Appendices to Century Introduction, Scheller, Hua, and others.

APPENDIX A – Development of the LANDIS-II Century Succession extension.

We developed a new succession extension for LANDIS-II that includes aboveground succession and soil carbon dynamics. The new extension combines elements of the existing Biomass Succession extension v2.1 (Scheller and Mladenoff 2004) and Century v4.5 (http://www.nrel.colostate.edu/projects/century/). A number of simplifications in representation of soil processes from Century were required for model integration, and further simplifications became possible since the model domain is limited to forests whereas Century was designed for all biomes. First, we limited our simulations to a single soil layer, which is more congruent with the coarse data typically available for large forested landscapes. Second, only nitrogen was simulated as a limiting nutrient. Third, because only forests were simulated, a number of parameters were given fixed values (Table 1). Parameters not relevant to forest dynamics were eliminated, e.g., irrigation. Fourth, each species-age cohort is represented as two separate compartments, wood and leaf or needle, and we did not include fine branches. Fine roots and coarse roots are calculated as a fixed fraction of the leaf and wood components respectively.

Growth and Reproduction

Individual cohort growth was largely estimated from the Century growth function whereby growth is governed by a maximum monthly NPP and further limited by soil moisture, available N, soil temperature, and leaf area index (LAI) (Parton and others 1993). Finally, a maximum aboveground biomass limits the capacity of each cohort (Scheller and Mladenoff 2004). Competition emerges from N limitations (older trees access mineral N first) and LAI limitations (older trees have lower LAI limits). Nitrogen limitations follow assumptions in (Aber and others 1979). With the exception of age-related mortality (senescence, Scheller and

Mladenoff 2004), mortality follows the Century approach with monthly mortality rates for wood compartments representing thinning and branch loss. We incorporated the probability of establishment (Scheller and others 2005) into the extension to take advantage of the dynamic weather (below) and site specific available N.

Time Step

Although the Century Succession extension is limited to annual or multiple-year time steps, cohort growth and soil decomposition operate at a monthly time step. Because most disturbances occur in the summer months, the monthly cycle proceeds from July to June. Therefore, disturbances and reproduction both occur between June and July. Both growth and decomposition are calculated on monthly time step.

Climate and Annual Weather

reflect monthly climate and therefore monthly climate is a required input. Required monthly climate inputs include minimum temperature (°C), maximum temperature, standard deviation of mean temperature, precipitation (cm), and standard deviation of precipitation. The climate inputs are used to generate annual weather, stochastically generated from the climatic means and standard deviations. The climate data can be updated at any annual time step.

Other Model Inputs

The new extension requires four general input types. Species-specific inputs include C, N, lignin (estimated from published Century forest type data) and other physiological attributes (Appendix B, Table 1). Species are assigned to functional types allowing for simplification of parameters that do not vary significantly among specific groups or are currently poorly understood (Appendix B, Table 2). Ecoregion inputs include soil properties and initial conditions (Appendix C).

Programming

The extension was written in C# using an object oriented design. Each SOM pool at each site is a separate object with an associated C (g m^{-2}), N (g m^{-2}), type (soil or surface), fraction lignin, and net N mineralization.

Table 1. Fixed parameters in the Century Succession extension. Full descriptions of variable and default values can be found at: http://www.nrel.colostate.edu/projects/century/manual4/man96.html for. Parameters not listed were excluded.

CENTURY 4.5 variable name	LANDIS-II Century Succession extension variable name	Default value
ANEREF(1)	RatioPrecipPETMaximum	1.5
ANEREF(2)	RatioPrecipPETMinimum	3.0
ANEREF(3)	AnerobicEffectMinimum	0.3
ANIMPT	AnaerobicImpactSlope	5.0
AWTL(1)	TranspirationLossFactor	0.8
DAMR(1,1)	FractionSurfNAbsorbed	0.0
DAMRMN(1)	MinResidueCN	15
DEC1(1)	DecayRateStructuralC[Surface]	3.9
DEC1(2)	DecayRateStructuralC[Soil]	4.9
DEC2(1)	DecayRateMetabolicC[Surface]	14.8
DEC2(2)	DecayRateMetabolicC[Soil]	18.5

DEC3(1)	DecayRateMicrobes[Surface]	6.0
DEC3(2)	DecayRateMicrobes[Soil]	7.3
DEC4	DecayRateSOM3	0.0045
DEC5	DecayRateSOM2	0.2
ELITST	EffectLitterSoilT	0.4
FWLOSS(1)	WaterLossFactor1	0.8
FWLOSS(2)	WaterLossFactor2	0.8
FWLOSS(4)	WaterLossFactor4	0.9
OMLECH(1)	OMLeachIntercept	0.03
OMLECH(2)	OMLeachSlope	0.12
OMLECH(3)	OMLeachWater	1.9
P1CO2A(1)	P1CO2_Surface	0.6
P1CO2A(2)	P1CO2_Soil_Intercept	0.17
P1CO2B(2)	P1CO2_Soil_Slope	0.68
P2CO2	FractionSOM2toCO2	0.55
P3CO2	FractionSOM3toCO2	0.55
PABRES	ResidueMaxDirectAbsorb	100.0
PCEMIC(1,1)	MaxCNSurfMicrobes	16.0
PCEMIC(2,1)	MinCNSurfMicrobes	10.0
PCEMIC(3,1)	MinNContentCNSurfMicrobes	0.02
PEFTXA	TextureEffectIntercept	0.25
PEFTXB	TextureEffectSlope	0.75
PLIGST(1)(2)	LigninDecayEffect	3.0

PMCO2(1)	MetabolicToCO2Surface	0.55
PMCO2(2)	MetabolicToCO2Soil	0.55
PMNTMP	EffectBiomassMinSurfT	0.004
PMXTMP	EffectBiomassMaxSurfT	-0.0035
PPRPTS(1)	PPRPTS1	0.0
PS1CO2(1)	StructuralToCO2Surface	0.45
PS1CO2(2)	StructuralToCO2Soil	0.55
PS1S3(1)	PS1S3_Intercept	0.003
PS1S3(2)	PS1S3_Slope	0.032
PS2S3(1)	PS2S3_Intercept	0.003
PS2S3(2)	PS2S3_Slope	0.009
RAD1P(1,1)	SurfaceActivePoolCNIntercept	12.0
RAD1P(2,1)	SurfaceActivePoolCNSlope	3.0
RAD1P(3,1)	SurfaceActivePoolCNMinimum	5.0
RCESTR(1)	StructuralCN	200
RSPLIG	LigninRespirationRate	0.3
SPL(1)	MetaStructSplitIntercept	0.85
SPL(2)	MetaStructSplitSlope	0.013
STRMAX(1), (2)	MaxStructuralC	5000
TEFF(1)	TemperatureEffectIntercept	0.0
TEFF(2)	TemperatureEffectSlope	0.125
TEFF(3)	TemperatureEffectExponent	0.06
TMELT(1)	TMelt1	-8.0

TMELT(2)	TMelt2	4.0
VARAT1(1,1)	MaxCNenterSOM1	18.0
VARAT1(2,1)	MinCNenterSOM1	8.0
VARAT1(3,1)	MinContentN_SOM1	2.0
VARAT2(1,1)	MaxCNenterSOM2	40.0
VARAT2(2,1)	MinCNenterSOM2	12.0
VARAT2(3,1)	MinContentN_SOM2	2.0
VARAT3(1,1)	MaxCNenterSOM3	20.0
VARAT3(2,1)	MinCNenterSOM3	6.0
VARAT3(3,1)	MinContentN_SOM3	2.0

Reference List

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Scheller RM, Mladenoff DJ, Crow TR, Sickley TS. 2005. Simulating the effects of fire reintroduction versus continued suppression on forest composition and landscape structure in the Boundary Waters Canoe Area, northern Minnesota (USA). Ecosystems 8: 396-411.

APPENDIX B – Physiological parameters for the LANDIS-II Century Succession extension

Table 1. Physiological parameters for 13 common tree species in northern Wisconsin, USA.

Species Name	Functional Type	Nitrogen Tolerance	Leaf Longevity (years)	Leaf Lignin (%)	Fine Root Lignin (%)	Wood Lignin (%)	Coarse Root Lignin (%)	Leaf CN Ratio	Fine Root CN Ratio	Wood CN Ratio	Coarse Root CN Ratio	Litter CN Ratio
Abies balsamifera	2	2	3	0.2	0.2	0.35	0.35	100	50	380	170	100
Acer rubrum	1	2	1	0.223	0.255	0.255	0.255	25	45	90	90	45
Acer saccharum	1	2	1	0.223	0.255	0.255	0.255	25	45	90	90	45
Betula alleghaniensis	1	2	1	0.223	0.255	0.255	0.255	25	45	90	90	45
Betula papyrifera	1	2	1	0.223	0.255	0.255	0.255	30	45	90	90	45
Fraxinus pennsylvanica	1	1	1	0.223	0.255	0.255	0.255	25	45	90	90	45
Pinus strobus	2	2	3	0.2	0.2	0.35	0.35	100	50	380	170	100
Populus tremuloides	1	3	1	0.223	0.255	0.255	0.255	30	45	90	90	45
Quercus	3	2	1	0.175	0.23	0.23	0.23	52	48	500	333	50

rubrum												
Thuja occidentalis	2	3	4	0.2	0.2	0.35	0.35	100	50	380	170	100
Tilia americana	1	1	1	0.223	0.255	0.255	0.255	25	45	90	90	45
Tsuga canadensis	2	2	3	0.2	0.2	0.35	0.35	100	50	380	170	100

Table 2. Functional type parameters for the species listed in Table 1, Appendix B.

Name	Functional Type Index	PPDF1 mean	PPDF2 max	PPDF3 shape1	PPDF4 shape2	NPP Leaf (%)
NHardwoods	1	20	32	0.2	8	0.5
Conifer	2	15	32	1	3.5	0.37
Oaks	3	25	45	1	3	0.5

Table 2 continued.

Name	BTOLAI	KLAI	MAXLAI	PPRPTS2	PPRPTS3	Wood Decay Rate	Wood Mortality (% / mo)
NHardwoods	0.00823	3000	20	1	0.8	0.6	0.003
Conifer	0.00823	3000	10	1	0.8	0.6	0.003
Oaks	0.00823	2000	20	1	0.8	0.6	0.003

APPENDIX C – Ecoregion Parameters.

Table 1. Ecoregion fixed parameters derived from data from the Willow Creek experimental forest, Wisconsin, USA.

Name	Soil depth (cm)	Sand (%)	Clay (%)	Field capacity (%)	Wilting Point (%)	Storm flow fraction	Base flow fraction	Drain (%)	Atmos N slope	Atmos N intercept	Latitude
eco1	50	0.591	0.069	0.3	0.2	0.4	0.4	0.75	0.06	0.05	44

Table 2. Initial Ecoregion Parameters. All parameter units g m^{-2}.

Name	SOM1 C surface	SOM1 N surface	SOM1 C soil	SOM1 N soil	SOM2 C	SOM2 N	SOM3 C	SOM3 N	Mineral N
eco1	45.6	2.93	132	13.92	2765	45.95	1294	41.47	3

APPENDIX D – List of Initial Communities

Initial forest communities used in simulations of a 9800 ha northeastern Wisconsin forest. Initial communities include species and cohort ages. Species codes are derived from the first four letters of the genus and species combined.

Community 1

abiebals	10	15	20	50	
acerrubr	100				
acersacc	5	10	60	90	120
betualle	40	60	75	85	100
fraxamer	10	100			
querrubr	85				
tiliamer	5	10	20	40	

Community 2

abiebals	5	10		
acerrubr	5	20	25	
acersacc	5	10	15	20
betualle	40	50	60	70
betupapy	80			
fraxamer	30	40	60	
poputrem	85			

querrubr	40	45	65	70		
tiliamer	10	15	30	35	50	

Community 3

abiebals	10	50				
acerrubr	85					
acersacc	5	10	60	90	120	
betualle	40	45	70	75	100	
fraxamer	10	100	115			
tiliamer	5	10	20	40	65	80
tsugcana	120					

Community 4

acerrubr	5			
acersacc	5	10	15	20
betualle	5	10	35	40
betupapy	85			
fraxamer	10	25	50	
pinustro	30			
poputrem	90			
querrubr	10	20		
thujocci	60			
tiliamer	10			

Community 5

abiebals	5	10					
acerrubr	5	15	20				
acersacc	5	10	15	20			
betualle	10	15	40	50	55	60	70
fraxamer	5	30	40	45	60		
tiliamer	10	30	50				

Community 6

abiebals	10	50			
acerrubr	50	75			
acersacc	5	10	60	90	95
betualle	40	60	95	100	115
fraxamer	10	100			
querrubr	85	120			
tiliamer	5	10	20	40	80

Community 7

acerrubr	5	20				
acersacc	5	10	15	20		
betualle	10	35	40	50	60	70
fraxamer	5	30	40	60		

querrubr	25	40	70	
tiliamer	10	15	30	50
pinustro	50	60		