SECTION II

Introduction to Temporal Scaling

WE HAVE laid the groundwork of forest ecosystem analysis in Chapters 2–4 by following the seasonal dynamics of water, carbon, and mineral cycles through individual stands. Stand-level models such as FOREST-BGC incorporate many of the principles derived from an understanding of the basic processes that control these cycles (Table II.1 and see Fig. 1.2). We now extend this understanding to longer time scales to address the concerns of managers who search for various harvest options, knowledge about changes in species composition, and the probability and impact of various types of disturbance on the structure and function of specific forest ecosystems. We start with an analysis of how structure and function change through a single forest life cycle by studying historical stand records, fire scars, tissue isotope ratios, and variation in annual ring increments. To gain insights into multiple forest life cycles that extend over many centuries we rely on information obtained from the analysis of pollen and wood samples extracted from bogs. On the basis of such analyses, models have been constructed that project forest development and vegetation dynamics well into the future (Fig. II.1). With these models, forest management may gain considerable insights into the probable consequences on future stand growth and composition of decisions made today. The degree of confidence that one can place in these kinds of models rests to a large extent on how well they incorporate principles validated in the study of individual stands.

TABLE II.1
Input Data Requirements for FOREST-BGC, with Example Values for Coniferous and Broadleaf Forests[a]

Parameter and units	Conifer forest	Broadleaf forest
Leaf C, kg ha^{-1}	2400	2400
Soil C, kg ha^{-1}	300000	300000
Litter C, kg ha^{-1}	100000	100000
Soil N, kg ha^{-1}	30000	30000
Litter N, kg ha^{-1}	2000	2000
Leaf turnover, year^{-1}	0.25	1.00
Stem turnover, year^{-1}	0.01	0.01
Coarse-root turnover, year^{-1}	0.01	0.01
Fine-root turnover, year^{-1}	0.5	0.5
Leaf lignin fraction, kg C lignin kg^{-1} C	**0.25**	**0.125**
Fine-root lignin fraction, kg C lignin kg^{-1} C	0.25	0.25
Specific leaf area, ha kg^{-1} C	**0.0025**	**0.0045**
Canopy light extinction coefficient, dimensionless	−0.5	−0.5
Precipitation interception coefficient, m H_2O projected LAI^{-1} day^{-1}	0.0002	0.0002
Snowmelt temperature coefficient, m H_2O °C^{-1}	0.005	0.005
Snow albedo decay coefficient, °C^{-1}	0.004	0.004
Snowpack energy deficit, °C	5.0	5.0
Spring minimum leaf water potential, −MPa	0.5	0.5
Leaf water potential at stomatal closure, −MPa	1.65	1.65
Maximum stomatal conductance, m H_2O s^{-1}	0.006	0.006
Cuticular conductance, m H_2O s^{-1}	0.00005	0.00005
Leaf boundary-layer conductance, m H_2O s^{-1}	0.001	0.001
Canopy aerodynamic conductance, m s^{-1}	0.2	0.2
Optimum stomatal conductance temperature, °C	20.0	20.0
Maximum stomatal conductance temperature, °C	40.0	40.0
Vapor pressure deficit, Pa		
Start of conductance reduction	750.0	750.0
Completion of conductance reduction	3000.0	3000.0
Leaf maintenance respiration coefficient, day^{-1}	0.0012	0.0012
Stem maintenance respiration coefficient, day^{-1}	0.0001	0.0001
Coarse-root maintenance respiration coefficient, day^{-1}	0.0001	0.0001
Fine-root maintenance respiration coefficient, day^{-1}	0.0012	0.0012
Q_{10} for plant maintenance respiration	2.0	2.0
Ratio of all-sided to projected LAI	2.3	2.0
Ratio of sapwood, kg C m^{-2} LAI^{-1}	**0.25**	**0.35**
Leaf retranslocation fraction	0.50	0.50
Q_{10} for soil maintenance respiration	2.4	2.4
Maximum leaf/(leaf + root) ratio for allocation	**0.70**	**0.80**
Maximum coarse root/stem ratio for allocation	0.25	0.25
Critical litter C : N ratio	25.0	25.0
Critical soil C : N ratio	10.0	10.0
Fine-root N fraction, $\%N_{\text{fine root}}\ \%N_{\text{leaf}}^{-1}$	0.5	0.5
Stem and coarse-root N fraction, $\%N_{\text{stem}}$ or $\%N_{\text{croot}}\ \%N_{\text{leaf}}^{-1}$	0.01	0.01
Leaf growth respiration fraction, kg^{-1} C	0.35	0.35
Stem/coarse-root/storage growth respiration factor, kg^{-1} C	0.30	0.30
Fine-root growth respiration fraction, kg^{-1} C	0.35	0.35

TABLE II.1 (*Continued*)

Parameter and units	Conifer forest	Broadleaf forest
Maximum storage fraction	0.20	0.20
Living fraction of sapwood	**0.08**	**0.10**
Water stress integral factor	–0.15	–0.15
Fraction N_{leaf} in Rubisco	0.10	0.10
Maximum soil decomposition rate, year^{-1}	0.03	0.03
Maximum N uptake by roots (V_{Nmax}), kg N kg^{-1} $C_{fine\ roots}$	0.05	0.05
N uptake Michaelis–Menten constant (K_n), kg N ha^{-1}	20.0	20.0
Maximum average N_{leaf} concentration, kg N kg^{-1} C	0.04	0.04
Minimum average N_{leaf} concentration, kg N kg^{-1} C	0.02	0.02
Leaf on, year day	**0.0**	**140.0**
Leaf off, year day	**365.0**	**260.0**
Fine root on, year day	60.0	60.0
Fine root off, year day	304.0	304.0
Volumetric saturated soil water content	0.44	0.44
b parameter for soil water potential	–6.09	–6.09
Soil matric potential, –MPa	0.002224	0.002224

[a] For very generalized simulations only the variables in bold type may need to be specifically defined; these default values can be used. When more site- and/or species-specific data are available, the model can incorporate the additional details. From J. D. White, P. E. Thornton, and S. W. Running, *Global Biogeochemical Cycles* **11**, 217–234, 1998, published by the American Geophysical Union.

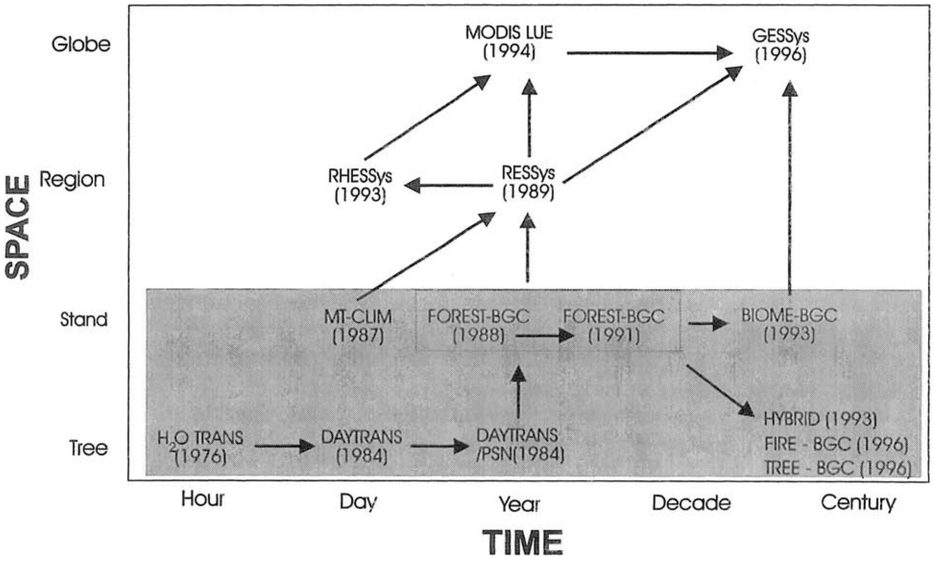

FIGURE II.1. Evolution of a family of related ecosystem simulation models for application at variable time scales, showing the model name and initial publication date. Each new model shows a progression from its precursor in extending the time scale. Reference papers for the seasonal dynamics of individual stands include the following: H2OTRANS (Waring and Running, 1976), DAYTRANS (Running, 1984a), DAYTRANS/PSN (Running, 1984b), FOREST-BGC (Running and Gower, 1991), HYBRID (Friend *et al.*, 1993), BIOME-BGC (Running and Hunt, 1993), FIRE-BGC (Keane *et al.,* 1996a,b), and TREE-BGC (Korol *et al.,* 1995). To extend the time scale these models progressively add seedling recruitment, stand development, tree mortality, and disturbance processes that are the focus of Chapters 5 and 6.