	15	3.7	12.3	0.9	2.0	1.2	8.4	60	18
31513	55	1.0	0.2	ln	35	0.3	0.9	30	0.6	1.7	0.1	0.4	0.4	2.5	30	14
31514	90	1.5	0.6	ln	25	0.3	0.9	30	0.9	2.2	0.2	0.7	0.8	3.9	30	23
31523	55	1.3	1.5	ln	25	0.2	0.7	50	1.5	6.7	0.2	0.6	0.9	5.0	60	14
31524	90	1.8	1.9	ln	15	0.2	0.7	50	2.1	7.8	0.3	0.7	0.9	9.0	60	23
31532	35	1.0	3.4	gr	25	0.2	0.7	70	2.1	13.5	0.2	0.7	0.7	3.4	40	8
31533	55	1.5	4.4	grbd	20	0.2	0.4	70	3.0	15.7	0.4	1.0	0.8	5.6	60	14
31534	90	2.0	4.8	grbd	15	0.2	0.2	60	4.6	15.7	0.5	1.1	0.9	10.6	60	23
31541	15	0.3	2.1	be	20	0.2	0.7	50	1.2	7.8	0.2	3.7	0.6	7.2	80	3
31542	35	0.5	3.4	be	15	0.2	0.4	40	3.0	12.3	0.3	0.5	0.8	7.8	80	8
31543	55	1.0	4.4	be	10	0.2	0.2	15	3.7	12.3	0.5	1.0	0.9	6.7	80	14
31544	90	1.5	4.8	be	5	0.2	0.1	15	3.7	12.3	0.6	2.0	1.0	7.8	60	18
41513	50	1.9	0.2	ln	60	0.3	0.3	5	0.6	1.1	0.1	0.4	0.2	1.7	45	10
41514	85	2.2	0.6	ln	60	0.3	0.3	5	0.6	1.1	0.8	0.7	0.4	2.9	45	12
41523	50	2.3	1.5	ln	45	0.2	0.2	10	0.9	1.5	0.1	0.4	0.2	1.9	65	10
41523	85	2.5	1.9	ln	35	0.2	0.1	10	0.9	1.5	0.2	0.8	0.4	3.4	65	12
41532	30	2.0	3.4	grbd	35	0.2	0.2	15	1.4	1.1	0.1	0.6	0.3	2.8	33	5
41533	50	2.3	4.4	grbd	25	0.2	0.1	15	1.5	1.7	0.2	1.1	0.5	4.5	65	10
41534	85	2.5	4.8	grbd	10	0.2	0.1	15	1.8	2.2	0.2	1.3	0.6	6.2	90	12
41541	10	0.5	0.1	bd	25	0.2	0.1	15	1.1	4.5	0.1	0.3	0.5	0.7	10	1
41542	30	1.0	0.2	bd	15	0.2	0.1	10	0.9	3.4	0.2	0.3	0.5	3.4	30	4
41543	50	1.5	0.4	bd	10	0.2	--	15	0.9	3.4	0.2	0.7	0.9	5.6	50	6
41544	85	2.0	1.1	bd	8	0.2	--	25	1.1	5.6	0.3	1.1	1.7	9.0	60	8
44541	10	0.5	0.1	sn	25	0.2	0.1	15	0.9	3.4	0.1	0.9	0.4	1.8	10	2
44542	30	1.0	0.2	sn	15	0.2	0.1	25	1.1	5.6	0.2	0.9	0.4	2.8	35	6
44543	50	1.5	0.4	sn	10	0.2	--	15	1.1	4.5	0.2	0.9	0.4	3.4	70	10
44544	85	2.0	1.1	sn	8	0.2	--	10	0.9	3.4	0.3	0.9	0.4	4.5	75	14

See table A-7 for subscript explanations and descriptions of litter type codes

Table A-6: Selected parameters for restoration treatment fuelbeds

	Litter				Herbs			Shrubs			Woody Fuel Loading[4]				Overstory	
Fuelbed No.[1]	Cover[2]	Depth[3]	Loading[4]	Type[5]	Cover[2]	Height[3]	Loading[4]	Cover[2]	Height[3]	Loading[4]	1-hr	10-hr	100-hr	1000-hr	Cover[2]	Height[3]
41211	65	5.1	7.8	sn	10	0.6	1.1	10	0.6	1.1	2.6	0.9	4.3	11.2	10	1
41212	65	2.5	5.6	sn	10	0.6	1.1	15	1.1	4.5	5.3	1.5	3.1	6.7	5	6
41213	65	3.8	6.7	sn	10	0.6	1.1	15	1.1	4.5	8.9	2.6	3.1	11.2	10	10
41313	65	1.3	4.5	beln	5	0.6	0.4	5	0.3	0.4	4.5	2.1	7.2	9.0	10	6
41314	65	3.8	6.7	ln	5	0.6	0.4	5	0.3	0.4	6.7	3.1	10.8	13.5	15	8
41315	65	3.8	6.7	ln	5	0.6	0.4	5	0.3	0.4	6.7	3.1	10.8	13.5	20	9
41316	65	3.8	6.7	ln	5	0.6	0.4	5	0.3	0.4	6.7	3.1	10.8	13.5	25	9
41413	65	1.3	4.5	ln	80	0.6	4.5	5	0.6	1.1	4.9	2.3	7.8	12.4	10	6
41414	65	3.8	6.7	ln	80	0.6	4.5	5	0.6	1.1	6.7	3.1	10.8	16.8	15	8
41415	65	3.8	6.7	ln	80	0.6	4.5	5	0.6	1.1	6.7	3.1	10.8	16.8	20	9
41416	65	3.8	6.7	ln	80	0.6	4.5	5	0.6	1.1	6.7	3.1	10.8	16.8	25	9

See table A-7 for subscript explanations and descriptions of litter type codes

Table A-7: Selected parameters for static fuelbeds

	Litter				Herbs			Shrubs			Woody Fuel Loading[4]				Overstory	
Fuelbed No.[1]	Cover[2]	Depth[3]	Loading[4]	Type[5]	Cover[2]	Height[3]	Loading[4]	Cover[2]	Height[3]	Loading[4]	1-hr	10-hr	100-hr	1000-hr	Cover[2]	Height[3]
16100	50	1.3	1.7	bl	10	0.3	1.1	85	1.5	17.9	0.4	0.4	0.4	--	--	--
16900	95	1.3	0.6	ge	15	0.5	--	10	3.0	3.3	0.4	0.4	1.1	--	--	--
17100	--	--	--	--	100	0.9	9.0	--	--	--	--	--	--	--	--	--
57900	--	--	--	--	50	0.2	1.1	2	0.9	--	--	--	--	--	--	--
58900	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
59900	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
60000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[1]See Table 1 for key to fuelbed numbers. [2]Percent cover. [3]Depth is in cm and height is in m. [4]Loading is mG ha-1. [5]Litter types are gr = grass; ln = long-needle pine, bd = broadleaf deciduous, be = broadleaf evergreen, sn = short-needle pine, four letter litter type codes indicate mixtures when there is a < 5 percent difference between two most common types, and mix denotes fuelbeds where more than two litter types are within 5 percent of each other.