MODELING MANUAL

Modeling the Carbon Implications of Ecologically-Based Forest Management

Fort Benning – Modeling Manual

SERDP Project RC-2118

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List of Acronyms

DBH – Diameter at Breast Height (1.37 m)
FB – Fort Benning
NECB – Net Ecosystem Carbon Balance
NEE – Net Ecosystem Exchange
NEP – Net Ecosystem Production
NPP – Net Primary Productivity
R_h – Heterotrophic Respiration
RCW – Red-cockaded Woodpecker
TEC – Total Ecosystem Carbon

Acknowledgements

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Background

The forest carbon cycle can be generically described as a series of carbon pools that interact with each other and the atmosphere through a series of fluxes (Figure 1). Carbon is removed from the atmosphere through photosynthesis by trees and understory vegetation, and some of this carbon is released back to the atmosphere through respiration. Once sequestered, carbon in plant material eventually transitions to the snag, woody debris, or surface fuel pool for trees, and the surface fuel pool in the case of understory vegetation. During decomposition, some of the carbon from the dead plant material is incorporated into the organic horizon and mineral soil. In the absence of disturbance, the expectation is that the carbon stock grows to a theoretical maximum where Net Ecosystem Productivity (NEP, the annual change in the total ecosystem carbon stock) approaches zero (Hudiburg et al., 2009).

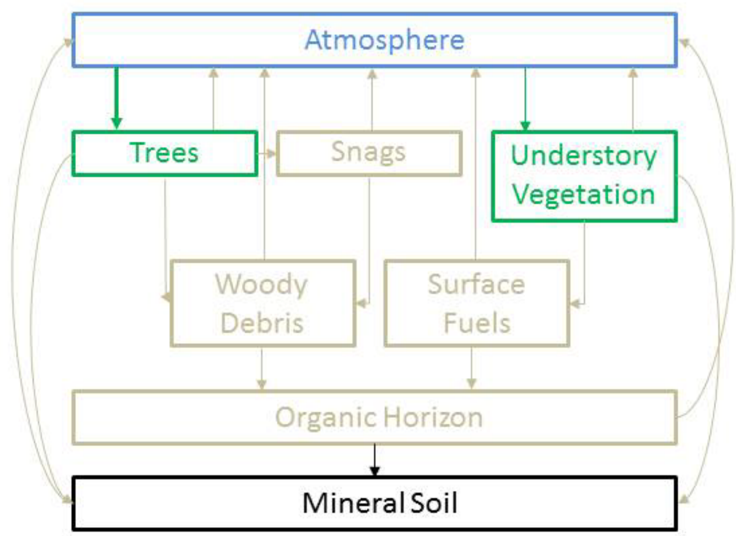


Figure 1: Generalized forest carbon pools and fluxes.

When fire enters into the equation, fluxes back to the atmosphere increase as a function of fire severity (Meigs et al., 2009; Wiedinmyer and Hurteau, 2010). Furthermore, increasing fire severity increases tree mortality (Agee and Skinner, 2005). When fire severity and tree mortality are high, NEP and carbon storage can decline precipitously (Dore et al., 2008; Meigs et al., 2009) and carbon stocks decline over longer time horizons as compared to forests experiencing lower fire severity (Hurteau and North, 2009; Hurteau, 2013). In fire-prone systems, the carbon carrying capacity - quantity of carbon that can be maintained under naturally prevailing conditions (Keith et al., 2009) - likely represents an appropriate target for carbon life-cycle management (Figure 2).

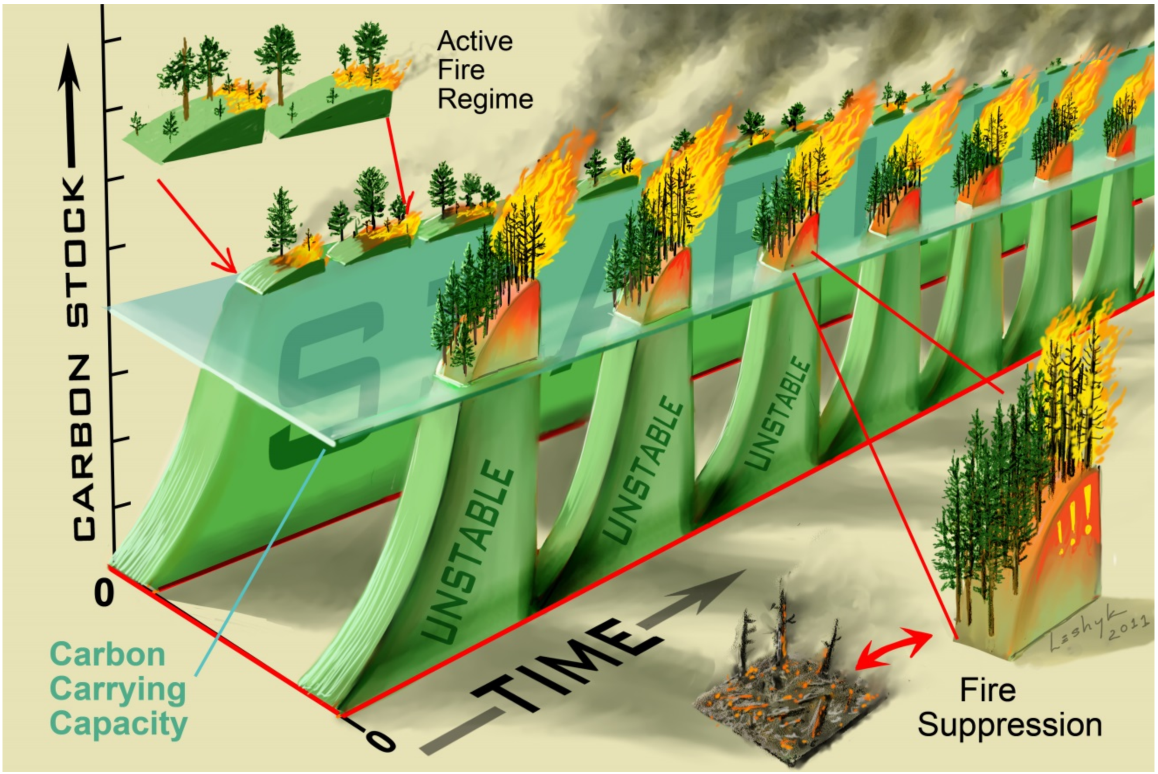


Figure 2: In dry, fire-prone forest types, the C stock varies as a function of the frequency of disturbance. An active fire regime results in a relatively stable C stock because frequent fires maintain fuel loads at levels that result in low-intensity fire. When we exclude fire from these systems, the C stock exceeds the C carrying capacity because of increased tree density and fuel buildup. When wildfire occurs in the fire-excluded forest, the C stock is reduced below the carrying capacity because of high fire severity. The C stock recovery following wildfire depends on the successional path of the forest recovery (from Hurteau , 2013).

Because forest carbon sequestration is a major part of the global carbon cycle (Canadell and Raupach, 2008), management actions that affect forest carbon dynamics are being increasingly scrutinized. In particular, the role of fire management, including its impacts on forest carbon and the resultant emissions is garnering substantial attention (Hurteau, 2013; Hurteau et al., 2013). Thus, quantifying the expected effects of management actions on forest carbon stocks prior to management implementation is increasingly important.

The objectives of this document are to present the modeling approach used to simulate forest carbon dynamics at Fort Benning, GA as part of SERDP funded project RC-2118. The results from Fort Benning are presented in Martin et al. (2015, in press).

LANDIS-II Model

This work used the LANDIS-II model, a landscape-scale forest succession and disturbance model that simulates forest succession using age cohorts of species (Scheller et al. 2007). The study area is gridded and each grid cell populated with age cohorts of species from forest inventory data. Species regeneration, growth, and mortality are functions of a species' life history characteristics and the environment within a given grid cell. The LANDIS-II base model has a number of extensions to expand its capabilities. As part of this research, we parameterized the Century Succession, Dynamic Fuels and Fire System, Leaf Biomass Fuels, and Leaf Biomass Harvest extensions. Executable files for the base model and extensions can be downloaded from http://www.landis-ii.org/.

Data Sources

Forest data: Fort Benning inventory data

Soils data: NRCS SSURGO

Climate data: NCDC station data (station ID GHCND: USW00093842)

Files Used in FB LANDIS-II Simulations

All simulations:

Initial Communities: FBICHW5.txt/ FBIC626.img

Ecoregions: FBER1.txt/ FBER626.img

Species: FBSPP5.txt

Century Succession: FBCSUCCALL19AUG13.txt

Climate: FBClimateTable2.txt

Age only disturbances: FBAODist1.txt

Leaf biomass output: FBLeafBioOutANNUAL.txt

Forest Management:

<u>Leaf biomass harvest</u>

Maps: Management areas: FBMGMT717.img; Stands: FBSTANDS717.img

Leaf biomass harvest: FBHarvestRCWMAX31JULY4.txt *Used in thin and burn

<u>Dynamic Fire & Fuels</u>

Dynamic Leaf biomass fuels: FBDyFuels30July4.txt *Used in thin and burn

Dynamic Fire System: FBDyFire31July4.txt *Used in thin and burn

Fire regions: FBFR78.img

Fire weather: FBIFW.csv

Scenario files: fbburn.TXT/ fbthinburn.TXT

File Descriptions

This section uses the thin and burn scenario (ftbhinburn.txt) simulated for this project to demonstrate how the different input files are used to set up simulations. The purpose of the thin and burn scenario is to restore RCW habitat across the installation. It involves three different harvest types.

The model uses the scenario file to call the species file, the ecoregions text and img files, and the extension files. For the fbthinburn.txt scenario file, the model calls the Century Succession extension using FBCSUCCALL19AUG13.txt, the Leaf Biomass Harvest extension using FBHarvestRCWMAX31JULY4.txt, the Dynamic Leaf Biomass Fuels extension using FBDyFuels30July4.txt, the Dynamic Fire System extension using FBDyFire31July4.txt, and the Output Leaf Biomass extension using FBLeafBioOutANNUAL.txt.

Species File

The species file (FBSPP5.txt) includes parameter values for the life history parameters for the tree species simulated at Fort Benning. The full list of species already parameterized includes:

- PIPA – *Pinus palustris*
- PITA – *Pinus taeda*
- PIEC – *Pinus echinata*
- QUFA – *Quercus falcata*
- QUAL – *Quercus alba*
- QUMA – *Quercus marilandica*
- CATO – *Carya tomentosa*
- LIST – *Liquidambar styraciflua*
- ACRU – *Acer rubrum*
- QULA – *Quercus laevis*

Century Succession File

The four letter species codes are used to reference physiological parameters for each species in the Century Succession file (FBCSUCCALL19AUG13.txt). The Century Succession extension is used to model fluxes and pools of carbon and nitrogen. It can also be used to simulate projected changes in climate using simulated climate. The Century Succession extension requires a range of physiological parameter values for each species (e.g. growing degree days, drought tolerance, leaf longevity, etc). We parameterized the species using values from the peer-reviewed literature (see Appendix 1). The Century Succession file also includes soil parameter values, which were obtained from NRCS SSURGO data. The Century Succession extension calls the initial communities text file, map files, and the climate file. The climate file is used to create monthly climate distributions for each ecoregion (subdivision within the installation) using climate data. The model draws from these distributions to obtain weather data for each calculation. The climate data file (FBClimateTable2.txt) was developed using 51 years of meteorological data (1962-2012) from the Columbus, GA weather station (station ID GHCND: USW00093842). The Century Succession extension also calls the age-only disturbances file (FBAODist1.txt). This file allows the biomass of age-cohorts to be distributed to the proper dead biomass pools once they are killed by disturbance.

Leaf Biomass Harvest File

The Leaf Biomass Harvest extension is used to simulate structural manipulations. The harvest extension requires that the simulation landscape be divided into management areas or stands and the map file of stands (FBMGMT717.img) is called by the harvest extension file. In this study we simulated three different silvicultural prescriptions: Convert, Restore, Thin (Table 1).

Table 1: Silvicultural prescriptions simulated as part of the thin and burn treatment at Fort Benning.

Harvest Prescription	Description	Implementation
Thin	Hardwoods: all removed Lobolly pine removals: all ≤60years old, 75% > 60 years old Shortleaf pine removals: 10% ≤ 10 years old, 5% 11-20 years old Longleaf pine removals: 25% ≤ 10 years old, 20% 11-60 years old	Approximately every 30 years in all stands, from the beginning of the simulation in longleaf pine and mixed pine stands and beginning in 30 years after a restore or convert prescription.
Restore	Hardwoods: all removed Lobolly pine removals, all ≤60years old, 75% > 60 years old Shortleaf & longleaf pine removals: 20% ≤ 10 years, 10% 11-30 years, 5% 31-60 years Longleaf pine planted	Applied once in stands with significant hardwood component.
Convert	Hardwoods: all removed Loblolly pine: all ≤ 60 years old removed Longleaf pine planted	Applied once to loblolly pine plantations.

The harvest input file is structured such that each harvest type is specified individually. It is important to remember that LANDIS-II is simulating age-cohorts of species and not individual trees. As a result, harvesting simulations specify the minimum age at which the harvest will occur and the minimum time between harvests. For each harvest type, the user specifies the percentage of age cohorts to be removed for each species. As an example, to initiate a thin-from-below for the Thin treatment in Table 1, we prescribe the following in the harvest file:

```
FBHarvestRCWMAX31JULY4.txt - Notepad
File  Edit  Format  View  Help

Prescription RCWThin
>> RCWThin will target younger cohorts (thin from below)

StandRanking MaxCohortAge

MinimumAge 30
MinimumTimeSinceLastHarvest 40
SiteSelection Complete
MinTimeSinceDamage 1

CohortsRemoved SpeciesList
>>  Species     Selection
>>------------  -------------
PIPA            1-10 (25%) 11-60 (20%)
PITA            1-60 (100%)61-200 (75%)
PIEC            1-10 (10%) 11-20 (5%)
QUAL            All
QUMA            All
QUFA            All
CATO            All
LIST            All
ACRU            All
QULA            All
```

This particular prescription tells the model to harvest 25% of PIPA cohorts age 1-10 and 20% of PIPA cohorts age 11-60. It harvests 100% of PITA cohorts less than 60 years old and 75% of PITA cohorts older than 60 years. Young PIEC cohorts are thinned and all other species are completely harvested. This prescription is implemented periodically throughout the simulation period as a function of stand conditions. The model can also be used to simulate planting following harvest. In the Restore prescription, we prescribed the following in the harvest file:

```
FBHarvestRCWMAX31JULY4.txt - Notepad
File  Edit  Format  View  Help

Prescription RCWRestore
>>convert pine-hw to increasing pine

StandRanking MaxCohortAge
MinimumAge 20
MinimumTimeSinceLastHarvest 100
SiteSelection Complete
MinTimeSinceDamage 1

CohortsRemoved SpeciesList
>>  Species     Selection
>>------------  -------------
PIPA            1-10 (20%) 11-30 (10%) 31-60 (5%)
PITA            1-60 (100%)61-200 (75%)
PIEC            1-10 (20%) 11-20 (10%) 21-30 (5%)
QUAL            All
QUMA            All
QUFA            All
CATO            All
LIST            All
ACRU            All
QULA            All

Plant PIPA
```

This prescription initiates the same harvesting prescription as the Thin treatment, but includes planting of PIPA following harvest. This treatment is scheduled to be implemented once in stands with a large hardwood component. The harvest file also prescribes the output files. In this case, we tell the model to provide maps of where harvest was implemented and how much biomass was removed for each time-step. We also output harvest logs in .csv format.

Dynamic Fire System File

The Dynamic Fire System is used to simulate prescribed burning or wildfire. In the thin and burn simulation, we used this extension to simulate prescribed burning with a mean fire return interval of three years. The fire extension requires a fire regions map (FBFR626.img), a fire weather file (FBIFW5.csv), and a fuel input file (FBDyFuels30July4.txt). The fuels file classifies fuels as a function of species, age, and other characteristics. Specific information regarding the parameter values in the fuels file can be found in the LANDIS-II Dynamic Leaf Biomass Fuel System Extension v2.0 User Guide.

The fire input file specifies fire parameters for each ecoregion, including a distribution for fire size. In the thin and burn simulations, we prescribed the following fire size characteristics:

```
FBDyFire31July4.txt - Notepad
File  Edit  Format  View  Help
LandisData "Dynamic Fire System"
>> Updated 29 May 2013 FOR RX FIRE- MAXIMUM CUT OFF AT APPROX 3 STANDS
>> updated 30 july for thinning fuel types
>> ---------------------------------------------

Timestep 1

EventSizeType  size_based << or duration based
>>EventSizeType duration_based

BuildUpIndex  no               << yes or no/ Y N
WeatherRandomizer 0            << optional 0-4

>> Fire Sizes (parameters applied for both size and duration based)
>> Eco  EcoName   Mu  Sigma  Max   SpFMCL    SpFMCH SpHProp  SuFMCL SuFMCH  SuHProp      FaFMCL   FaFMCH FaHiProp OpFuelIndex NumFires
0 Inactive     1  1       1  120         120     0.0      120    120         0.0       120      120     0.0            0        0.0
1 Eco5         7  3      13   95         120     0.5      90     120         0.5       90       120     0.50           1        690
2 Eco6         7  3      13   95         120     0.6      90     120         0.6       90       120     0.60           1        245
3 Eco7         7  3      13   95         120     0.6      90     120         0.6       90       120     0.60           1         85
4 Eco8         7  3      13   95         120     0.6      90     120         0.6       90       120     0.60           1         28
5 Eco9         7  3      13   95         120     0.6      90     120         0.6       90       120     0.60           1         95
```

Using Eco5 as an example, this file provides the model with a distribution from which to draw the number of ignitions in a time-step (NumFires). The NumFires value is used as the average number of ignitions for a Poisson distribution for a given fire region. In the case of Eco5, the average number of fires is 690. The model draws the number of ignitions from the distribution and then randomly selects cells from the fire region and determines if a fire occurs based on the ignition and fuel type. Fire size is determined using a lognormal distribution with Mu being the mean of the associated normal distribution and Sigma being the scale parameter of the lognormal distribution. The Max parameter defines the maximum fire size. The spring foliar moisture content provides the low (SpFMCL) and high (SpFMCH) foliar moisture values and the spring high proportion parameter (SpHProp) specifies the proportion of fires that occur during the high foliar moisture content period. The same parameters are provided for summer and fall. The open fuel type index (OpFuelIndex) is used to calculate fire spread rates when no trees are present in a grid cell. The season table is used to specify the season in which fires occur.

```
SeasonTable
>>              Leaf      Proportion        Percent          DayLen
>> Name Status            Fire              Curing           Proportion
>>----------------------------------------------------------------------------------------------
Spring          LeafOff    0.55             0                1.0
Summer          LeafOn     0.35             50               1.0
Fall            LeafOff    0.10             100              1.0
```

In the season table, the user specifies leaf off or leaf on for deciduous species, the proportion of fires that happen within each season, the degree that grasses in the understory have cured, and the proportion of each 24-hour day that fires can spread. The fuel type table specifies the ignition probability for each fuel type and parameter values specific to calculating fire behavior for each fuel type.

```
FuelTypeTable   << parameters follow Canadian Forest Fire Behavior Prediction System
>> Index    Base                Surface      IngProb     a     b       c     q     BUI       MaxBE   CBH
>>--------  ---------           ---------    -------   -----  ------  ---   ---   ----      ------  ------
    1       Conifer             C5           1.0        30    0.080   3.5   0.8     56      1.220      0
    2       Conifer             C5           1.0        30    0.080   3.5   0.8     56      1.220      2
    3       Conifer             C5           1.0        30    0.080   3.5   0.8     56      1.220      5
    4       Deciduous           D1           1.0        30    0.0232  1.6   0.9     32      1.179      0
    5       Deciduous           D1           1.0        30    0.0232  1.6   0.9     32      1.179      2
    6       Conifer             M1           1.0        0     0       0     0.8     50      1.250      0
    7       Conifer             C5           1.0        30    0.08    3.0   0.8     50      1.460      5
    8       Conifer             C5           0.0        30    0.080   3.5   0.8     50      1.220      0
    9       Conifer             C5           0.0        30    0.080   3.5   0.8     50      1.220      0
    10      Conifer             C5           1.0        30    0.08    3.0   0.8     50      1.460      5

SeverityCalibrationFactor  1.0
```

The fire damage table is used to determine fire effects on tree age-cohorts. Fire tolerance is prescribed based on the percentage of a species maximum longevity. The fire severity – fire tolerance parameter determines mortality by fire and is the minimum difference between the severity of a fire event and the fire tolerance for an individual species.

```
FireDamageTable
>> Cohort  Age           Fire Severity-
>> % of longevity        Fire Tolerance
>>-------------------    --------------------
1%                        -4
1.5%                      -3
2%                        -2
2.5%                      -1
3%                         0
8%                         1
10%                        2
25%                        3
95%                        4
```

The fire input file is also used to specify the simulation outputs related to fire. In this case, we have specified a fire log summary and fire severity maps for each time-step.

Getting Started

You will need to download and install the following:

- LANDIS-II 6.0
- Century Succession
- Dynamic Fuels and Fire System
- Leaf Biomass Fuels
- Leaf Biomass Harvest
- Leaf Biomass Output
- Cohort Statistics Output

Once you have installed the model and extensions, you will need to create a directory for your input files. In your My Documents folder, create a new folder called “FB LANDIS”. Copy and paste the provided files into this folder.

The next step is to ensure that all of your input files are referenced properly in the text files. You will need to edit the file path to match your working directory in the following files:

Scenario File: fbburn.txt or fbthinburn.txt

Century File: FBCSUCCALL19AUG13.txt

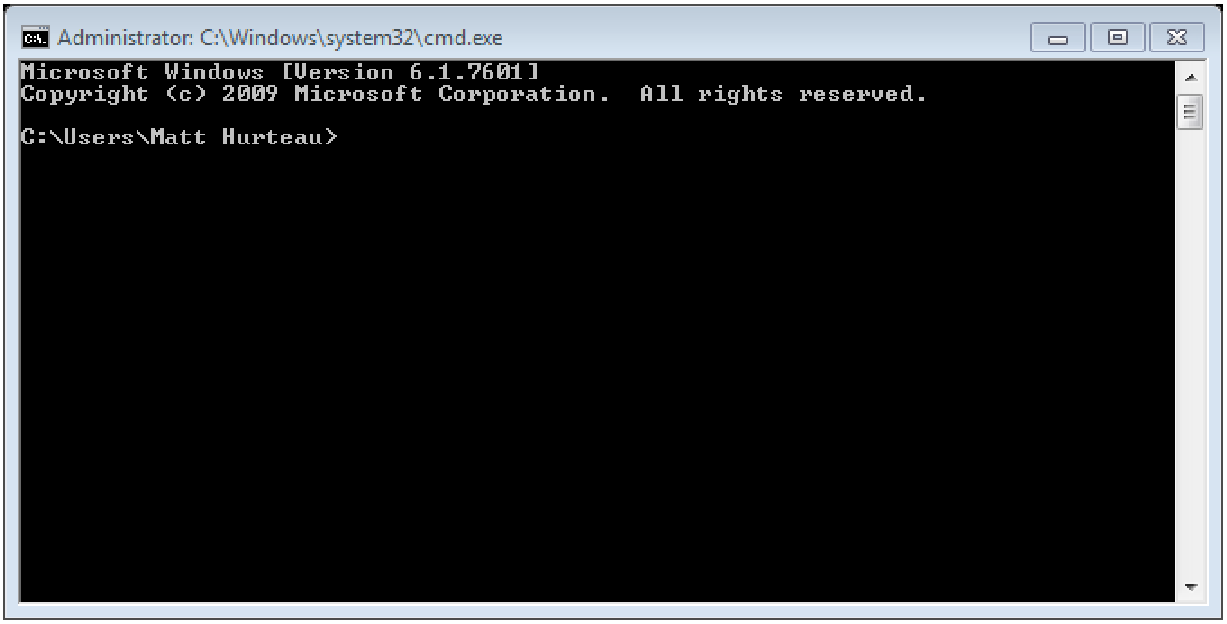
Fire File: FBDyFire31July4.txt

Harvest File: FBHarvestRCWMAX31JULY4.txt

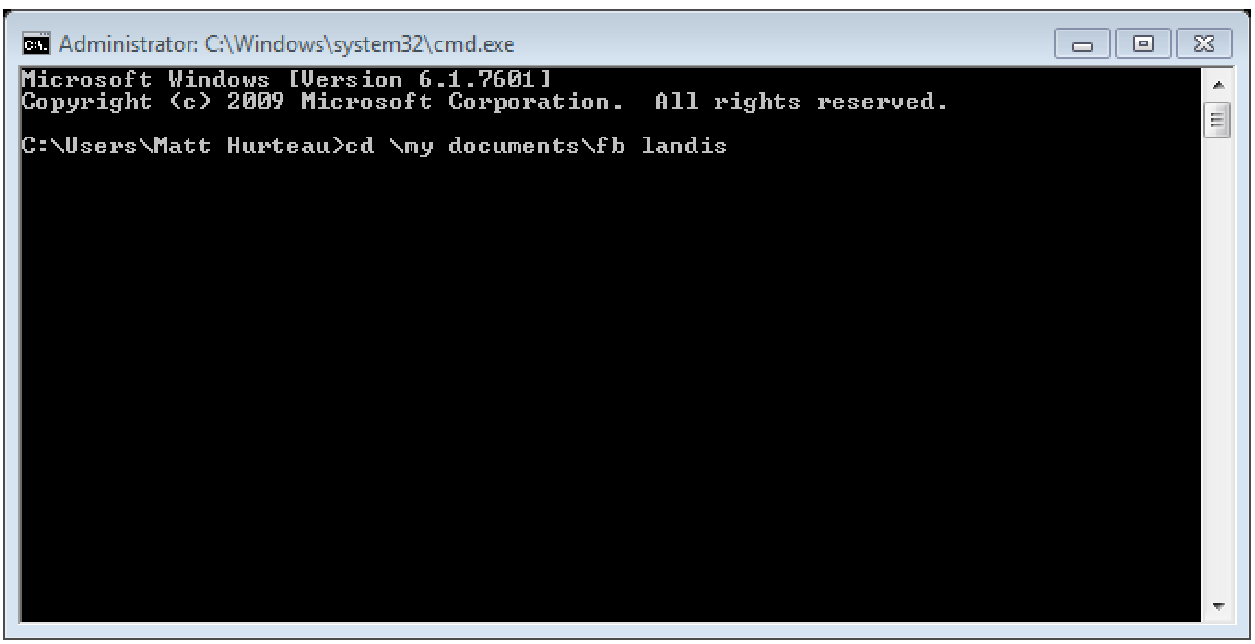
Example scenario file. Note that there are seven different file paths that require updating.

```
fbburn.txt - Notepad
File  Edit  Format  View  Help
LandisData "Scenario"

Duration 100

Species "c:\My Documents\FB LANDIS\FBSPP5.txt"

Ecoregions "c:\My Documents\FB LANDIS\FBER1.txt"
EcoregionsMap "c:\My Documents\FB LANDIS\FBER626.img"

CellLength 200 << meters

>>  Succession Extension    Initialization File
>> ----------------------   -------------------
   "Century Succession"    "c:\My Documents\FB LANDIS\FBCSUCCALL19AUG13.txt"


>> Disturbance Extensions      Initialization File
>> ----------------------      -------------------
   "Dynamic Leaf Biomass Fuels" "c:\My Documents\FB LANDIS\FBDyFuels30July4.txt"
   "Dynamic Fire System"        "c:\My Documents\FB LANDIS\FBDyFire31July4.txt"


>>   DisturbancesRandomOrder  yes  << optional parameter; default = no


>>    Other Extensions      Initialization File
>> ----------------------   -------------------
   "Output Leaf Biomass"        "C:\My Documents\FB LANDIS\FBLeafBioOutANNUAL.txt"

>>RandomNumberSeed  off  << optional parameter; default = the seed is randomly generated using the current time
```

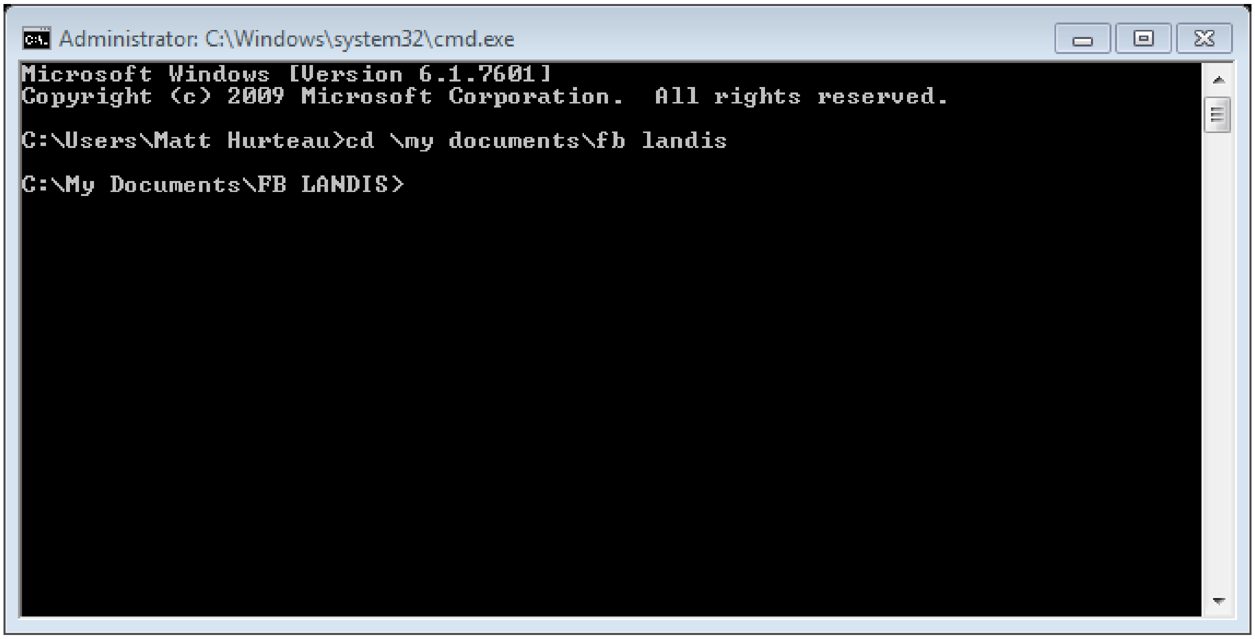
To open the model, you will need to open the ms dos prompt by typing "cmd" in the search box on the start menu.



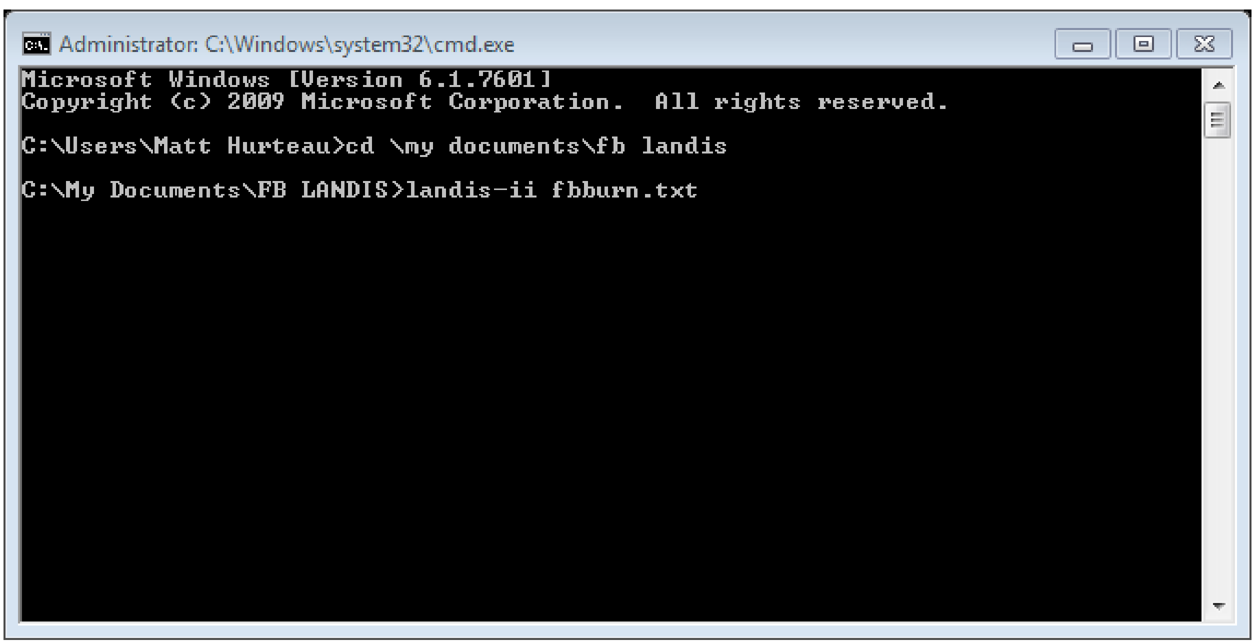
Next you will need to map to the folder you just created. To do this you will need to use the change directory command (cd).



Once you have typed the new directory command, your prompt should indicate that you are working from the FB LANDIS folder.



To initiate a model run, you need to type landis-ii followed by the name of the scenario file.



The model will initiate after hitting enter. The command window will show progress through each time-step as the model runs. If the model stops running, the command window will display any file reference issues.

Model Outputs

The model run produces a number of output files. In your working folder (FB LANDIS) you will find the following outputs:

Folders:

- biomassMAP – biomass by species for each simulation time-step
- conmap – percent conifer maps for each time-step
- deadfirmap – percent dead fir maps for each time-step
- DFFS-output – time of last fire maps for each time-step
- Firelog – fire information (e.g. number of pixels, fires) in each ecoregion for each time-step
- Firesevmap – maps of fire severity for each time-step
- Fuelsmap – fuel maps for each time-step
- NEEMap – maps of net ecosystem exchange for each time-step
- NPPMap – maps of net primary productivity for each time-step
- SoilCMap – maps of soil carbon for each time-step

Files:

- Century-prob-establish-log.csv – probability of establishment for each species in each ecoregion for each time-step
- Century-succession-log.csv – annual outputs of carbon and nitrogen pools and fluxes by ecoregion
- Century-succession-montly-log.csv – monthly outputs of precipitation, temperature, respiration, net ecosystem exchange, and nitrogen deposition for each ecoregion.
- Landis-log.txt – simulation log
- Spp-biomass-log.csv – biomass of each species by ecoregion for each time-step

Model Output Considerations

There are a few things that you need to consider when examining model outputs. We have parameterized the model such that each grid cell is 200 x 200 m (4 hectares). We have divided the Fort Benning landscape into four ecoregions based on soil type. The land area by ecoregion is displayed in Table 2. To calculate average carbon pools and fluxes across the installation, you will need to use a weighted average and weight each ecoregion value by the area occupied by that ecoregion.

Table 2: Number of grid cells and land area by ecoregion.

Ecoregion	Grid Cells (number)	Total Land Area (ha)
Eco1	3222	12,888
Eco2	1988	7,952
Eco3	204	816
Eco4	1080	4,320

As an example, if we have the following model output for Net Ecosystem Exchange of Carbon (NEEC) for one time-step:

Ecoregion	Grid Cells (number)	NEEC	% of Total	NEEC Contribution
Eco1	3222	-19.77	0.49615	-9.80
Eco2	1988	-104.69	0.306129	-32.04
Eco3	204	-132.84	0.031414	-4.17
Eco4	1080	-56.13	0.166307	-9.33
Total Grid Cells	6494		**Total NEEC**	**-55.36**

Flux results are in g m^{-2} yr^{-1} and pools are in g m^{-2}. NEE flux is from an atmospheric perspective and when a value is negative it means carbon is being removed from the atmosphere and sequestered by the forest. In this case, forests at Fort Benning sequestered on average 55.36 g m^{-2} in this particular simulation year. Multiplying the g m^{-2} value by 0.01 converts to megagrams (10^6 gC) per hectare (10^4 m^2), in this case giving a value of 0.5536 MgC ha^{-1}. The NEE value accounts for carbon sequestered by the ecosystem through photosynthesis, carbon lost through respiration, and carbon emitted from burning. The Century-succession-log.csv output file provides pool and flux values for a number of ecosystem attributes. The most useful outputs for the purposes of evaluating the effects of different management actions on carbon pools and fluxes are presented in Table 3. The Century-succession-monthly-log.csv output file allows you to evaluate the monthly fluxes of carbon. The net primary productivity (NPPC) value provides a monthly carbon uptake value by ecoregion. The respiration (Resp) value provides a monthly value of carbon respired by the ecosystem by ecoregion.

Table 3: Century Succession outputs useful for evaluating the effects of forest management on carbon pools and fluxes.

Output	Name	Units	Conversion
NEEC	Net Ecosystem Exchange	gC m^{-2} yr^{-1}	multiply by -1 to get C sequestered; multiply by 0.01 to get Mg ha^{-1}
SOMTC	Soil Organic Matter Total C	gC m^{-2}	multiply by 0.01 to get Mg ha^{-1}
AGB	Aboveground Biomass	gBiomass m^{-2}	multiply by 0.5 to get carbon; multiply by 0.01 to get Mg ha^{-1}
FireCEfflux	Fire emission of Carbon	gC m^{-2} yr^{-1}	multiply by 0.01 to get Mg ha^{-1}

Additional Resources

Scheller, RM, M Lucash (Eds). Forecasting forested landscapes: an introduction to LANDIS-II with exercises 2nd edition.

www.landis-ii.org

There are manuals for the core model and each extension on the LANDIS-II website.

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Appendix 1 – Parameter Values

Appendix 1 contains parameter values used for LANDIS-II simulations and a list of references used to determine parameter values.

Table A1: Species-specific parameter values used for the species file.

Species	Longevity (years)	Sexual Maturity (years)	Shade Tolerance (1-5)	Fire Tolerance (1-5)	Effective Seed Dispersal Distance (m)	Maximum Seed Dispersal Distance (m)
Pinus palustris	400	30	1	5	30	200
Pinus taeda	350	15	2	4	45	200
Pinus echinata	350	20	1	4	30	200
Quercus falcata	150	25	3	2	30	500
Quercus alba	300	20	3	3	30	500
Quercus marilandica	300	5	2	3	30	500
Carya tomentosa	300	25	3	1	30	500
Liquidambar styraciflua	350	20	2	1	60	180
Acer rubrum	250	10	4	1	100	1000
Quercus laevis	150	10	2	2	30	500

Species	Vegetative reproduction probability (0-1)	Minimum age of sprouting	Maximum age of sprouting	Post-fire Regeneration
Pinus palustris	0	0	3	None
Pinus taeda	0	0	3	None
Pinus echinata	0	0	25	Resprout
Quercus falcata	0.75	5	20	Resprout
Quercus alba	0.5	5	40	Resprout
Quercus marilandica	0.75	5	50	Resprout
Carya tomentosa	0.75	1	250	Resprout
Liquidambar styraciflua	0.75	5	50	Resprout
Acer rubrum	0.5	10	150	None
Quercus laevis	0.75	5	50	Resprout

Table A2: Species-specific parameter values for the Century Succession extension of LANDIS-II.

Species	**Functional Type**	**N Fixation**	**Growing Degree Days Min**	**Growing Degree Days Max**	**Minimum Jan Temp**	**Max Drought**	**Leaf Longevity**	**Epicormic Sprouting**
Pinus palustris	1	N	4000	7000	3	0.423	2	N
Pinus taeda	1	N	4000	7000	1	0.360	3	N
Pinus echinata	1	N	4000	7000	1	0.423	3	N
Quercus falcata	2	N	4000	7000	-5	0.423	1	N
Quercus alba	2	N	3176	7000	1	0.330	1	N
Quercus marilandica	2	N	4000	7000	1	0.423	1	N
Carya tomentosa	2	N	3788	7000	1	0.300	1	N
Liquidambar styraciflua	2	N	3912	7000	1	0.300	1	N
Acer rubrum	2	N	1260	7000	-18	0.230	1	N
Quercus laevis	2	N	4000	7000	1	0.423	1	N

Species	**Leaf Lignin**	**Fine Root Lignin**	**Wood Lignin**	**Coarse Root Lignin**	**Leaf C:N**	**Fine Root C:N**	**Wood C:N**	**Coarse Root C:N**	**Litter C:N**
Pinus palustris	0.2	**0.35**	**0.35**	**0.35**	**50**	**50**	**380**	**170**	**100**
Pinus taeda	0.2	**0.35**	**0.35**	**0.35**	**50**	**50**	**380**	**170**	**100**
Pinus echinata	0.2	**0.35**	**0.35**	**0.35**	**50**	**50**	**380**	**170**	**100**
Quercus falcata	**0.293**	**0.23**	**0.23**	**0.35**	**24**	**48**	**500**	**333**	**55**
Quercus alba	**0.367**	**0.23**	**0.23**	**0.23**	**24**	**48**	**500**	**333**	**55**
Quercus marilandica	**0.293**	**0.23**	**0.23**	**0.35**	**24**	**48**	**500**	**333**	**55**
Carya tomentosa	**0.293**	**0.23**	**0.23**	**0.23**	**24**	**48**	**500**	**333**	**55**
Liquidambar styraciflua	**0.331**	**0.255**	**0.255**	**0.255**	**25**	**45**	**90**	**90**	**45**
Acer rubrum	**0.223**	**0.255**	**0.255**	**0.255**	**20**	**45**	**90**	**90**	**45**
Quercus laevis	**0.293**	**0.23**	**0.23**	**0.35**	**24**	**48**	**500**	**333**	**55**

Table A3: Functional group parameters for the Century Succession extension of LANDIS-II.

Functional Group Name	Index	PPDF1 T-Mean	PPDF2 T-Max	PPDF3 T-Shape	PPDF4- T-Shape	FCFRAC Leaf	BTOLAI	KLAI	MAXLAI
Pine	1	28.0	45.0	4.5	5.0	0.37	0.00823	1000.0	10.0
Hardwood	2	27.0	45.0	3.0	3.5	0.5	0.00823	1000.0	20.0

Functional Group Name	Index	PPRPTS2	PPRPTS3	Wood Decay Rate	Monthly Wood Mortality	Mortality Age Shape	Leaf Drop Month
Pine	1	1.0	0.8	0.6	0.003	15	10
Hardwood	2	1.0	0.8	0.6	0.003	15	10

Table A4: Ecoregion parameters for the Century Succession extension of LANDIS-II.

InitialEcoregionParameters										
Name	**SOM1**	**SOM1**	**SOM1**	**SOM1**	**SOM2**	**SOM2**	**SOM3**	**SOM3**	**Minrl**	
		C	**N**	**C**	**N**	**C**	**N**	**C**	**N**	**N**
		surf	**surf**	**soil**	**soil**					
Eco1		136.8	1.52	62.6	5.21	876.4	17.5	626.0	15.7	0.9
Eco2		98.4	1.09	124.2	10.4	1739.0	34.8	1242.1	31.1	0.9
Eco3		139.7	1.55	157.1	13.1	2199.4	44.0	1571.0	39.3	0.7
Eco4		139.7	1.55	31.5	2.62	441.4	8.8	315.3	7.88	0.7

	Soil Depth	% Clay	% Sand	Field Cap	Wilt Point	StormF Frac	BaseF Frac	Drain	Atm N dep	Atm N intercept	Latitude
Eco1	100	0.06	0.84	0.16	0.06	0.4	0.1	1.0	0.006	0.02	32
Eco2	100	0.12	0.66	0.23	0.10	0.4	0.1	1.0	0.006	0.02	32
Eco3	100	0.34	0.30	0.35	0.16	0.4	0.1	0.9	0.006	0.02	32
Eco4	100	0.36	0.53	0.32	0.17	0.4	0.1	0.9	0.006	0.02	32

Ecoregion Parameters cont	Decay Surf	Decay SOM1	Decay SOM2	Decay SOM3	Denitrifi
Eco1	0.127	0.305	0.0224	0.00008	0.03
Eco2	0.19	0.242	0.0134	0.00008	0.03
Eco3	0.134	0.332	0.013	0.00019	0.03
Eco4	0.15	1.08	0.0654	0.00058	0.03

Table A5: Species productivity parameters for the Century Succession extension of LANDIS-II.

MonthlyMaxNPP (g m^{-2} $month^{-1}$)

	Eco1	Eco2	Eco3	Eco4
PIPA	110	125	150	150
PITA	110	125	150	150
PIEC	110	125	150	150
QUFA	100	100	120	120
QUAL	90	100	120	120
QUMA	90	100	110	110
CATO	90	100	120	120
LIST	80	90	140	140
ACRU	80	90	120	120
QULA	90	100	110	110

Maximum Biomass (g m^{-2})

	Eco1	Eco2	Eco3	Eco4
PIPA	21000	22000	24000	24000
PITA	21000	22000	24000	24000
PIEC	21000	22000	24000	24000
QUFA	21000	22000	22000	22000
QUAL	20000	22000	24000	24000
QUMA	20000	20000	21000	21000
CATO	20000	22000	24000	24000
LIST	15000	16000	24000	24000
ACRU	15000	16000	23000	23000
QULA	20000	20000	21000	21000

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