Abbreviations

A	Soil horizon
A_{area}	Photosynthetic rate (per unit leaf area)
A_{mass}	Photosynthetic rate (per unit leaf mass)
A_n	Quantity of energy or material assimilated by a trophic level
a_n	Nutrient productivity
A_{net}	Net photosynthesis (per unit leaf mass or per unit ground area)
ABA	Abscisic acid
ADP	Adenosine diphosphate
Al^{3+}	Aluminum
AM	Arbuscular mycorrhizae
ANPP	Aboveground NPP
APAR	Absorbed photosynthetically active radiation
Ar	Argon
ATP	Adenosine triphosphate
B	Soil horizon
BT	Gene from the bacterium *Bacillus thuringiensis* that has been introduced into the corn genome and is toxic to the European corn borer
C	Celsius degrees; carbon; soil horizon
C_3	Photosynthetic pathway whose initial carboxylation products are three-carbon acids
C_4	Photosynthetic pathway whose initial carboxylation products are four-carbon acids
C_{S1}	Percentage of soil carbon derived from the initial vegetation type
C_{S2}	^{13}C content of second soil type
$^{13}C_{std}$	^{13}C content of a standard
C_{V1}	^{13}C content of vegetation from the initial vegetation type
C_{V2}	^{13}C content of vegetation from the second vegetation type
Ca^{2+}	Calcium ion
cal	Calorie
CAM	Crassulacean acid metabolism
CEC	Cation exchange capacity
CFC	Chlorofluorocarbon
CH_4	Methane
CH_2O	Organic matter
Cl^-	Chloride ion
cm	Centimeter (10^{-2} m)
cmo	Centimole
C:N	Carbon:nitrogen ratio
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_3^-	Carbonate ion
COOH	Carboxyl group
C:P	Carbon:phosphorus ratio
cP	Centipoise (unit of viscosity)
CPOM	Coarse particulate organic matter
D	Deuterium
d	Day
DDT	An insecticide
DIC	Dissolved inorganic carbon
DIN	Dissolved inorganic nitrogen
DMS	Dimethylsulfoxide
DNA	Deoxyribonucleic acid
DOC	Dissolved organic carbon
DON	Dissolved organic nitrogen

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E	Soil horizon
E	Evapotranspiration rate of an ecosystem
e	Exponential base
e^-	Electron
E_{assim}	Assimilation efficiency
$E_{consump}$	Consumption efficiency
E_{prod}	Production efficiency
E_{troph}	Trophic efficiency
ENSO	El Niño/Southern Oscillation
F_{CH4}	Flux of methane into ecosystem
F_{CO}	Flux of carbon monoxide into ecosystem
F_{DIC}	Flux of dissolved inorganic carbon into ecosystem
$F_{disturb}$	Flux of carbon from an ecosystem to the atmosphere due to disturbance
F_{DOC}	Flux of dissolved organic carbon into ecosystem
F_n	Component of the gravitational force that is normal to the slope
F_p	Component of the gravitational force that is parallel to the slope
F_{POC}	Flux of particulate organic carbon into ecosystem
F_t	Total gravitational force
F_{VOC}	Flux of volatile organic carbon into ecosystem
f( )	Function of (parameters in parenthesis)
Fe^{2+}	Ferrous iron
Fe^{3+}	Ferric iron
FPAR	Fraction of PAR absorbed by vegetation
FPOM	Fine particulate organic matter
G	Ground heat flux
g	Gram
GIS	Geographic Information System
GPP	Gross primary production
H	Hydrogen; herbivore
H	Sensible heat flux
h	Hour; height
H^+	Hydrogen ion
H_2	Hydrogen gas
HCO_3^-	Bicarbonate ion
H_2CO_3	Carbonic acid
HNLC	High-nutrient, low-chlorophyll
HNO_3	Nitric acid
H_2O	Water
H_2S	Hydrogen sulfide
H_2SO_4	Sulfuric acid
I_0	Irradiance above the canopy or at the water surface
I_n	Quantity of energy or material ingested by trophic level n
I_z	Irradiance at depth z (beneath the canopy or water surface)
ICDP	Integrated Conservation and Development Project
ITCZ	Intertropical convergence zone
J	Joule
J_p	Rate of water flow through plants
J_s	Rate of water flow through the soil
K	Degrees Kelvin
K	Equilibrium constant
k	Extinction coefficient; decomposition constant
K^+	Potassium ion
K_{in}	Incoming shortwave radiation
K_{out}	Outgoing shortwave radiation
kcal	Kilocalorie
kg	Kilogram (10^3 g)
kJ	Kilojoule (10^3 J)
km	Kilometer (10^3 m)
L	Liter; lignin
L	Latent heat of vaporization; leaf area index
l	Path length of a column of soil or xylem; length of organism
L_{in}	Incoming longwave radiation
L_{out}	Outgoing longwave radiation
L_p	Hydraulic conductivity of plant xylem
L_s	Hydraulic conductivity of soil
L_t	Litter mass at time t
L_0	Litter mass at time zero
LAI	Leaf area index
Lidar	Light Detection and Ranging
L:N	Lignin:nitrogen ratio
LUE	Light use efficiency
M	Microbivore; moisture
m	Meter
m	Mass
M_a	Angular momentum
Ma	Million years
mg	Milligram (10^{-3} g)
Mg^{2+}	Magnesium ion
MJ	Megajoule (10^6 J)
mL	Milliliter (10^{-3} L)

mm	Millimeter (10^{-3} m)
Mn^{4+}	Manganese ion
MODIS	Moderate Resolution Imaging Spectroradiometer
Mol	Mole
MPa	Megapascal
MRT	Mean residence time
mV	Millivolt
N	Atomic nitrogen; north
N_2	Di-nitrogen gas
N_{avail}	Available nitrogen
N_{org}	Organic nitrogen
Na^+	Sodium ion
NADP	Nicotinamide adenine dinucleotide phosphate (in oxidized form)
NADPH	Nicotinamide adenine dinucleotide phosphate (in reduced form)
NAO	North Atlantic Oscillation
NDVI	Normalized difference vegetation index
NECB	Net ecosystem carbon balance
NEE	Net ecosystem exchange
NEP	Net ecosystem production
NH_3	Ammonia gas
NH_4^+	Ammonium ion
NIR	Near infrared radiation
nl	Natural log
nm	Nanometer (10^{-9} m)
nmol	nanomole (10^{-9} mol)
N_2O	Nitrous oxide
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_2^-	Nitrite ion
NO_3^-	Nitrate ion
NO_x	Nitric oxides in general (includes NO and NO_2)
N:P	Nitrogen-to-phosphorus ratio
NPP	Net primary production
NUE	Nutrient (or nitrogen) use efficiency
O	Atomic oxygen; soil horizon
O_2	Molecular oxygen
O_3	Ozone
O_a	Highly decomposed organic horizon
O_e	Moderately decomposed organic horizon
O_i	Slightly decomposed organic horizon
OH	Hydroxyl radical
OH^-	Hydroxide ion
P	Phosphorus
P	Precipitation
P_{org}	Organic phosphorus
p	Person
Pa	Pascal
PAR	Photosynthetically active radiation
PBL	Planetary boundary layer
PCB	Polychlorinated biphenyl (an industrial class of compounds containing chlorine)
PDO	Pacific decadal oscillation
PEP	Phosphoenolpyruvate
Pg	Petagram (10^{15} g)
pH	Negative log of H^+ activity
PNA	Pacific North America pattern
PO_4^{3-}	Phosphate ion
POC	Particulate organic carbon
PON	Particulate organic nitrogen
ppbv	Parts per billion by volume
ppmv	Parts per million by volume
ppt	Parts per thousand
$Prod_n$	Production by trophic level n
$Prod_{n-1}$	Production by the preceding trophic level
PW	Petawatt
Q_{10}	Proportional increase in the rate of a process with a 10°C increase in temperature
R	Bedrock
R	Runoff; respiration; universal gas constant
r	Radius
$R_{ecosyst}$	Ecosystem respiration
R_{growth}	Growth respiration
R_{het}	Heterotrophic respiration
R_{ion}	Respiration associated with ion uptake
R_{maint}	Maintenance respiration
R_{net}	Net radiation
R_{plant}	Plant respiration
R_{sam}	Isotope ratio of a sample
R_{std}	Isotope ratio of a standard
Re	Reynolds number
RH	Relative humidity
Rubisco	Ribulose-bis-phosphate carboxylase
RuBP	Ribulose-bis-phosphate

S	Sulfur; south
S	Heat storage by a surface; water storage by an ecosystem
s	Second
S_{org}	Organic sulfur
SE	Standard error
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
Si	Silicon
SLA	Specific leaf area
SO_2	Sulfur dioxide
SO_4^{2-}	Sulfate ion
SOM	Soil organic matter
SRL	Specific root length
T	Temperature
t	Time
t_r	Residence time
Tg	Teragram (10^{12} g)
U.K.	United Kingdom
U.S.	United States
UV	Ultraviolet
v	Velocity
V_k	Kinematic viscosity
VAM	Vesicular arbuscular mycorrhizae
VIS	Visible radiation
VPD	Vapor pressure deficit
W	Watt
WUE	Water use efficiency
yr	Year
z	Depth beneath the canopy or water surface
α	Albedo
β	Bowen ratio
δ	del; difference in isotope concentration relative to a standard
Δ	Change in a quantity
ε	Emissivity
μg	Microgram (10^{-6} g)
μm	Micrometer (10^{-6} m)
μL	Microliter (10^{-6} L)
μmol	Micromole (10^{-6} moles)
ρ	Density
σ	Stefan-Boltzman constant
Ψ_m	Matric potential
Ψ_o	Osmotic potential
Ψ_p	Pressure potential
Ψ_t	Total water potential

Glossary

A horizon Uppermost mineral horizon of soils.

Abiotic Not directly caused or induced by organisms.

Abiotic condensation Non-enzymatic reaction of quinones with other organic materials in soil.

Abscisic acid Plant hormone that is transported from roots to leaves and causes a reduction in stomatal conductance.

Absorbence Fraction of the global solar irradiance incident on a surface that is absorbed.

Acclimation Morphological or physiological adjustment by an individual plant to compensate for the change in performance caused by a change in one environmental factor (e.g., temperature).

Acid rain Rain that has low pH, due to high concentrations of sulfuric and nitric acid released from combustion of fossil fuels.

Active transport Energy-requiring transport of ions or molecules across a membrane against an electrochemical gradient.

Activity budget Proportion of time that an animal spends in various activities.

Actual vegetation Vegetation that actually occurs on a site.

Adaptation Genetic adjustment by a population to maximize performance in a particular environment.

Adaptive management Management involving experimentation in the design and implementation of policies so that subsequent management can be modified based on learning from these experiments; "learning by doing."

Adaptive range Difference between the upper and lower tolerance limits of the system.

Advection Net horizontal transfer of gases or water.

Aerobic Occurring in the presence of oxygen.

Aerodynamic conductance Conductance of water vapor through a canopy from the vegetation or soil surface to the bulk atmosphere. Sometimes termed the boundary layer conductance of a canopy.

Aerosol Small (0.005 to 5 μm) solid or liquid particles suspended in air.

Afforestation Planting of new forests on previously non-forested sites.

Aggregate Clumps of soil particles bound together by polysaccharides, fungal hyphae, or minerals.

Albedo Fraction of the incident shortwave radiation reflected from a surface.

Alfisol Soil order that develops beneath temperate and subtropical forests, characterized by less leaching than spodosol.

Allocation Proportional distribution of photosynthetic products or newly acquired nutrients among different organs or functions in a plant.

Allochthonous input Input of energy and nutrients from outside the ecosystem; synonymous with subsidy.

Alternative stable states Alternative system states, each of which is plausible in a particular environment.

Ammonification See nitrogen mineralization.

Amorphous minerals Minerals with no regular arrangements of atoms.

Amplifying feedback Interaction in which two components of a system both have a positive effect on one another, or both have a negative effect on one another; this accentuates the changes in the system; synonymous with positive feedback.

Anadromous Life cycle in which reproduction occurs in lakes, streams or rivers, and the adult phase occurs primarily in the ocean.

Anaerobic Occurring in the absence of oxygen.

Andisol Soil order characterized by young soils on volcanic substrates.

Angular momentum Intensity of rotational motion.

Anion Negatively charged ion.

Anion exchange capacity Capacity of a soil to hold exchangeable anions on positively charged sites at the surface of soil minerals and organic matter.

Anioshydric plants Plants from dry sites that show little response of stomatal conductance to soil drying and therefore continue to photosynthesize and to absorb and lose water as the soil dries.

Anoxic Without oxygen.

Anthropocene Geologic epoch characterized by human impacts, initiated with the Industrial Revolution.

Anthropogenic Resulting from or caused by people.

Arbuscular mycorrhizae Mycorrhizae that exchange carbohydrates between plant roots and fungal hyphae via arbuscules; also termed vesicular arbuscular mycorrhizae or endomycorrhizae.

Arbuscules Exchange organs between plant and mycorrhizal fungus that occur within plant cells.

Aridisol Soil order that develops in arid climates.

Aspect Compass direction that a slope faces.

Assimilation Incorporation of an inorganic resource (e.g., CO_2 or NH_4^+ into organic compounds; transfer of digested food from the intestine to the bloodstream of an animal.

Assimilation efficiency Proportion of ingested energy that is assimilated into the bloodstream of an animal.

Assisted migration Movement of genotypes or species from a region where climate is becoming unfavorable to new places where climate is, or is expected to become, more favorable.

Autochthonous production Production occurring within the ecosystem.

Autotroph Organism that produces organic matter from CO_2 and environmental energy rather than by consuming organic matter produced by other organisms. Most autotrophs produce organic matter by photosynthesis; synonymous with primary producer.

B horizon Soil horizon with maximum accumulation of iron and aluminum oxides and clays.

Backscatter Reflection from small particles.

Base cations Non-hydrogen, non-aluminum cations.

Base flow Background stream flow from groundwater input in the absence of recent storm events.

Base saturation Percentage of the total exchangeable cation pool that is accounted for by base cations.

Bedrock Unweathered rock at the base of a soil profile.

Beneficial nutrients Elements that enhance growth under specific conditions or for specific groups of plants.

Benthic Associated with aquatic sediments.

Biofilm Microbial community embedded in a matrix of polysaccharides secreted by bacteria.

Biogenic Biologically produced.

Biogeochemical hot spot Zone of high rates of biogeochemical processes in a soil or landscape.

Biogeochemistry Biological interactions with chemical processes in ecosystems.

Biological pump Flux of carbon and nutrients in feces and dead organisms from the euphotic zone to deeper waters and the sediments of the ocean.

Biomass Quantity of living material (e.g., plant biomass).

Biomass burning Combustion of plants and soil organic matter following forest clearing.

Biomass pyramid Quantity of biomass in different trophic levels of an ecosystem.

Biome General class of ecosystems (e.g., tropical rain forest, arctic tundra).

Biosphere Biotic component of Earth, including all ecosystems and living organisms.

Biotic Caused or induced by organisms.

Bloom Rapid increase in phytoplankton biomass.

Blue water Liquid water in rivers, lakes, reservoirs, and groundwater aquifers that is potentially available to society.

Bottom-up controls Regulation of consumer populations by quantity and quality of food.

Bottom water Deep ocean water below about 1000 m depth.

Boundary layer Thin layer around a leaf or root in which the conditions differ from those in the bulk atmosphere or soil, respectively.

Boundary layer conductance Conductance of water vapor across the boundary layer of still air near an individual leaf; sometimes also applied to the aerodynamic conductance of a canopy.

Bowen ratio Ratio of sensible to latent heat flux.

Brine rejection Exclusion of salt during formation of ice crystals in sea ice.

Buffering capacity Capacity of the soil to release cations to replace ions lost from the soil by uptake or leaching.

Bulk air Air above the canopy that is not strongly influenced by the canopy.

Bulk density Mass of soil per unit volume.

Bulk soil Soil outside the rhizosphere.

Bundle sheath cells Cells surrounding the vascular bundle of a leaf; site of C_3 photosynthesis in C_4 plants.

C horizon Soil horizon that is relatively unaffected by the soil-forming processes.

C_3 photosynthesis Photosynthetic pathway in which CO_2 is initially fixed by Rubisco, producing three-carbon acids.

C_4 photosynthesis Photosynthetic pathway in which CO_2 is initially fixed by PEP carboxylase during the day, producing four-carbon organic acids.

Calcic horizon Hard calcium (or magnesium) carbonate-rich horizon formed in deserts; formerly termed caliche.

Caliche See calcic horizon.

Canopy interception Fraction of precipitation that does not reach the ground.

Capital Productive assets of a system. Natural capital consists of both non-renewable resources (e.g., oil reserves) and renewable ecosystem resources (e.g., plants, animals, and water) that support the production of goods and services on which society depends. Built capital consists of the physical means of production beyond that which occurs in nature (e.g., tools, clothing, shelter, dams, and factories). Human capital is the capacity of people to accomplish their goals; it can be increased through various forms of learning. Social capital is the capacity of groups of people to act collectively to solve problems.

Carbon-based defense Organic compounds that contain no nitrogen and defend plants against pathogens and herbivores.

Carbon-fixation reactions Those reactions in photosynthesis that use the products of the light-harvesting reactions to reduce CO_2 to sugars; also termed light-independent reactions or dark reactions.

Carboxylase Enzyme that catalyzes the reaction of a substrate with CO_2.

Carboxylation Attachment of CO_2 to an acceptor molecule.

Carnivore Organism that eats live animals.

Catalyst Molecule that speeds the conversion of substrates to products.

Catchment See drainage basin.

Catena Sequence of soils or ecosystems between hillcrests and valley bottoms, whose characteristics reflect slope position, drainage, and other topographic processes.

Cation Positively charged ion.

Cation exchange capacity Capacity of a soil to hold exchangeable cations on negatively charged sites at the surface of soil minerals and organic matter.

Cavitation Breakage of water columns under tension in the xylem.

Cellobiase Enzyme that breaks down cellobiose to form glucose.

Cellobiose Organic compound composed of two glucose units formed by cellulose breakdown.

Charge density Charge per unit hydrated volume of the ion.

Chelation Reversible chemical combination, usually with high affinity, with a metal ion (e.g., iron, copper).

Chemical alteration Chemical changes in dead organic matter during decomposition.

Chemodenitrification Abiotic conversion of nitrite to nitric oxide (NO).

Chlorofluorocarbon Organic chemicals containing chlorine and/or fluorine; gases that destroy stratospheric ozone.

Chlorophyll Green pigment involved in light capture by photosynthesis.

Chloroplast Organelles that carry out photosynthesis.

Chronosequence Sites that are similar to one another with respect to all state factors except time since disturbance.

Circadian rhythms Innate physiological cycles in organisms that have a period of about 24 hours.

Clay Soil particles less than 0.002 mm diameter.

Climate modes Relatively stable patterns of global atmospheric circulation.

Climate system Interactive system made up of the atmosphere, hydrosphere, biosphere, cryosphere, and land surface.

Climatic climax Hypothetical endpoint of succession that is determined only by climate.

Closed-basin lake Lakes in dry climates that have such high evaporation rates that outflow seldom occurs.

Closed system System in which the internal transfers of substances are much greater than inputs and outputs.

Cloud condensation nuclei Aerosols around which water vapor condenses to form cloud droplets.

C:N ratio Ratio of carbon mass to nitrogen mass.

CO_2 compensation point CO_2 concentration at which net photosynthesis equals zero.

Coarse particulate organic matter Organic matter in aquatic ecosystems, including leaves and wood, that is larger than 1 mm diameter.

Collector Benthic macroinvertebrate that feeds on fine organic particles; includes filtering collectors that consume suspended particles and gathering collectors that consume deposited particles.

Common-pool resources Resources that are held in common, are depletable, and from which it is costly to exclude people's use (e.g., the atmosphere, fresh water, marine fish).

Community Group of co-existing organisms in an ecosystem.

Compensation depth Depth at which GPP equals phytoplankton respiration integrated through the water column.

Compensation point Temperature, CO_2 concentration or light level at which net carbon exchange by a leaf is zero (i.e., photosynthesis equals respiration).

Competition Interactions among organisms that use the same limiting resources (resource competition) or that harm one another in the process of seeking a resource (interference competition).

Competitive release Sudden increase in growth, when resource availability increases in response to death or reduced growth of neighboring individuals.

Complementary resource use Use of resources that differ in type, depth, or timing by co-occurring species.

Complex adaptive system System whose components interact in ways that cause the system to adjust (i.e., adapt) in response to changes in conditions.

Conductance Flux per unit driving force (e.g., concentration gradient); inverse of resistance.

Configuration Spatial arrangement of patches in a landscape.

Connectivity Degree of connectedness among patches in a landscape.

Consortium Group of genetically unrelated bacteria, each of which produce only some of the enzymes required to break down complex macromolecules.

Consumer Organism that meets its energetic and nutritional needs by eating other living organisms.

Consumption efficiency Proportion of the production at one trophic level that is ingested by the next tropic level.

Convection Heat transfer by turbulent movement of a fluid (e.g., air or water).

Coriolis effect Tendency, due to Earth's rotation, of objects to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere.

Cortex Layers of root cells outside the endodermis involved in nutrient uptake.

Coupling Effectiveness of atmospheric mixing between the canopy and the atmosphere. Also the linkages among biogeochemical cycles.

Crassulacean acid metabolism Photosynthetic pathway in which stomates open and carbon is fixed at night into four-carbon acids. During the day stomates close, C_4 acids are decarboxylated, and CO_2 is fixed by C_3 photosynthesis.

Credible science Science that is grounded in understanding and facts rather than in arguments of how the world should work.

Critical ecosystem services Those services that are most vulnerable to change, have fewest options for technological or ecological substitution, and are most valued by society.

Cross-scale linkages Processes that connect the dynamics of a system to events occurring at other times and places.

Crystalline minerals Minerals with highly regular arrangements of atoms.

Cultural services Non-material benefits that are important to society's well-being (e.g., recreational, aesthetic, and spiritual benefits).

Cytoplasm Contents of a cell that are contained within its plasma membrane, but outside the vacuole and the nucleus.

Dead zone Coastal zone of anoxic conditions that kill benthic organisms and bottom-feeding shrimp and fish and dramatically alter nutrient cycling at the sediment-water interface; often triggered by eutrophication.

Deciduous Shedding leaves in response to specific environmental cues.

Decomposer Organism that breaks down dead organic matter and consumes the resulting energy and nutrients for its own production.

Decomposition Breakdown of dead organic matter through fragmentation, chemical alteration, and leaching.

Decomposition rate constant Constant (k) that describes the exponential breakdown of a tissue.

Decoupling coefficient Measure of the extent to which the canopy is decoupled from the bulk atmosphere.

Deep water Ocean water greater than 1,000 m depth.

Deforestation Conversion of forest to a non-forest ecosystem type.

Demand Requirement; the term is used in the context of the control of the rate of a process (e.g., nutrient uptake) by the amount needed.

Denitrification Conversion of nitrate to gaseous forms (N_2, NO, and N_2O).

Deposition Atmospheric input of materials to an ecosystem.

Depositional zone Portion of a drainage basin, where deposition rate exceeds erosion rate.

Desertification Soil degradation that occurs in drylands.

Detritivore Organism that derives energy from breakdown of dead organic matter.

Detritus Dead plant and animal material, including leaves, stems, roots, dead animals, and animal feces.

Detritus-based trophic system Organisms that consume detritus or energy derived from detritus.

Diffuse radiation Shortwave radiation that is scattered by particles and gases in the atmosphere.

Diffusion Net movement of molecules or ions along a concentration gradient due to their random kinetic activity.

Diffusion shell Zone of nutrient depletion around individual roots caused by active nutrient uptake at the root surface.

Direct radiation Radiation that comes directly from the sun without scattering or reradiation by the atmosphere or objects in the environment.

Discrimination Preferential reaction (or diffusive flux) of the lighter isotope of an element or compound containing that element.

Dissimilatory nitrate reduction Microbial reduction of nitrate to ammonium.

Dissolved inorganic carbon CO_2, bicarbonate, and carbionate dissolved in water.

Dissolved organic carbon Water-soluble organic carbon.

Dissolved organic nitrogen Water-soluble organic nitrogen compounds.

Disturbance Relatively discrete event in time that removes plant biomass.

Disturbance intensity Energy released per unit area and time.

Disturbance regime Range of severity, frequency, type, size, timing, and intensity of disturbances characteristic of an ecosystem.

Disturbance severity Magnitude of loss of biomass, soil resources, and species caused by a disturbance.

Divalent Ions with two charges.

Doldrums Region near the equator with light winds and high humidity.

Double-loop learning Learning that requires that managers evaluate the approach they have used previously before taking further action, for example assessing the costs and benefits of managing forests for multiple ecosystem services rather than for a single product (e.g., trees).

Down-regulation Decrease in capacity to carry out a reaction; for example down-regulation of CO_2 uptake in response to elevated CO_2.

Downwelling Downward movement of surface ocean water, due to high density associated with high salinity and low temperature.

Drainage basin A river or stream and all the terrestrial surfaces that drain into it; synonymous with catchment or watershed.

Drift Invertebrates that move downstream in flowing water.

E horizon Heavily leached horizon beneath the A horizon that is formed in humid climates.

Eccentricity Degree of ellipticity of Earth's orbit around the sun.

Ecosystem Ecological system consisting of all the organisms in an area and the physical environment with which they interact.

Ecosystem ecology Study of the interactions between organisms and their environment as an integrated system.

Ecosystem engineer Organism that alters resource availability by modifying the physical properties of soils and litter.

Ecosystem goods See provisioning services.

Ecosystem management Application of ecological science to resource management to promote long-term sustainability of ecosystems and the delivery of essential ecosystem goods and services to society.

Ecosystem model Framework that describes the major pools and fluxes in an ecosystem and the factors that regulate these fluxes.

Ecosystem processes Inputs or losses of materials and energy to and from the ecosystem and the transfers of these substances among components of the system.

Ecosystem respiration Sum of plant respiration and heterotrophic respiration.

Ecosystem services Benefits that people derive from ecosystems, including provisioning, regulating, and cultural services.

Ectomycorrhizae Mycorrhizal association in some woody plants in which a large part of the fungal tissue is found outside the root.

Eddy covariance Method of estimating flux of energy and materials (e.g., water vapor and CO_2) between the ecosystem and the atmosphere by measuring their transfer in eddies of air.

El Niño Warming of surface water throughout the central and eastern tropical Pacific Ocean.

Electron-transport chain Series of membrane-bound enzymes that produce ATP and NADPH as a result of passing electrons down an electropotential gradient.

Emissivity Coefficient that describes the maximum rate at which a body emits radiation, relative to a perfect (black body) radiator, which has a value of 1.0.

Endocellulase Enzyme that breaks down the internal bonds to disrupt the crystalline structure of cellulose.

Endodermis Layer of suberin-coated cells between the cortex and xylem of roots; water penetrates this layer only by moving through the cytoplasm of these cells.

Energy pyramid Quantity of energy transferred between successive trophic levels.

Entisol Soil order characterized by minimal soil development.

Environmental stress Environmental factor that reduces plant performance; physical force that promotes mass wasting of soils.

Enzyme Organic molecule produced by an organism that catalyzes a chemical reaction.

Epidermis Layer of cells on the surface of a leaf or root.

Epilimnion Surface water layer that is heated by absorbed radiation and mixed by wind.

Epiphytic Attached to plant surfaces.

Equilibrium Condition of a system that remains unchanged over time because of a balance among opposing forces.

Equinox Date when the sun is directly overhead at the equator, and the entire earth surface receives approximately twelve hours of daylight.

Erosional zone Portion of a drainage basin, where erosion dominates over deposition.

Estuary Coastal ecosystem where a river mixes with seawater.

Euphotic zone Uppermost layer of water in aquatic ecosystems where there is enough light to support phytoplankton growth, i.e., where algal photosynthesis exceeds algal respiration.

Eutrophic Nutrient-rich.

Eutrophication Nutrient-induced increase in phytoplankton productivity.

Evapotranspiration Water loss from an ecosystem by transpiration and surface evaporation; equivalent to latent heat flux, but expressed in water units.

Evergreen Retention of green leaves throughout the year.

Exocellulase Enzyme that cleaves off disaccharide units from the ends of cellulose chains, forming cellobiose.

Exoenzyme Enzyme that is secreted by an organism into the environment.

Extensification Expansion of the aerial extent of land-cover change due to human activities.

Extinction coefficient Constant that describes the exponential decrease in irradiance through a canopy or medium (e.g., water).

Exudation Secretion of soluble organic compounds by organisms into the environment.

Facilitation Processes by which some species make the environment more favorable for the growth of other species.

Fast variables Variables that change rapidly and are often the focus of resource managers.

Feedback Response in which the product of one of the final steps in a chain of events affects one of the first steps in this chain; fluctuations in rate or concentration are minimized with stabilizing feedbacks or magnified with amplifying feedbacks.

Fermentation Anaerobic process that breaks down labile organic matter to produce organic acids and CO_2.

Ferrell cell Atmospheric circulation cell between 30° and 60° N or S latitude that is driven indirectly by dynamical processes.

Field capacity Water held by a soil after gravitational water has drained.

Filter feeder Aquatic animal that feeds on suspended particles.

Fine particulate organic matter Particulate organic matter in aquatic ecosystems that is smaller than 1 mm diameter.

Fire intensity Rate of heat production.

Fixation Covalent binding of an ion to a mineral surface.

Flow path Subsurface pathway of water movement.

Flux Flow of energy or materials from one pool to another.

Food chain Group of organisms that are linked together by the linear transfer of energy and nutrients from one organism to another.

Food web Group of organisms that are linked together by the transfer of energy and nutrients that originates from the same source.

Fossil groundwater Groundwater that accumulated during a wetter climate and is no longer being replenished at a significant rate.

Fractionation Preferential incorporation of a light isotope (e.g., ^{12}C vs. ^{13}C).

Fragmentation Breaking up of intact litter into small pieces.

Fulvic acids Humic compounds that are relatively water-soluble due to their extensive side chains and many charged groups.

Functional matrix Matrix of all the functional traits represented by the species in an ecosystem.

Functional mosaic Landscape with functionally important differences among patches.

Functional type Group of species that are similar with respect to their impacts on community or ecosystem processes (effects functional type) and/or their response to a given environmental change, such as elevated CO_2 (response functional types).

Gap-phase succession Succession that occurs in small patches within a stand due to death of individual plants or plant parts.

Gelisol Soil order characterized by presence of permafrost.

Generalist herbivore Herbivore that is relatively non-selective in its choice of plant species.

Geotropism Growth direction of plant organs with respect to gravity.

Gley soil Blue-gray soil due to conversion of ferric to ferrous iron; formed under anaerobic conditions.

Glomalin Glycoprotein produced by many mycorrhizal fungi that cements microaggregates together to form macroaggregates.

Graminoid Grass-like plant (grasses, sedges, and rushes).

Grazer Herbivore that consumes herbaceous plants (terrestrial ecosystems) or periphyton (aquatic ecosystems).

Grazing lawn Productive grassland or wetland ecosystem in which plants are heavily grazed but supported by large nutrient inputs from grazers.

Great acceleration Rapid increase in human impacts on Earth's life support system since 1950.

Greenhouse effect Warming of the atmosphere due to atmospheric absorption of longwave radiation.

Greenhouse gas Atmospheric gas that absorbs longwave radiation.

Green water Water that evaporates from the soil surface or is transpired by plants.

Gross primary production Net carbon input to ecosystems, i.e., net photosynthesis expressed at the ecosystem scale (g C m^{-2} yr^{-1}).

Ground heat flux Heat transferred from the surface into the soil.

Groundwater Water in soil and rocks beneath the rooting zone.

Growth Production of new biomass.

Guano Large accumulations seabird feces.

Gyres Large circulation systems in surface ocean waters.

Hadley cell Atmospheric circulation cell between the equator and 30˚N or S latitude, driven by expansion and uplift of equatorial air and subsidence of cool dense subtropical air.

Halocline Relatively sharp vertical gradient in salinity in a lake or ocean.

Hard pan Soil horizon with low hydraulic conductivity.

Hartig net Hyphae that penetrate cell walls of root cortical cells in ectomycorrhizae.

Heat capacity Amount of energy required to raise the temperature of unit volume of a body by 1˚C.

Herbivore Organism that eats live plants.

Herbivory Consumption of plants by animals.

Heterocyst Specialized non-photosynthetic cells of phototrophs that protect nitrogenase from denaturation by oxygen.

Heterotroph Organism that consumes organic matter produced by other organisms rather than producing organic matter from CO_2 and environmental energy. Hetertrophs include decomposers, consumers, and parasites.

Heterotrophic respiration Respiration by non-autotrophic organisms (i.e., microbes and animals).

Histosol Soil order characterized by highly organic soils due to poor drainage and low oxygen.

Homeothermy Maintenance of a constant body temperature.

Horizon Layer in a soil profile. The horizons, from top to bottom, are the O horizon, which consists of organic matter above mineral soil; the A horizon, a dark layer with substantial organic matter; the E horizon, which is heavily leached; a B horizon, where iron and aluminum oxides and clays accumulate; and a C horizon, which is relatively unaffected by soil-forming processes.

Horse latitudes Latitudes 30˚N and S, characterized by weak winds and high temperatures.

Human well-being Quality of life; basic material needs for a good life, freedom and choice, good social relations, and personal security.

Humic acid Relatively insoluble humic compounds with extensive networks of aromatic rings and few side chains.

Humification Non-enzymatic process by which recalcitrant breakdown products of decomposition are complexed to form humus.

Humus Complex mixture of soil organic compounds with highly irregular structure.

Hydraulic conductivity Capacity of a given volume of a substance (such as soil) to conduct water; this defines the relationship between discharge and the hydraulic gradient causing it.

Hydraulic lift Upward movement of water through roots from deep moist soils to dry surface soils along a gradient in water potential.

Hydrothermal vent Vent that emits reduced gases such as H_2S in zones of sea-floor spreading.

Hyphae Filamentous structures that make up the vegetative body of fungi.

Hypolimnion Deep water layer that is unaffected by surface turbulence.

Hyporheic zone Zone of flowing groundwater within the streambed.

Hypoxic Weakly oxygenated.

Ice-albedo feedback Atmospheric warming caused by warming-induced decrease in albedo due to earlier melting of sea ice.

Igneous rocks Rocks formed when magma from Earth's core cools near the surface.

Immobilization Removal of inorganic nutrients from the available pool by microbial uptake and chemical fixation.

Inceptisol Soil order characterized by weak soil development.

Infiltration Movement of water into the soil.

Integrated Conservation and Development Project Project in a developing nation that focuses simultaneously on biological conservation and human development.

Intensification Intensive application of water, energy, and fertilizers to agricultural ecosystems to enhance their productivity.

Interactive controls Factors that control and respond to ecosystem characteristics, including resource supply, microenvironment, functional types of organisms, and disturbance regime.

Interception Contact of nutrients with roots due to the growth of roots to the nutrients; fraction of precipitation that does not reach the ground (canopy interception).

Intermediate water Middle layer of ocean water between about 200 and 1000 m depth.

Intertropical convergence zone Region of low pressure and rising air where surface air from the northern and southern hemispheres converges.

Inversion Increase in atmospheric temperature with height.

Inverted biomass pyramid Biomass pyramid in which there is a smaller biomass of primary producers than of upper trophic levels; typical of pelagic ecosystems of lakes, streams, and oceans.

Investment Increase in the quantity of an asset times its value. Genuine investment constitutes an increase in the total capital of the system.

Ionic binding Electrostatic attraction between oppositely charged ions or surfaces.

Irradiance Radiant energy flux density received at a surface, i.e., the quantity of radiant energy received at a surface per unit time.

Isohydric plants Plants from moist sites that close their stomata at relatively high soil moisture before they experience large changes in plant water potential.

Jet stream Strong winds over a broad height range in the upper troposphere.

Katabatic winds Downslope winds that occur at night when air cools, becomes more dense, and flows downhill.

Kelvin waves Large-scale ocean waves that travel back and forth across the ocean.

Keystone species Species that has a much greater impact on ecosystem processes than would be expected from its biomass; functional type represented by a single species.

La Niña Sea surface temperatures in the equatorial Pacific Ocean associated with strong upwelling of cold water off South America and warm currents in the western Pacific.

Labile Easily decomposed.

Land breeze Night breeze from the land to the ocean caused by the higher surface temperature over the ocean at night.

Landscape Mosaic of patches that differ in ecologically important properties.

Land-use conversion Human-induced change of an ecosystem to one that is dominated by a different physical environment or different plant functional types.

Land-use modification Human alteration of an ecosystem in ways that significantly affect ecosystem processes, community structure and population dynamics without changing the physical environment or the dominant plant functional type of the ecosystem.

Lapse rate Rate at which air temperature decreases with height above Earth's surface; averages about 6.5˚C km^{-1}.

Latent heat flux Energy transferred between a surface and the atmosphere by the evaporation of water or the condensation of water vapor; equivalent to evapotranspiration, but expressed in energy units.

Latent heat of vaporization Energy required to change a gram of a substance from a liquid to a vapor without change in temperature.

Laterite See plinthite layer.

Law of the minimum Plant growth is limited by a single resource at any one time; another resource becomes limiting only when the supply of the first resource is increased above the point of limitation.

Leaching Downward movement of materials in solution. This can occur from the canopy to the soil, from soil organic matter to the soil solution, from one soil horizon to another, or from the ecosystem to ground water or aquatic ecosystems.

Leaf area index (LAI) Projected (i.e., one side of a flat leaf) leaf area per unit ground area.

Legacy Effect of past events on the current functioning of an ecosystem.

Legitimate science Science that is unbiased and respectful of multiple user groups with different concerns and views on preferred policy outcomes.

Life history traits Traits (e.g., seed size and number, potential growth rate, maximum size, and longevity) of an organism that determine how quickly a species can get to a site, how quickly it grows, how tall it gets, and how long it survives.

Light compensation point Irradiance at which net photosynthesis equals zero.

Light-harvesting reactions Reactions of photosynthesis that transform light energy into chemical energy; also termed light-dependent reactions.

Light saturation Range of light availabilities over which the rate of photosynthesis is insensitive to irradiance.

Light use efficiency Ratio of GPP to absorbed photosynthetically active radiation at the leaf or ecosystem scale.

Limitation Reduced rate of a process (e.g., NPP, growth or photosynthesis) due to inadequate supply of a resource (e.g., nutrient or light) or low temperature. Proximate limitation reflects the immediate response to addition of the resource. Ultimate limitation reflects long-term transformation of the system when the resource is added.

Lithosphere Hard outermost shell of Earth

Litter Dead plant material that is sufficiently intact to be recognizable.

Litterbag Mesh bag used to measure decomposition rate of detritus.

Litterfall Shedding of aboveground plant parts and death of plants.

Littoral zone Shore of a lake or ocean.

Loam Soil with substantial proportions of at least two size classes of soil particles.

Loess Soil derived primarily from wind-blown silt particles.

Longwave radiation Radiation with wavelengths of about 4–30 μm.

Lotic Characterized by flowing water.

Luxury consumption Accumulation of nutrients in excess of immediate needs for growth (storage).

Macrofauna Soil animals > 2 mm in width.

Macronutrients Nutrients that are required in large quantities by organisms.

Macrophyte Large aquatic plant (not phytoplankton).

Macropores Large pores between soil aggre-

gates that allow rapid movement of water, roots, and soil animals.

Magma Molten rock in Earth's crust.

Mantle Fungal hyphae that surround the root in ectomycorrhizae; also termed sheath.

Mass flow Bulk transport of solutes due to the movement of soil solution.

Mass wasting Downslope movement of soil or rock material under the influence of gravity without the direct aid of other media such as water, air, or ice.

Matric potential Component of water potential caused by adsorption of water to surfaces; it is considered a component of pressure potential in some treatments.

Matrix Predominant patch type in a landscape.

Mean residence time Mass divided by the flux into or out of the pool over a given time period; synonymous with turnover time.

Mesofauna Soil animals 0.1–2 mm in width.

Mesopause Boundary between the mesosphere and thermosphere.

Mesophyll cells Photosynthetic cells in a leaf.

Mesosphere Atmospheric layer between the stratosphere and the thermosphere, which is characterized by a decrease in temperature with height.

Metalimnion Water layer of intermediate depth (between the epilimnion and the hypolimnion).

Metamorphic rocks Sedimentary or igneous rocks that are modified by exposure to heat or pressure.

Metapopulations Populations of a species that consist of partially isolated subpopulations.

Methanogen Methane-producing bacteria.

Methanotroph Methane-consuming bacteria.

Microbial loop Microbial food web (including both plant- and detritus-based organic material) that recycles carbon and nutrients within the euphotic zone.

Microbial transformation Transformation of plant-derived substrates into microbial-derived substrates as a result of microbial turnover.

Microbivore Organism that eats microbes.

Microenvironment Local environmental conditions (e.g., temperature, pH) that influence the rates of ecosystem processes. It influences organism activity but is not consumed nor depleted by organisms.

Microfauna Soil animals < 0.1 mm in width.

Micronutrients Nutrients that are required in small quantities by organisms.

Micropores Small pores between soil particles, often within soil aggregates.

Milankovitch cycles Cycles of solar input to Earth caused by regular variations in Earth's orbit (eccentricity, tilt, and precession).

Mineralization Conversion of carbon and nutrients from organic to inorganic forms due to the breakdown of litter and soil organic matter. Gross mineralization is the total amount of nutrients released via mineralization (regardless of whether they are subsequently immobilized or not). Net mineralization is the *net* accumulation of inorganic nutrients in the soil solution over a given time interval.

Mollisol Soil order characterized by an organic-rich, fertile A horizon that grades into a B horizon.

Monovalent Ions with a single charge.

Monsoon Tropical or subtropical system of air flow characterized by a seasonal shift between prevailing onshore and offshore winds.

Mutualism Symbiotic relationship between two species that benefits both partners.

Mycorrhizae Symbiotic relationship between plant roots and fungal hyphae, in which the plant acquires nutrients from the fungus in return for carbohydrates that constitute the major carbon source for the fungus.

Mycorhizosphere Zone of soil that is directly influenced by mycorrhizal hyphae.

Nanoplankton Plankton 2 to 20 μm in diameter.

Negative feedback See stabilizing feedback.

Net ecosystem carbon balance Net annual carbon accumulation by the ecosystem.

Net ecosystem exchange Net CO_2 exchange between the land or ocean and the atmosphere.

Net ecosystem production Balance between gross primary production and ecosystem respiration (or between net primary production and heterotrophic respiration).

Net photosynthesis Net rate of carbon gain

measured at the level of individual cells or leaves. It is the balance between simultaneous CO_2 fixation and respiration of photosynthetic cells in the light (including both photorespiration and mitochondrial respiration).

Net primary production Quantity of new plant material produced annually (GPP minus plant respiration); includes new biomass, hydrocarbon emissions, root exudates, and transfers to mycorrhizae.

Net radiation Balance between the inputs and outputs of shortwave and longwave radiation.

New production Phytoplankton production supported by nutrients mixed upward from below the euphotic zone.

Niche Ecological role of an organism in an ecosystem.

Nitrification Conversion of ammonium to nitrate in the soil. Autotrophic nitrifiers use the energy yield from NH_4^+ oxidation to fix carbon used in growth and maintenance, analogous to the way plants use solar energy to fix carbon via photosynthesis. Heterotrophic nitrifiers gain their energy from breakdown of organic matter.

Nitrogenase Enzyme that converts to di-nitrogen to ammonium.

Nitrogen-based defense Plant defensive compound containing nitrogen.

Nitrogen fixation Conversion of di-nitrogen gas to ammonium.

Nitrogen mineralization Conversion of dissolved organic nitrogen to ammonium; synonymous with ammonification.

Nitrogen saturation Ecosystem condition in which nitrogen inputs exceed plant and microbial nitrogen requirements so that the system loses nitrogen to the atmosphere and to groundwater and streams.

Non-steady-state mosaic Landscape that is not in equilibrium with the current environment because large-scale disturbances cause large proportions of the landscape to be in one or a few successional stages.

Normalized difference vegetation index (NDVI) Index of vegetation greenness.

North Atlantic Drift Poleward extension of the Gulf Stream.

Nutrients Material resources in addition to carbon, oxygen, and water that are required for life.

Nutrient cycling Mineralization and uptake of nutrients within an ecosystem patch.

Nutrient limitation Limitation of plant growth due to insufficient supply of a nutrient. See proximate and ultimate nutrient limitation.

Nutrient productivity Instantaneous rate of carbon gain per unit nutrient.

Nutrient spiraling Mineralization and uptake of nutrients that occurs as dead organic matter, dissolved nutrients, and organisms move along a section of a stream or river.

Nutrient uptake Nutrient absorption by plant roots.

Nutrient use efficiency Growth per unit of plant nutrient; ratio of nutrients to biomass lost in litterfall; also calculated as nutrient productivity times residence time.

O horizon Organic horizon above mineral soil.

Occluded phosphorus Unavailable phosphate that is most tightly bound to oxides of iron and aluminum.

Oligotrophic Nutrient-poor.

Omnivore Organism that eats food from several trophic levels.

Open access Situation in which potential users are not excluded from using a resource.

Orographic effects Effects due to presence of mountains.

Osmotic potential Component of water potential due to the presence of substances dissolved in water.

Overland flow Movement of water over the soil surface.

Oxidation Loss of electrons by an electron donor in oxidation-reduction reactions.

Oxisol Soil order found in the wet tropics characterized by highly weathered, leached soils.

Oxygenase Enzyme that catalyzes a reaction with oxygen.

Ozone Molecular form of oxygen (O_3) that is a reactive component of pollution in the troposphere and an absorber of UV radiation in the stratosphere.

Ozone hole Zone of destruction of stratospheric ozone at high southern and high northern latitudes. This hole allows increased penetration of UV radiation to Earth's surface.

Parent material Rocks or other substrates that generate soils through weathering.

Patch Relatively homogeneous stand of an ecosystem in a landscape.

Path dependence Effects of historical legacies on the future trajectory of a system.

Pelagic Open water.

PEP carboxylase Initial carboxylating enzyme in C_4 photosynthesis.

Periphyton Assemblages of algae, bacteria, and invertebrates that attach to stable surfaces such as rocks and vascular plants.

Permafrost Permanently frozen ground, i.e., soil that remains frozen for at least two years.

Permanent wilting point Water held by a soil that cannot be extracted by plant uptake.

pH Negative log of the hydrogen ion (H^+) activity (effective concentration) in solution and is a measure of the active acidity of the system.

Phagocytosis Consumption of material by a cell by enclosing it in a membrane-bound structure that enters the cell.

Phenology Time course of periodic events in organisms that are correlated with climate (e.g., budbreak).

Phloem Long-distance transport system in plants for flow of carbohydrates and other solutes.

Phosphatase Enzyme that hydrolyzes phosphate from a phosphate-containing organic compound.

Phosphorus fixation Binding of phosphorus in soils by strong chemical bonds.

Photodestruction Breakdown of photosynthetic pigments under high light.

Photo-oxidation Oxidation of compounds by light energy; photosynthetic enzymes can be photo-oxidized under conditions of high light.

Photoperiod Daylength.

Photoprotection Protection of photosynthetic pigments from destruction by high light.

Photorespiration Production of CO_2 due to the oxygenation reaction catalyzed by Rubisco; best viewed as a process that recovers much of the products of the oxygenase activity of Rubisco.

Photosynthesis Biochemical process that uses light energy to convert CO_2 to sugars. Net photosynthesis is the net carbon input to ecosystems; synonymous at the ecosystem scale with gross primary production.

Photosynthetic capacity Photosynthetic rate per unit leaf mass measured under favorable conditions of light, moisture, and temperature.

Photosynthetically active radiation Visible light that supports photosynthesis; radiation with wavelengths between 400 and 700 nm.

Phototroph Nitrogen-fixing microorganism that produces its own organic carbon through photosynthesis.

Phreatophyte Deep-rooted plant that taps groundwater.

Phyllosphere decomposition Decomposition that occurs on leaves prior to senescence.

Phytoplankton Microscopic primary producers suspended in the surface water of aquatic ecosystems.

Picoplankton Plankton < 2 μm in diameter.

Pixel Individual cell of a satellite image that provides a generalized spectral response for that area.

Planetary boundary layer Lower portion of the troposphere that is directly affected by the fluxes and friction of Earth's surface.

Planetary waves Large (>1500 km length) waves in the atmosphere that are influenced by the Coriolis effect, land-ocean heating contrasts, and the locations of large mountain ranges.

Plankton Microscopic organisms suspended in the surface water of aquatic ecosystems.

Plant-based trophic system Plants, herbivores, and organisms that consume herbivores and their predators.

Plant defense Chemical or physical property of plants that deters herbivores.

Plasmodesmata Cytoplasmic connections between adjacent cortical cells.

Plate tectonics Theory describing the large-scale motions of continental and ocean plates across Earth's surface.

Plinthite layer Iron-rich layer in tropical soils that have hardened irreversibly on exposure to repeated saturation and drying cycles; formerly termed laterite.

Podzol See spodosol.

Poikilothermic Organism whose body temperature depends on the environment.

Polar cell Atmospheric circulation cell between 60° and the pole driven by subsidence of cold converging air at the poles.

Polar front Boundary between the polar and subtropical air masses characterized by rising air and frequent storms.

Polyphenol Soluble organic compound with multiple phenolic groups.

Pool Quantity of energy or material in an ecosystem compartment such as plants or soil.

Positive feedback See amplifying feedback.

Potential biota Organisms that are present in a region and could potentially occupy the site.

Potential vegetation Vegetation that would occur in the absence of human disturbance.

Precession A "wobbling" in Earth's axis of rotation with respect to the stars, determining the date during the year when solstices and equinoxes occur.

Precipitation Water input to an ecosystem as rain and snow.

Pressure potential Component of water potential generated by gravitational forces and by physiological processes of organisms.

Prevailing wind Most frequent wind direction.

Primary detritivore Organisms (bacteria and fungi) that eat dead organic matter.

Primary minerals Minerals present in the rock or unconsolidated parent material before chemical changes have taken place.

Primary producers Organisms that convert CO_2, water, and solar energy into biomass (i.e., plants); synonymous with autotroph.

Primary production Conversion of CO_2, water, and solar energy into biomass. Gross primary production (GPP) is the net carbon input to ecosystems, i.e., net photosynthesis expressed at the ecosystem scale (g C m^{-2} yr^{-1}). Net primary production is the net carbon accumulation by vegetation (GPP minus plant respiration).

Primary succession Succession following severe disturbances that remove or bury most products of ecosystem processes, leaving little or no organic matter or organisms.

Production efficiency Proportion of assimilated energy that is converted to animal production, including both growth and reproduction.

Profile Vertical cross-section of soil.

Protease Protein-hydrolyzing enzyme.

Proteoid roots Dense clusters of fine roots produced by certain families such as the Proteaceae.

Protozoan Single-celled animal.

Provisioning services Products of ecosystems that are directly harvested by people (e.g., food, fiber, and water); synonymous with ecosystem goods or renewable resources.

Proximate limiting nutrient Nutrient that immediately enhances plant growth after it is added (short-term nutrient limitation).

Pseudosand Stable aggregates of clay particles cemented together by iron oxides in clay-rich oxisols and ultisols.

Pycnocline Relatively sharp vertical gradient in water density in a lake or ocean.

Quality Chemical nature of live or dead organic matter that determines the ease with which it is broken down by herbivores or decomposers, respectively.

Quantum yield Moles of CO_2 fixed per mole of light quanta absorbed; the initial slope of the light-response curve.

Quinone Highly reactive class of compounds produced from polyphenols.

Radiatively active gases Gases that absorb infrared radiation (water vapor, CO_2, CH_4, N_2O and industrial products like chlorofluorocarbons [CFCs]).

Rain shadow Zone of low precipitation downwind of a mountain range.

Reach Stream segment.

Recalcitrant Resistant to microbial breakdown.

Redfield ratio Ratio of nitrogen to phosphorus atoms (≈16) giving optimal growth of algae.

Redox potential Electrical potential of a system due to the tendency of substances in it to lose or gain electrons.

Reduction The gain of electrons by an electron acceptor in oxidation-reduction reactions.

Reflected radiation Shortwave radiation that is reflected from clouds and objects in the landscape.

Regenerated production Phytoplankton production supported by nutrients regenerated within the euphotic zone.

Regime shift Abrupt large-scale change to a new state characterized by very different structure and feedbacks.

Regulating services Effects of ecosystems on processes that extend beyond their boundaries (e.g., regulation of climate, water quantity and quality, disease, wildfire spread, and pollination).

Relative growth rate Growth per unit plant biomass.

Relative humidity Ratio of the actual amount of water held in the atmosphere compared to maximum that could be held at that temperature.

Renewable resources See provisioning services.

Renewal ecology Enhancement of the natural capital of a system to provide ecosystem services in the context of the current or desired future state of the system.

Residence time Average time that an element or tissue remains in a system, calculated as the pool size divided by the input; synonymous with turnover time.

Resilience Capacity of a social-ecological system to maintain similar structure, functioning, and feedbacks despite shocks and perturbations.

Resorption Withdrawal of nutrients from tissues during their senescence.

Resorption efficiency Proportion of the maximum tissue nutrient pool that is resorbed prior to tissue senescence or death.

Resources Substances that are taken up from the environment and used by organisms to support their growth and maintenance (e.g., light, CO_2, water, nutrients).

Respiration Biochemical process that converts carbohydrates into CO_2 and water, releasing energy that can be used for growth and maintenance. Respiration can be associated with trophic groups (plant respiration, animal respiration, microbial respiration) or combinations of groups (heterotrophic respiration: animal plus microbial respiration; ecosystem respiration: heterotrophic plus plant respiration). Alternatively, respiration can be defined by the way in which the resultant energy is used (maintenance respiration, growth respiration, respiration to support ion uptake).

Rhizosphere Zone of soil that is directly influenced by roots.

Riparian Located along a streambank.

River continuum concept Idealized transition in ecosystem structure and functioning that integrates stream size, energy sources, food webs, and nutrient processing into a longitudinal model of river metabolism from headwaters to the ocean.

Rock cycle Formation, transformation, and weathering of rocks.

Root cap Cells at the tips of roots that produce mucilaginous carbohydrates that lubricate the movement of roots through soil.

Root cortex Layers of root cells involved in nutrient absorption.

Root exudation Diffusion and secretion of organic compounds from roots into the soil.

Root hair Elongate epidermal cell of the root that extends out into the soil.

Root:shoot ratio Ratio of root biomass to shoot biomass.

Roughness element Obstacle to air flow (e.g., a tree) that creates mechanical turbulence.

Rubisco Ribulose bisphosphate carboxylase; photosynthetic enzyme that catalyzes the initial carboxylation in C_3 photosynthesis.

Runoff Water loss from an ecosystem in streams and rivers.

Salient science Science that is presented to the right people at the right time.

Saline Salty.

Salinization Salt accumulation due to evaporation of surface water.

Salt flat Depression in an arid area that accumulates salt because it receives runoff but has no outlet; see also closed-basin lake.

Salt lick Mineral-rich springs or outcrops that are used by animals as a source of minerals.

Salt pan Surface salt accumulation in desert depressions.

Sand Soil particles 0.05 to 2 mm diameter.

Saprotrophic Eating dead organic matter (as with non-mycorrhizal fungi).

Sapwood Total quantity of functional conducting tissue of the xylem.

Saturated flow Drainage of water under the influence of gravity.

Savanna Grassland with scattered trees or shrubs.

Sea breeze Daytime onshore breeze that occurs on coastlines due to greater heating of the land than the water.

Secondary metabolites Compounds produced by plants that are not essential for normal growth and development.

Secondary minerals Crystalline and amorphous products that are formed through the reaction of materials released during weathering.

Secondary succession Succession that occurs on previously vegetated sites after a disturbance in which there are residual effects of organisms and organic matter from organisms present before the disturbance.

Sedimentary rocks Rocks formed from sediments.

Seed bank Seeds produced after previous disturbances that remain dormant in the soil until post-disturbance conditions (light, wide temperature fluctuations, and/or high soil nitrate) trigger germination.

Seedling bank Seedlings beneath a canopy that show negligible growth in the dense shade of a forest canopy but grow rapidly in tree-fall gaps.

Selective preservation Increase in concentration of recalcitrant material as a result of decomposition of labile substrates.

Senescence Programmed breakdown of plant tissues.

Sense of place Self-identification with a particular location or region.

Sensible heat Heat energy that can be sensed (e.g., by a thermometer) and involves no change in state.

Sensible heat flux Energy that is conducted from a warm surface to the air immediately above it and then moved upward to the bulk atmosphere by convection.

Serotiny Extent to which seeds are retained in cones.

Seston Particles suspended in the water column, including algae, bacteria, detritus, and mineral particles.

Shade leaf Leaf that is acclimated to shade or is produced by a plant adapted to shade.

Shear strength of soil Shear stress that a soil can sustain without slope failure.

Shear stress of soil Force parallel to the slope that drives mass wasting events such as landslides.

Shifting agriculture Clearing of forest for crops followed by a fallow period during which forests regrow, after which the cycle repeats; synonymous with slash-and-burn or swidden agriculture.

Shifting steady-state mosaic Landscape in which the vegetation at any point in the landscape is always changing but, averaged over a large enough area, the proportion of the landscape in each successional stage remains relatively constant.

Shortwave radiation Radiation with wavelengths of about 0.2–4.0 μm, including ultraviolet, visible, and near infrared radiation.

Shredder Invertebrate that breaks leaves and other detritus into pieces and digests the microbial jam on the surface of these particles.

Siderophore Organic chelate produced by plant roots.

Silt Soil particles 0.002–0.05 mm diameter.

Single-loop learning Learning that adjusts actions to meet previously agreed-upon management goals, such as changes in harvest levels needed to sustain populations of a particular fish or tree species.

Sink strength Demand of a plant organ or process for carbohydrates.

Slash-and-burn agriculture See shifting agriculture.

Slow variables Variables that change slowly and are key control variables over longer time scales.

Snow-albedo feedback Atmospheric warming caused by warming-induced decrease in albedo due to earlier snowmelt.

Social-ecological stewardship Strategy for shaping the trajectory of social-ecological change to enhance ecosystem resilience and human well-being.

Soil The weathered portion of Earth's crust between the litter layer and bedrock; see also horizons.

Soil creep Downhill movement of soil; dubious character covered with dirt.

Soil order Major soil groupings in the U.S. soil taxonomic classification.

Soil organic matter Dead organic matter in the soil that has decomposed to the point that its original identity is uncertain.

Soil phase Soils belonging to the same soil type that differ in landscape position, stoniness, or other soil properties.

Soil resources Water and nutrients available in the soil.

Soil series Soils belonging to the same order that differ in profile characteristics, such as number and types of horizons, thickness, and horizon properties.

Soil structure Binding together of soil particles to form aggregates.

Soil texture Proportional distribution of soil particle sizes.

Soil types Soils belonging to the same soil series but having different textures of the A horizon.

Solstice Date of maximum or minimum daylength.

Solubility pump Downward flux of carbon from surface to deep waters due to the downwelling of CO_2-rich North Atlantic or Antarctic waters.

Sorption Binding of an ion to a mineral surface, ranging from electrostatic attraction to covalent binding.

Source Part of a system (e.g., plant, landscape, or climate system) that shows a net export of a compound.

Southern Oscillation Atmospheric pressure changes over the southeastern Pacific and Indian Ocean.

Specialist herbivore Herbivore that specializes on consumption of one or a few plant species or tissues.

Species diversity Number, evenness, and composition of species in an ecosystem; the total range of biological attributes of all species present in an ecosystem.

Species richness Number of species in an ecosystem.

Specific heat Energy required to warm a gram of a substance by 1˚C.

Specific leaf area Ratio of leaf area to leaf mass.

Specific root length Root length per unit root mass.

Spiraling length Average horizontal distance that a nutrient moves between successive uptake events.

Spodosol Soil order characterized by highly leached soils that develop in cold climates; also termed podzol in European terminology.

Stabilizing feedback Interaction in which two components of a system have opposite effects on one another; this reduces the rate of change in the system; synonymous with negative feedback.

Stakeholders People who are affected by the outcomes of a policy or action.

Stand-replacing disturbance Large disturbance that affects an entire stand of vegetation.

State factors Independent variables that control the characteristics of soils and ecosystems (climate, parent material, topography, potential biota, time, and human activities).

Steady state State of a system in which increments are approximately equal to losses, when averaged over a long time (e.g., the turnover time of the system); there are no *net* changes in the major pools in a system at steady state.

Stemflow Water that flows down stems to the ground.

Stoichiometric relationship Element ratio.

Stomata Pores in the leaf surface through which water and CO_2 are exchanged between the leaf and the atmosphere.

Stomatal conductance Flux of water vapor or CO_2 per unit driving force between the interior of a leaf and the atmosphere.

Stratification Separation of lake or ocean water into 2–3 layers of differing density due to differences in temperature and/or salinity.

Stratopause Boundary between the stratosphere and the mesosphere.

Stratosphere Atmospheric layer above the troposphere, which is heated from the top and characterized by an increase in temperature with height.

Stroma Gel matrix within the chloroplast in which the carbon-fixation reactions occur.

Subduction Downward movement of a plate margin beneath another plate.

Suberin Hydrophobic waxy substance that occurs in the cell walls of the endodermis and exodermis of plant roots.

Sublimation Vaporization of a solid such as snow.

Subsidy Energy or nutrient transfers from one ecosystem to another; synonymous with allochthonous input.

Substitutibility Capacity of one form of capital (e.g., a wetland) to provide the function that might be provided by another (e.g., water treatment plant).

Succession Directional change in ecosystem structure and functioning after disturbance.

Sunfleck Short period of high irradiance that interrupts a general background of low diffuse radiation.

Sun leaf Leaf that is acclimated to high light or is produced by a plant adapted to high light.

Surface conductance Potential of the leaf and soil surfaces in the ecosystem to lose water. Similar to stomatal conductance but applied at the canopy scale.

Surface roughness Vertical irregularities in the height of the canopy surface.

Surface water Surface layer of the ocean heated by the sun and mixed by winds, typically 75–200 m deep.

Surplus production Production in excess of that which would occur when the fish stock is limited by density-dependent mortality.

Sustainability Use of the environment and resources to meet the needs of the present without compromising the ability of future generations to meet their needs.

Swidden agriculture See shifting agriculture.

Systems ecology Study of the ecosystem as a group of components linked by fluxes of materials or energy.

Taiga Boreal forest.

Teleconnections Dynamic interactions that interconnect distant regions of the atmosphere.

Temporal scaling Extrapolation of measurements made at one time interval to longer (or occasionally shorter) time intervals.

Thermocline Relatively sharp vertical temperature gradient in a lake or ocean.

Thermohaline circulation Global circulation of deep and intermediate ocean waters driven by downwelling of cold saline surface water off of Greenland and Antarctica.

Thermosphere Outermost layer of the atmosphere, which is characterized by an increase in temperature with height.

Threshold Critical level of one or more ecosystem controls that, when crossed, cause abrupt ecosystem changes.

Throughfall Water that drops from the canopy to the ground.

Thylakoids Membrane-bound vesicles in chloroplasts in which the light-harvesting reactions of photosynthesis occur.

Tilt Angle of Earth's axis of rotation and the plane of its orbit around the sun.

Time step Shortest time interval simulated by a model.

Top-down controls Regulation of population dynamics by predation.

Toposequence Series of ecosystems that are similar except with respect to their topographic position.

Tradeoffs Alternative choices, for example among management regimes that offer different bundles of ecosystem services.

Tradewinds Easterly winds between 30°N and 30°S latitudes.

Transfer zone Portion of a drainage basin, where erosion and deposition are in dynamic balance over long time scales.

Transformation Conversion of the organic compounds contained in litter to recalcitrant organic compounds in soil humus. Also, fundamental change in the state of a system that results in different control variables and feedbacks defining the state of the system.

Transpiration Water movement through stomata from plants to the atmosphere.

Transporter Membrane-bound proteins that transport ions across cell membranes.

Trophic cascade top-down effect of predators on the biomass of organisms at lower trophic levels; results in alternation of high and low biomass of organisms in successive trophic levels.

Trophic efficiency Proportion of production of prey that is converted to production of consumers at the next trophic level.

Trophic interactions Feeding relationships among organisms.

Trophic level organisms that obtain their energy with the same number of steps removed from plants or detritus.

Trophic transfer Flux of energy or materials due to consumption of one organism by another.

Tropopause Boundary between the troposphere and the stratosphere.

Troposphere Lowest atmospheric layer, which is heated from the bottom, continually mixed by weather systems, and characterized by a decrease in temperature with height.

Tundra Ecosystem type that is too cold to support growth of trees.

Turbulence Irregular velocities of air or water movement that can transport heat and materials much more rapidly than by diffusion. Mechanical turbulence is caused by the uneven slowing of air by a rough surface. Convective turbulence is caused by the increased buoyancy of surface air caused by heat transfer from the surface.

Turnover Replacement of a pool; ratio of the flux to the pool size; lake mixing that occurs when surface waters become more dense than deep waters.

Turnover length Downstream distance traveled by a particle of carbon or nutrient between entering the stream and being respired to CO_2.

Turnover time Average time that an element spends in a system (pool/input); synonymous with mean residence time.

Ultimate limiting nutrient Nutrient whose sustained addition stimulates production and transforms a community or ecosystem.

Ultisol Soil order characterized by substantial leaching a warm, humid environment.

Unsaturated flow Water movement through soils with a water content less than field capacity.

Uplift Upward movement of Earth's surface.

Uptake Absorption of water or mineral by an organism or tissue.

Uptake length Average distance that an atom moves from the time it is released by mineralization until it is absorbed again.

Upwelling Upward movement of deep and intermediate ocean water, usually driven by offshore winds near coasts.

Validation Comparison of model predictions with data.

Vapor density Mass of water per volume of air; absolute humidity.

Vapor pressure Partial pressure exerted by water molecules in the air.

Vapor pressure deficit Difference in actual vapor pressure and the vapor pressure in air of the same temperature and pressure that is saturated with water vapor; loosely used to describe the difference in vapor pressure in air immediately adjacent to an evaporating surface and the bulk atmosphere, although strictly speaking the air masses are at different temperatures.

Vertisol Soil order characterized by swelling and shrinking clays.

Vesicular arbuscular mycorrhizae See arbuscular mycorrhizae.

Voids Spaces between soil particles.

Water holding capacity Difference in soil water content between field capacity and permanent wilting point.

Water potential Potential energy of water relative to pure water at the soil surface.

Water residence time Time required to replace the water volume of a system.

Water-saturated All soil pores filled with water.

Watershed See drainage basin. In England the term refers to the ridge that separates two drainages.

Water use efficiency Ratio of GPP to water loss; also sometimes calculated as the ratio of NPP to cumulative transpiration (growth water use efficiency).

Water vapor feedback Greenhouse effect provided by water vapor, when the atmosphere warms and increases its water vapor content.

Weathering Processes by which parent rocks and minerals are altered to more stable forms. Physical weathering breaks rocks into smaller fragments with greater surface area. Chemical weathering results from chemical reactions between rock minerals and the atmosphere or water.

Westerlies Surface winds that blow from the west.

Xanthophyll cycle Transfer of absorbed energy to xanthophyll and eventually to heat at times when electron acceptors are not available to transfer electrons to carbon-fixation reactions.

Xeric Characterized by plants that are tolerant of dry conditions.

Xylem Water-conducting tissue of plants.

Zooplankton Microscopic animals suspended in the surface water of aquatic ecosystems.

References

Aber, J., W. McDowell, K. Nadelhoffer, A. Magill, G. Bernstson, et al. 1998. Nitrogen saturation in temperate forest ecosystems. *BioScience* 48:921–934.

Aber, J.D., A. Magill, S.G. McNulty, R.D. Boone, K.J. Nadelhoffer, et al. 1995. Forest biogeochemistry and primary production altered by nitrogen saturation. *Water Air and Soil Pollution* 85:1665–1670.

Adair, E.C., W.J. Parton, S.J. Del Grosso, W.L. Silver, M.E. Harmon, et al. 2008. A simple three-pool model accurately describes patterns of long-term, global litter decomposition in the Long-term Intersite Decomposition Experiment Team (LIDET) data set. *Global Change Biology* 14:2636–2660.

Aerts, R. and F. Berendse. 1988. The effect of increased nutrient availability on vegetation dynamics in wet heathlands. *Vegetatio* 76:63–69.

Aerts, R. 1995. Nutrient resorption from senescing leaves of perennials: Are there general patterns? *Journal of Ecology* 84:597–608.

Aerts, R. 1997. Climate, leaf litter chemistry and leaf litter decomposition in terrestrial ecosystems: A triangular relationship. *Oikos* 79:439–449.

Aerts, R. and F.S. Chapin, III. 2000. The mineral nutrition of wild plants revisited: A re-evaluation of processes and patterns. *Advances in Ecological Research* 30:1–67.

Agrawal, A., A. Chhatre, and R. Hardin. 2008. Changing governance of the world's forests. *Science* 320:1460–1462.

Ahrens, C.D. 1998. *Essentials of Meteorology: An Invitation to the Atmosphere*. 2nd edition. Wadsworth, Belmont, California.

Ainsworth, E.A. and S.P. Long. 2005. What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. *New Phytologist* 165: 351–371.

Algesten, G., S. Sobek, A.K. Bergström, A. Ågren, L.J. Tranvik, et al. 2003. The role of lakes in organic carbon cycling in the boreal zone. *Global Change Biology* 10:141–147.

Allan, J.D. and M.M. Castillo. 2007. *Stream Ecology: Structure and Function of Running Waters*. 2nd edition. Springer, Dordrecht.

Allen, J.L., S. Wesser, C.J. Markon, and K.C. Winterberger. 2006. Stand and landscape level effects of a major outbreak of spruce beetles on forest vegetation in the Copper River Basin, Alaska. *Forest Ecology and Management* 227:257–266.

Allen, M.F. 1991. *The Ecology of Mycorrhizae*. Cambridge University Press, Cambridge.

Allison, S.D. 2006. Brown ground: A soil carbon analog for the Green World Hypothesis? *American Naturalist* 167:619–627.

Alpert, P. 1996. Integrated conservation and development projects: Examples from Africa. *BioScience* 46: 845–855.

Altieri, M.A. 1990. Why study traditional agriculture? Pages 551–564 *in* C.R. Carrol, J.H. Vandermeer, and P.M. Rosset, editors. *Agroecology*. McGraw Hill, New York.

Amthor, J.S. 2000. The McCree-deWit-Penning de Vries-Thornley respiration paradigms: 30 years later. *Annals of Botany* 86:1–20.

Amundson, R. and H. Jenny. 1997. On a state factor model of ecosystems. *BioScience* 47:536–543.

Amundson, R., D.D. Richter, G.S. Humphreys, E.G. Jobbágy, and J. Gaillardet. 2007. Coupling between biota and earth materials in the critical zone. *Elements* 3:327–332.

Anderson, R.V., D.C. Coleman, and C.V. Cole. 1981. Effects of saprotrophic grazing on net mineralisation. Pages 201–216 *in* F.E. Clark and T. Rosswall, editors. *Terrestrial Nitrogen Cycles: Processes, Ecosystem Strategies and Management Impacts*. Ecological Bulletins, Stockholm.

Andersson, T. 1991. Influence of stemflow and throughfall from common oak (*Quercus robur*) on soil chemistry and vegetation patterns. *Canadian Journal of Forest Research* 21:917–924.

Archer, D., M. Eby, V. Brovkin, A. Ridgwell, L. Cao, et al. 2009. Atmospheric lifetime of fossil fuel carbon dioxide. *Annual Review of Earth and Planetary Science* 37:117–134.

Armesto, J.J., R. Rozzi, and J. Caspersen. 2001. Temperate forests of North and South America. Pages 223–249 *in* F.S. Chapin, III, O.E. Sala, and E. Huber-Sannwald, editors. *Global Biodiversity in a Changing Environment: Scenarios for the 21st Century*. Springer-Verlag, New York.

Armitage, D., F. Berkes, and N. Doubleday, editors. 2007. *Adaptive Co-Management: Collaboration, Learning, and Multi-Level Governance*. University of British Columbia Press, Vancouver.

Arrow, K., L. Goulder, P. Dasgupta, G. Daily, P. Ehrlich, et al. 2004. Are we consuming too much? *Journal of Economic Perspectives* 18:147–172.

Asner, G.P., D.E. Knapp, M.O. Jones, T. Kennedy-Bowdoin, R.E. Martin, et al. 2007. Carnegie Airborne Observatory: In-flight fusion of hyperspectral imaging and waveform light detection and ranging (wLiDAR) for three-dimensional studies of ecosystems. *Journal of Applied Remote Sensing* 1:DOI: 10.1117/1111.2794018.

Asner, G.P., G.V.N. Powell, J. Mascaro, D.E. Knapp, J.K. Clark, et al. 2010. High resolution forest carbon stocks and emissions in the Amazon. *Proceedings of the National Academy of Sciences, USA* 107:16738–16742.

Aston, A.R. 1979. Rainfall interception by eight small trees. *Journal of Hydrology* 42:383–396.

Ataroff, M. and M.E. Naranjo. 2009. Interception of water by pastures of *Pennisetum clandestinum* Hochst ex Chiov. and *Melinus minutiflora* Beauv. *Agricultural and Forest Meteorology* 149:1616–1620.

Ayres, E., H. Steltzer, B.L. Simmons, R.T. Simpson, J.M. Steinweg, et al. 2009. Home-field advantage accelerates leaf litter decomposition in forests. *Soil Biology and Biochemistry* 41:606–610.

Ayres, M.P. and S.F. MacLean, Jr. 1987. Development of birch leaves and the growth energetics of *Epirrita autumnata* (Geometridae). *Ecology* 68:558–568.

Ayres, M.P. 1993. Plant defense, herbivory, and climate change. Pages 75–94 *in* P.M. Kareiva, J.G. Kingsolver, and R.B. Huey, editors. *Biotic Interactions and Global Change*. Sinauer Assoc., Sunderland, MA.

Bailey, R.G. 1998. *Ecoregions: The Ecosystem Geography of the Oceans and Continents*. Springer-Verlag, New York.

Baines, S.B. and M.L. Pace. 1994. Sinking fluxes along a trophic gradient: Patterns and their implications for the fate of primary production. *Canadian Journal of Fisheries and Aquatic Sciences* 51:25–36.

Baker, J.M., T.E. Ochsner, R.T. Veterea, and T.J. Griffis. 2007. Tillage and soil carbon sequestration. What do we really know? *Agriculture, Ecosystems & Environment* 118:1–5.

Baldocchi, D., F.M. Kelliher, T.A. Black, and P.G. Jarvis. 2000. Climate and vegetation controls on boreal zone energy exchange. *Global Change Biology* 6 (Suppl. 1): 69–83.

Baldocchi, D., E. Falge, L. Gu, R. Olson, D. Hollinger, et al. 2001. FLUXNET: A new tool to study the temporal and spatial variability of ecosystem-scale carbon dioxide water vapor, and energy flux densities. *Bulletin of the American Meteorological Society* 82: 2415–2434.

Baldocchi, D.D. and J.S. Amthor. 2001. Canopy photosynthesis: History, measurements, and models.*in* J. Roy, B. Saugier, and H.A. Mooney, editors. *Terrestrial Global Productivity*. Academic Press, San Diego.

Baldocchi, D.D. 2003. Assessing the eddy covariance technique for evaluating carbon dioxide exchange rates of ecosystems: past, present and future. *Global Change Biology* 9:479–492.

Baldocchi, D.D., L. Xu, and N. Kiang. 2004. How plant functional-type, weather, seasonal drought, and soil physical properties alter water and energy fluxes of an oak-grass savanna and an annual grassland. *Agricultural and Forest Meteorology* 123:13–39.

Barber, S.A. 1984. *Soil Nutrient Bioavailability*. John Wiley & Sons, New York.

Barbier, E.B. 1987. The concept of sustainable economic development. *Environmental Conservation* 14: 101–110.

Barboza, P.S., K.L. Parker, and I.D. Hume. 2009. *Integrative Wildlife Nutrition*. Springer, Berlin.

Bardgett, R.D. 2005. *The Biology of Soil: A Community and Ecosystem Approach*. Oxford University Press, Oxford.

Bardgett, R.D., W.D. Bowman, R. Kaufmann, and S.K. Schmidt. 2005a. A temporal approach to linking aboveground and belowground ecology. *Trends in Ecology & Evolution* 20:634–641.

Bardgett, R.D., M.B. Usher, and D.W. Hopkins, editors. 2005b. *Biological Diversity and Function in Soils*. Cambridge University Press, Cambridge.

Barrett, C.B. and P. Arcese. 1995. Are integrated conservation-development projects sustainable? On the conservation of large mammals in sub-Saharan Africa. *World Development* 23:1073–1084.

Barron, A.R., N. Wurzburger, J.P. Bellenger, S.J. Wright, A.M.L. Kraepiel, et al. 2009. Molybdenum limitation of asymbiotic nitrogen fixation in tropical forest soils. *Nature Geoscience* 2:42–45.

Barry, R.G. and R.J. Chorley. 2003. *Atmosphere, Weather and Climate*. 8th edition. Routledge, London.

Baskin, C.C. and J.M. Baskin. 1998. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, San Diego.

Bates, T.R. and J.P. Lynch. 1996. Stimulation of root hair elongation in *Arabidopsis thaliana* by low phosphorus availability. *Plant Cell and Environment* 19:529–538.

Bayley, P.B. 1989. Aquatic environments in the Amazon Basin, with an analysis of carbon sources, fish production, and yield. Pages 399–408 *in* D.P. Dodge, editor. *Proceedings of the International Large River Symposium, Canadian Special Publications of Fisheries and Aquatic Sciences*.

Bazzaz, F.A. 1996. *Plants in Changing Environments. Linking Physiological, Population, and Community Ecology*. Cambridge University Press, Cambridge.

Beare, M.H., R.W. Parmelee, P.F. Hendrix, W. Cheng, D.C. Coleman, et al. 1992. Microbial and faunal inter-

actions and effects on litter nitrogen and decomposition in agroecosystems. *Ecological Monographs* 62:569–591.

Berendse, F. and R. Aerts. 1987. Nitrogen-use efficiency: A biologically meaningful definition? *Functional Ecology* 1:293–296.

Berendse, F., R. Aerts, and R. Bobbink. 1993. Atmospheric nitrogen deposition and its impact on terrestrial ecosystems. Pages 104–121 *in* C.C. Vos and P. Opdam, editors. *Landscape Ecology of a Stressed Environment*. Chapman and Hall, London.

Berg, B. and H. Staaf. 1980. Decomposition rate and chemical changes of Scots pine needle litter. II. Influence of chemical composition. Pages 373–390 *in* T. Persson, editor. *Structure and Function of Northern Coniferous Forests: An Ecosystem Study*. Ecological Bulletins, Stockholm.

Berg, B., M.-B. Johansson, V. Meentemeyer, and W. Kratz. 1998. Decomposition of tree root litter in a climatic transect of coniferous forests in Northern Europe: A synthesis. *Scandinavian Journal of Forest Research* 13:202–212.

Berg, B. and V. Meentemeyer. 2002. Litter quality in a north European transect vs. carbon storage potential. *Plant and Soil* 242:83–92.

Bergh, J. and S. Linder. 1999. Effects of soil warming during spring on photosynthetic recovery in boreal Norway spruce stands. *Global Change Biology* 5: 245–253.

Berkes, F., J. Colding, and C. Folke, editors. 2003. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge University Press, Cambridge.

Berkes, F., T.P. Hughes, and R.S. Steneck. 2006. Globalization, roving bandits, and marine resources. *Science* 311:1557–1558.

Berkes, F. 2008. *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. 2nd edition. Taylor & Francis, Philadelphia.

Berkes, F., G.P. Kofinas, and F.S. Chapin, III. 2009. Conservation, community, and livelihoods: Sustaining, renewing, and adapting cultural connections to the land. Pages 129–147 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Berner, E.K., R.A. Berner, and K.L. Moulton. 2004. Plants and mineral weathering: Past and present. Pages 169–188 *in* J.I. Drever, editor. *Surface and Ground Water, Weathering, and Soils. Treatise on GeoChemistry 5*. Elsevier, San Diego.

Berner, R.A. 1997. The rise of plants and their effect on weathering and atmosphere CO_2. *Science* 276: 544–546.

Bernhardt, E.L., T.N. Hollingsworth, and F.S. Chapin, III. 2011. Fire severity mediates climate-driven shifts in understory composition of black spruce stands in interior Alaska. *Journal of Vegetation Science* 22:32–44.

Berry, J. and O. Björkman. 1980. Photosynthetic response and adaptation to temperature in higher plants. *Annual Review of Plant Physiology* 31:491–543.

Berry, W.L. 1970. Characteristics of salts secreted by *Tamarix aphylla*. *American Journal of Botany* 57: 1226–1230.

Beschta, R.L. and W.J. Ripple. 2009. Large predators and trophic cascades in terrestrial ecosystems in the western United States. *Biological Conservation* 142: 2401–2414.

Bettis, E.A., III, D.R. Muhs, H.M. Roberts, and A.G. Wintle. 2003. Last Glacial loess in the conterminous USA. *Quaternary Science Reviews* 22:1907–1946.

Betts, A.K. and J.H. Ball. 1997. Albedo over the boreal forest. *Journal of Geophysical Research-Atmospheres* 102:28901–28909.

Betts, E.F. and J.B. Jones. 2009. Impact of wildfire on stream nutrient chemistry and ecosystem metabolism in boreal forest catchments of interior Alaska. *Arctic, Antarctic, and Alpine Research* 41:407–417.

Bhupinderpal-Singh, A. Nordgren, M.O. Lövfvenius, M.N. Högberg, P.-E. Mellander, et al. 2003. Tree root and soil heterotrophic respiration as revealed by girdling of boreal Scots pine forest: Extending observations beyond the first year. *Plant, Cell & Environment* 26:1287–1296.

Biggs, B.J.F. 1996. Patterns in benthic algae of streams. Pages 31–56 *in* R.J. Stevenson, M.L. Bothwell, and R.L. Lowe, editors. *Algal Ecology*. Academic Press, San Diego.

Bilby, R.E. and G.E. Likens. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. *Ecology* 61:1107–1113.

Billen, G., J. Garnier, J. Némery, M. Sebilo, A. Sferratore, et al. 2007. Human activity and material fluxes in a regional river basin: The Seine River watershed. *Science of the Total Environment* 375:80–97.

Billings, W.D. and H.A. Mooney. 1968. The ecology of arctic and alpine plants. *Biological Review* 43:481–529.

Bird, M.I., J. Lloyd, and G.D. Farquhar. 1994. Terrestrial carbon storage at the LGM. *Nature* 371:585.

Birkeland, P.W. 1999. *Soils and Geomorphology*. 3rd edition. Oxford University Press, New York.

Bloom, A.J., F.S. Chapin, III, and H.A. Mooney. 1985. Resource limitation in plants: An economic analogy. *Annual Review of Ecology and Systematics* 16: 363–392.

Bloom, A.J. and F.S. Chapin, III. l98l. Differences in steady-state net ammonium and nitrate influx by cold and warm-adapted barley varieties. *Plant Physiology* 68:1064–l1067.

Bohlen, P.J., S. Scheu, C.M. Hale, M.A. McLean, S. Migge, et al. 2004. Non-native invasive earthworms as agents of change in northern temperate forests. *Frontiers in Ecology and the Environment* 2:427–435.

Bolin, B., P. Crutzen, P. Vitousek, R. Woodmansee, E. Goldberg, et al. 1983. Interactions of biogeochemical

cycles. Pages 1–39 *in* B. Bolin and R. Cook, editors. *The Major Biogeochemical Cycles and Their Interactions*. Wiley, New York.

Bonan, G.B. 1993. Physiological controls of the carbon balance of boreal forest ecosystems. *Canadian Journal of Forest Research* 23:1453–1471.

Bonan, G.B. 2008. *Ecological Climatology: Principles and Applications*. 2nd edition. Cambridge University Press, Cambridge.

Bond, W.J. 1993. Keystone species. Pages 237–253 *in* E.-D. Schulze and H.A. Mooney, editors. *Ecosystem Function and Biodiversity*. Springer-Verlag, Berlin.

Bond-Lamberty, B.P., S.D. Peckham, D.E. Ahl, and S.T. Gower. 2007. Fire as the dominant driver of central Canadian boreal forest carbon balance. *Nature* 450:89.

Booth, M.G. and J.D. Hoeksema. 2010. Mycorrhizal networks counteract competitive effects of canopy trees on seedling survival. *Ecology* 91:2294–2302.

Booth, M.S., J.M. Stark, and E.B. Rastetter. 2005. Controls on nitrogen cycling in terrestrial ecosystems: A synthetic analysis of literature data. *Ecological Monographs* 75:139–157.

Borchert, R. 1994. Soil and stem water storage determine phenology and distribution of tropical dry forest trees. *Ecology* 75:1437–1449.

Borer, E.T., E.W. Seabloom, J.B. Shurin, K.E. Anderson, C.A. Blanchette, et al. 2005. What determines the strength of a trophic cascade? *Ecology* 86: 528–537.

Bormann, B.T. and R.C. Sidle. 1990. Changes in productivity and distribution of nutrients in a chronosequence at Glacier Bay National Park, Alaska. *Journal of Ecology* 78:561–578.

Bormann, B.T. and A.R. Kiester. 2004. Options forestry: Acting on uncertainty. *Journal of Forestry* 102: 22–27.

Bormann, F.H. and G.E. Likens. 1979. *Pattern and Process in a Forested Ecosystem*. Springer-Verlag, New York.

Bousquet, P., P. Cias, J.B. Miller, E.J. Dlugokenck, D.A. Houglustaine, et al. 2006. Contribution of anthropogenic and natural sources of atmospheric methane variability. *Nature* 443:439–443.

Boyd, R.S. 2004. Ecology of metal hyperaccumulation. *New Phytologist* 162:563–567.

Bradford, M.A., C.A. Davies, S.D. Frey, T.R. Maddox, J.M. Melillo, et al. 2008. Thermal adaptation of soil microbial respiration to elevated temperature. *Ecology Letters* 11:1316–1327.

Bradley, B.A. and J.F. Mustard. 2005. Identifying land cover variability distinct from land cover change: Cheatgrass in the Great Basin. *Remote Sensing of Environment* 94:204–213.

Bradshaw, A.D. 1983. The reconstruction of ecosystems. *Journal of Ecology* 20:1–17.

Brady, N.C. and R.R. Weil. 2001. *The Nature and Properties of Soils*. 13th Edition edition. Prentice Hall, Upper Saddle River, New Jersey.

Brady, N.C. and R.R. Weil. 2008. *The Nature and Properties of Soils*. 14th edition. Pearson Education, Inc., Upper Saddle River, NJ.

Bridgham, S.D., C.A. Johnston, J. Pastor, and K. Updegraff. 1995. Potential feedbacks of northern wetlands on climate change. *BioScience* 45:262–274.

Brimblecombe, P. 2004. The global sulfur cycle. Pages 645–682 *in* W.H. Schlesinger, editor. *Biogeochemistry*. Elsevier, Amsterdam.

Brokaw, N.V.L. 1985. Gap-phase regeneration in a tropical forest. *Ecology* 66:682–687.

Brooker, R.W. and T.V. Callaghan. 1998. The balance between positive and negative plant interactions and its relationship to environmental gradients: A model. *Oikos* 81:196–207.

Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, et al. 2004. Effects of invasive alien plants on fire regimes. *BioScience* 54:677–688.

Brown, A.E., L. Zhang, T.A. McMahon, A.W. Western, and R.A. Vertessy. 2005. A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. *Journal of Hydrology* 310:28–61.

Brown, K. 2003. Integrating conservation and development: A case of institutional misfit. *Frontiers of Ecology and the Environment* 1:479–487.

Bryant, J.P. and P.J. Kuropat. 1980. Selection of winter forage by subarctic browsing vertebrates: The role of plant chemistry. *Annual Review of Ecology and Systematics* 11:261–285.

Bryant, J.P., F.S. Chapin, III, and D.R. Klein. 1983. Carbon/nutrient balance of boreal plants in relation to vertebrate herbivory. *Oikos* 40:357–368.

Bump, J.K., K.B. Tischler, A.J. Schrank, R.O. Peterson, and J.A. Vucetich. 2009. Large herbivores and aquatic-terrestrial links in southern boreal forests. *Journal of Animal Ecology* 78:338–345.

Burgess, S.S.O., M.A. Adams, N.C. Turner, and C.K. Ong. 1998. The redistribution of soil water by tree root systems. *Oecologia* 115:306–311.

Burke, I.C., C.M. Yonker, W.J. Parton, C.V. Cole, K. Flach, et al. 1989. Texture, climate, and cultivation effects on soil organic matter content in U.S. grassland soils. *Soil Science Society of America Journal* 53:800–805.

Burke, I.C., D.S. Schimel, C.M. Yonker, W.J. Parton, L.A. Joyce, et al. 1990. Regional modeling of grassland biogeochemistry using GIS. *Landscape Ecology* 4:45–54.

Burke, I.C. and W.K. Lauenroth. 1995. Biodiversity at landscape to regional scales. Pages 304–311 *in* V.H. Heywood, editor. *Global Biodiversity Assessment*. Cambridge University Press, Cambridge.

Burke, I.C., W.K. Lauenroth, R. Riggle, P. Brannen, B. Madigan, et al. 1999. Spatial variability of soil properties in the shortgrass steppe: The relative importance of topography, grazing, microsite, and plant species in controlling spatial patterns. *Ecosystems* 2:422–438.

Cabido, M.R. and M.R. Zak. 1999. *Vegetación del Norte de Córdoba*. Imprenta Nico, Córdoba, Argentina.

Cadenasso, M.L., S.T.A. Pickett, and K. Schwarz. 2007. Spatial heterogeneity in urban ecosystems: Reconceptualizing land cover and a framework for classification. *Frontiers in Ecology and the Environment* 5:80–88.

Caldwell, M.M. and J.H. Richards. 1989. Hydraulic lift: Water efflux from upper roots improves effectiveness of water uptake from deep roots. *Oecologia* 79:1–5.

Callaway, R.M. 1995. Positive interactions among plants. *Botanical Review* 61:306–349.

Canadell, J., R.B. Jackson, J.R. Ehleringer, H.A. Mooney, O.E. Sala, et al. 1996. Maximum rooting depth of vegetation types at the global scale. *Oecologia* 108: 585–595.

Canadell, J.G., C. Le Quéré, M.R. Raupach, C.B. Field, E.T. Buitehuls, et al. 2007. Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences, USA* 104:10288–10293.

Cardille, J.A. and M. Lambois. 2010. From the redwood forest to the Gulf Stream waters: human signature nearly ubiquitous in representative US landscapes. *Frontiers in Ecology and the Environment* 8:130–134.

Cardinale, B.J., E. Duffy, D. Srivastava, M. Loreau, M. Thomas, et al. 2009. Towards a food-web perspective on biodiversity and ecosystem functioning Pages 105–120 *in* S. Naeem, D.E. Bunker, M. Loreau, A. Hector, and C. Perring, editors. *Biodiversity, Ecosystem Functioning, and Human Well-being: An Ecological and Economic Perspective*. Oxford University Press, New York.

Carmack, E. and D.C. Chapman. 2003. Wind-driven shelf/basin exchange on an Arctic shelf: The joint roles of ice cover extent and shelf-break bathymetry. *Geophysical Research Letters* 30:1778, doi:1710.1029/2003GL017526.

Carpenter, S.R., J.F. Kitchell, and J.R. Hodgson. 1985. Cascading trophic interactions and lake productivity. *BioScience* 35:634–639.

Carpenter, S.R., S.G. Fisher, N.B. Grimm, and J.F. Kitchell. 1992. Global change and freshwater ecosystems. *Annual Review of Ecology and Systematics* 23:119–139.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, et al. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications* 9:559–568.

Carpenter, S.R. and M.G. Turner. 2000. Hares and tortoises: Interactions of fast and slow variables in ecosystems. *Ecosystems* 3:495–497.

Carpenter, S.R., J.J. Hodgson, J.F. Kitchell, M.L. Pace, D. Bade, et al. 2001. Trophic cascades, nutrients, and lake productivity: Whole-lake experiments. *Ecological Monographs* 71:163–186.

Carpenter, S.R. 2003. *Regime Shifts in Lake Ecosystems: Pattern and Variation*. International Ecology Institute, Lodendorf/Luhe, Germany.

Carpenter, S.R., E.M. Bennett, and G.D. Peterson. 2006. Scenarios for ecosystem services: An overview. *Ecology and Society* 11:http://www.ecologyandsociety.org/vol11/iss11/art29/.

Carpenter, S.R. and W.A. Brock. 2006. Rising variance: A leading indicator of ecological transition. *Ecology Letters* 9:308–315.

Carpenter, S.R. and C. Folke. 2006. Ecology for transformation. *Trends in Ecology & Evolution* 21:309–315.

Carpenter, S.R. and R. Biggs. 2009. Freshwaters: Managing across scales in space and time. Pages 197–220 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Carson, R. 1962. *Silent Spring*. Crest, New York.

Cerling, T.E. 1999. Paleorecords of C_4 plants and ecosystems. Pages 445–469 *in* R.F. Sage and R.K. Monson, editors. *C_4 Plant Biology*. Academic Press, San Diego.

Chabot, B.F. and D.J. Hicks. 1982. The ecology of leaf life spans. *Annual Review of Ecology and Systematics* 13:229–259.

Chadwick, O.A., L.A. Derry, P.M. Vitousek, B.J. Huebert, and L.O. Hedin. 1999. Changing sources of nutrients during 4 million years of soil and ecosystem development. *Nature* 397:491–497.

Chambers, J.Q., G.P. Asner, D.C. Morton, L.O. Anderson, S.S. Saatchi, et al. 2007. Regional ecosystem structure and function: Ecological insights from remote sensing of tropical forests. *Trends in Ecology & Evolution* 22:414–423.

Chambers, S. 1998. *Short- and Long-Term Effects of Clearing Native Vegetation for Agricultural Purposes*. PhD. Flinders University of South Australia, Adelaide, Australia.

Chambers, S. and F.S. Chapin, III. 2002. Fire effects on surface-atmosphere energy exchange in Alaskan black spruce ecosystems: Implications for feedbacks to regional climate. *Journal of Geophysical Research* 108:8145, doi:8110.1029/2001JD000530.

Chambers, S., J. Beringer, J. Randerson, and F.S. Chapin, III. 2005. Fire effects on net radiation and energy partitioning: Contrasting responses of tundra and boreal forest ecosystems. *Journal of Geophysical Research – Atmospheres* 110:D09106.

Chapin, F.S., III. 1980. The mineral nutrition of wild plants. *Annual Review of Ecology and Systematics* 11:233–260.

Chapin, F.S., III and G.R. Shaver. 1985. Individualistic growth response of tundra plant species to environmental manipulations in the field. *Ecology* 66:564–576.

Chapin, F.S., III, K. Van Cleve, and P.R. Tryon. 1986a. Relationship of ion absorption to growth rate in taiga trees. *Oecologia* 69:238–242.

Chapin, F.S., III, P.M. Vitousek, and K. Van Cleve. 1986b. The nature of nutrient limitation in plant communities. *American Naturalist* 127:48–58.

Chapin, F.S., III, N. Fetcher, K. Kielland, K.R. Everett, and A.E. Linkins. 1988. Productivity and nutrient cycling of Alaskan tundra: Enhancement by flowing soil water. *Ecology* 69:693–702.

Chapin, F.S., III. 1989. The cost of tundra plant structures: Evaluation of concepts and currencies. *American Naturalist* 133:1–19.

Chapin, F.S., III, E.-D. Schulze, and H.A. Mooney. 1990. The ecology and economics of storage in plants. *Annual Review of Ecology and Systematics* 21: 423–448.

Chapin, F.S., III. 1991a. Integrated responses of plants to stress. *BioScience* 41:29–36.

Chapin, F.S., III. 1991b. Effects of multiple environmental stresses on nutrient availability and use. Pages 67–88 *in* H.A. Mooney, W.E. Winner, and E.J. Pell, editors. *Response of Plants to Multiple Stresses*. Academic Press, San Diego.

Chapin, F.S., III and L. Moilanen. 1991. Nutritional controls over nitrogen and phosphorus resorption from Alaskan birch leaves. *Ecology* 72:709–715.

Chapin, F.S., III. 1993a. Physiological controls over plant establishment in primary succession. Pages 161–178 *in* J. Miles and D.W.H. Walton, editors. *Primary Succession*. Blackwell Scientific Publishers, Ltd., Oxford.

Chapin, F.S., III. 1993b. Functional role of growth forms in ecosystem and global processes. Pages 287–312 *in* J.R. Ehleringer and C.B. Field, editors. *Scaling Physiological Processes: Leaf to Globe*. Academic Press, San Diego.

Chapin, F.S., III, L. Moilanen, and K. Kielland. 1993. Preferential use of organic nitrogen for growth by a non-mycorrhizal arctic sedge. *Nature* 361:150–153.

Chapin, F.S., III, L.R. Walker, C.L. Fastie, and L.C. Sharman. 1994. Mechanisms of primary succession following deglaciation at Glacier Bay, Alaska. *Ecological Monographs* 64:149–175.

Chapin, F.S., III, G.R. Shaver, A.E. Giblin, K.G. Nadelhoffer, and J.A. Laundre. 1995. Response of arctic tundra to experimental and observed changes in climate. *Ecology* 76:694–711.

Chapin, F.S., III, M.S. Torn, and M. Tateno. 1996. Principles of ecosystem sustainability. *American Naturalist* 148:1016–1037.

Chapin, F.S., III, B.H. Walker, R.J. Hobbs, D.U. Hooper, J.H. Lawton, et al. 1997. Biotic control over the functioning of ecosystems. *Science* 277:500–504.

Chapin, F.S., III, W. Eugster, J.P. McFadden, A.H. Lynch, and D.A. Walker. 2000a. Summer differences among arctic ecosystems in regional climate forcing. *Journal of Climate* 13:2002–2010.

Chapin, F.S., III, E.S. Zavaleta, V.T. Eviner, R.L. Naylor, P.M. Vitousek, et al. 2000b. Consequences of changing biotic diversity. *Nature* 405:234–242.

Chapin, F.S., III, P.A. Matson, and H.A. Mooney. 2002. *Principles of Terrestrial Ecosystem Ecology*. Springer-Verlag, New York.

Chapin, F.S., III. 2003. Effects of plant traits on ecosystem and regional processes: A conceptual framework for predicting the consequences of global change. *Annals of Botany* 91:455–463.

Chapin, F.S., III and V.T. Eviner. 2004. Biogeochemistry of terrestrial net primary production. Pages 215–247 *in* W.H. Schlesinger, editor. *Treatise on Geochemistry*. Elsevier, Amsterdam.

Chapin, F.S., III, M. Sturm, M.C. Serreze, J.P. McFadden, J.R. Key, et al. 2005. Role of land-surface changes in arctic summer warming. *Science* 310:657–660.

Chapin, F.S., III, G.M. Woodwell, J.T. Randerson, G.M. Lovett, E.B. Rastetter, et al. 2006a. Reconciling carbon-cycle concepts, terminology, and methods. *Ecosystems* 9:1041–1050.

Chapin, F.S., III, J. Yarie, K. Van Cleve, and L.A. Viereck. 2006b. The conceptual basis of LTER studies in the Alaskan boreal forest. Pages 3–11 *in* F.S. Chapin, III, M.W. Oswood, K. Van Cleve, L.A. Viereck, and D.L. Verbyla, editors. *Alaska's Changing Boreal Forest*. Oxford University Press, New York.

Chapin, F.S., III, J.T. Randerson, A.D. McGuire, J.A. Foley, and C.B. Field. 2008. Changing feedbacks in the earth-climate system. *Frontiers in Ecology and the Environment* 6:313–320.

Chapin, F.S., III. 2009. Managing ecosystems sustainably: The key role of resilience. Pages 29–53 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Chapin, F.S., III, G.P. Kofinas, and C. Folke, editors. 2009. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Chapin, F.S., III, S.R. Carpenter, G.P. Kofinas, C. Folke, N. Abel, et al. 2010. Ecosystem stewardship: Sustainability strategies for a rapidly changing planet. *Trends in Ecology & Evolution* 25:241–249.

Charney, J.G., W.J. Quirk, S.-H. Chow, and J. Kornfield. 1977. A comparative study of effects of albedo change on drought in semiarid regions. *Journal of Atmospheric Sciences* 34:1366–1385.

Chase, T.N., R.A. Pielke, Sr., T.G.F. Kittel, R.R. Nemani, and S.W. Running. 2000. Simulated impacts of historical land cover changes on global climate in northern winter. *Climate Dynamics* 16:93–105.

Chazdon, R.L. and N. Fetcher. 1984. Photosynthetic light environments in a lowland rain forest in Costa Rica. *Journal of Ecology* 72:553–564.

Chazdon, R.L. and R.W. Pearcy. 1991. The importance of sunflecks for forest understory plants. *BioScience* 41:760–766.

Chen, J., J.F. Franklin, and T.A. Spies. 1995. Growing-season microclimatic gradients from clearcut edges into old-growth Douglas-fir forests. *Ecological Applications* 5:74–86.

Chen, Y.-H. and R.G. Prinn. 2006. Estimation of atmospheric methane emission between 1996–2001 using a 3-D global chemical transport model. *Journal of Geophysical Research – Atmospheres* 110:D10307, doi:10310.11029/12005JD006058.

Cheng, W., Q. Zhang, D.C. Coleman, C.R. Carroll, and C.A. Hoffman. 1996. Is available carbon limiting microbial respiration in the rhizosphere? *Soil Biology and Biochemistry* 28:1283–1288.

Cheng, W., D.W. Johnson, and S. Fu. 2003. Rhizosphere effects on decomposition. *Soil Science Society of America Journal* 67:1418–1427.

Cherry, K.A., M. Shepherd, P.J.A. Withers, and S.J. Mooney. 2008. Assessing the effectiveness of actions to mitigate nutrient loss from agriculture: A review of methods. *Science of the Total Environment* 406:1–23.

Chetkiewicz, C.-L.B., C.C. St. Clair, and M.S. Boyce. 2006. Corridors for conservation: integrating pattern and process. *Annual Review of Ecology, Evolution and Systematics* 37:317–342.

Chivers, M.R., M.R. Turetsky, J.M. Waddington, J.W. Harden, and A.D. McGuire. 2009. Effects of experimental water table and temperature manipulations on ecosystem CO_2 fluxes in an Alaskan boreal peatland. *Ecosystems* 12:1329–1342.

Choi, Y.D. 2007. Restoration ecology to the future: A call for a new paradigm. *Restoration Ecology* 15:351–353.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, et al. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. *Ecological Applications* 6:665–691.

Church, M. 2002. Geomorphic thresholds in riverine landscapes. *Freshwater Biology* 47:541–557.

Ciais, P., P.P. Tans, M. Trolier, J.W.C. White, and R.J. Francey. 1995. A large northern hemisphere terrestrial CO_2 sink indicated by the $^{13}C/^{12}C$ ratio of atmospheric CO_2. *Nature* 269:1098–1102.

Ciais, P., I. Janssens, A. Shvidenko, C. Wirth, Y. Malhi, et al. 2005a. The potential for rising CO_2 to account for the observed uptake of carbon by tropical, temperate and boreal forest biomes. Pages 109–150 *in* H. Griffith and P. Jarvis, editors. *The Carbon Balance of Forest Biomes*. Taylor and Francis, Milton Park, UK.

Ciais, P., M. Reichstein, N. Viovy, A. Granier, J. Ogée, et al. 2005b. Europe-wide reduction in primary productivity caused by heat and drought in 2003. *Nature* 437:529–533.

Ciais, P., A.V. Borges, G. Abril, M. Meybeck, G. Folberth, et al. 2008. The lateral carbon pump and the European carbon balance. Pages 341–360 *in* A.J. Dolman, R. Valentini, and A. Freibauer, editors. *The Continental-Scale Greenhouse Gas Balance of Europe*. Springer-Verlag, New York.

Clarholm, M. 1985. Interactions of bacteria, protozoa and plants leading to mineralization of soil nitrogen. *Soil Biology and Biochemistry* 17:181–187.

Clark, D.A., S. Brown, D.W. Kicklighter, J.Q. Chambers, J.R. Thomlinson, et al. 2001. Measuring net primary production in forests: Concepts and field methods. *Ecological Applications* 11:356–370.

Clark, W.C. and N.M. Dickson. 2003. Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences, USA* 100:8059–8061.

Clark, W.C. and L. Holliday. 2006. *Linking Knowledge with Action for Sustainable Development: The Role of Program Management*. National Academies Press, Washington.

Clarkson, D.T. 1985. Factors affecting mineral nutrient acquisition by plants. *Annual Review of Plant Physiology* 36:77–115.

Clay, K. 1990. Fungal endophytes of grasses. *Annual Review of Ecology and Systematics* 21:275–297.

Clein, J.S. and J.P. Schimel. 1994. Reduction in microbial activity in birch litter due to drying and rewetting events. *Soil Biology and Biochemistry* 26: 403–406.

Clein, J.S., B.L. Kwiatkowski, A.D. McGuire, J.E. Hobbie, E.B. Rastetter, et al. 2000. Modeling carbon responses of tundra ecosystems to historical and projected climate: A comparison of a plot- and a global-scale ecosystem model to identify process-based uncertainties. *Global Change Biology* 6(Suppl. 1): 127–140.

Clements, F.E. 1916. *Plant Succession: An Analysis of the Development of Vegetation*. Carnegie Institution of Washington Publication 242, Washington, D. C.

Cleveland, C.C. and D. Liptzin. 2007. C:N:P stoichiometry in soil: Is there a "Redfield ratio" for the microbial biomass? *Biogeochemistry* 85:235–252.

Codispoti, L.A. 2010. Interesting times for marine N_2O. *Science* 327:1339–1340.

Cody, M.L. and H.A. Mooney. 1978. Convergence versus nonconvergence in mediterranean-climate ecosystems. *Annual Review of Ecology and Systematics* 9:265–321.

Cohen, J.E. 1994. Marine and continental food webs: Three paradoxes. *Philosophical Transactions of the Royal Society of London, Series B* 343:57–69.

COHMAP. 1988. Climatic changes of the last 18,000 years: Observations and model simulations. *Science* 241:1043–1052.

Cole, J.J., N.F. Caracao, G.W. Kling, and T.K. Kratz. 1994. Carbon dioxide supersaturation in the surface waters of lakes. *Science* 265:1568–1570.

Cole, J.J., Y.T. Prairie, N.F. Caraco, W.H. McDowell, L.J. Tranvik, et al. 2007. Plumbing the global carbon cycle: Integrating inland waters into the terrestrial carbon budget. *Ecosystems* 10:171–184.

Coleman, D.C. 1994. The microbial loop concept as used in terrestrial soil ecology studies. *Microbial Ecology* 28:245–250.

Coleman, J. 1990. *Foundations of Social Theory*. Harvard University Press, Cambridge, MA.

Coley, P.D., J.P. Bryant, and F.S. Chapin, III. 1985. Resource availability and plant anti-herbivore defense. *Science* 230:895–899.

Coley, P.D. 1986. Costs and benefits of defense by tannins in a neotropical tree. *Oecologia* 70:238–241.

Comeleo, R.L., J.F. Paul, P.V. August, J. Copeland, C. Baker, et al. 1996. Relationships between watershed stressors and sediment contamination in Chesapeake Bay estuaries. *Landscape Ecology* 11:307–319.

Connell, J.H. and R.O. Slatyer. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. *American Naturalist* 111:1119–1114.

Cornelissen, J.H.C. 1996. An experimental comparison of leaf decomposition rates in a wide range of temperate

plant species and types. *Journal of Ecology* 84: 573–582.

Correll, D.L. 1997. Buffer zones and water quality protection: General principles.*in* N.E. Haycock, T.P. Burt, K.W.T. Goulding, and G. Pinay, editors. *Buffer Zones: Their Processes and Potential in Water Protection*. Quest Environmental, Harpenden.

Costa, M.H. and J.A. Foley. 1999. Trends in the hydrological cycle of the Amazon basin. *Journal of Geophysical Research* 104:14189–14198.

Costanza, R. and H. Daly. 1992. Natural capital and sustainable development. *Conservation Biology* 6:37–46.

Cottingham, K.L., B.L. Brown, and J.T. Lennon. 2001. Biodiversity may regulate the temporal variability of ecological processes. *Ecology Letters* 4:72–85.

Coûteaux, M.-M., P. Bottner, and B. Berg. 1995. Litter decomposition, climate and litter quality. *Trends in Ecology & Evolution* 10:63–66.

Cowles, H.C. 1899. The ecological relations of the vegetation on the sand dunes of Lake Michigan. *Botanical Gazette* 27:95–117.

Craine, J.M., D.A. Wedin, and F.S. Chapin, III. 1999. Predominance of ecophysiological over environmental controls over CO_2 flux in a Minnesota grassland. *Plant and Soil* 207:77–86.

Craine, J.M. and P.B. Reich. 2005. Leaf-level light compensation points are lower in shade-tolerant woody seedlings: Evidence from a synthesis of 115 species. *New Phytologist* 166:710–713.

Craine, J.M., C. Morrow, and W.D. Stock. 2008. Nutrient concentration ratios and co-limitation of aboveground production by nitrogen and phosphorus in Kruger National Park, South Africa. *New Phytologist* 179: 829–836.

Craine, J.M. 2009. *Resource Strategies of Wild Plants*. Princeton University Press, Princeton.

Cramer, W., A. Bondeau, F.I. Woodward, I.C. Prentice, R.A. Betts, et al. 2001. Global response of terrestrial ecosystem structure and function to CO_2 and climate change: Results from six dynamic global vegetation models. *Global Change Biology* 7:357–373.

Crews, T.E., K. Kitayama, J.H. Fownes, R.H. Riley, D.A. Herbert, et al. 1995. Changes in soil phosphorus fractions and ecosystem dynamics across a long chronosequence in Hawaii. *Ecology* 76:1407–1424.

Crocker, R.L. and J. Major. 1955. Soil development in relation to vegetation and surface age at Glacier Bay, Alaska. *Journal of Ecology* 43:427–448.

Croll, D.A., J.L. Maron, J.A. Estes, E.M. Danner, and G.V. Byrd. 2005. Introduced predators transform subarctic islands from grassland to tundra. *Science* 307:1959–1961.

Crowley, T.J. 1995. Ice-age terrestrial carbon changes revisited. *Global Biogeochemical Cycles* 9: 377–389.

Crutzen, P.J. 2002. Geology of mankind. *Nature* 415:23.

Cunningham, S.A., B. Summerhayes, and M. Westoby. 1999. Evolutionary divergences in leaf structure and chemistry, comparing rainfall and soil nutrient gradients. *Ecological Monographs* 69:569–588.

Currie, W.S., M.E. Harmon, I.C. Burke, S.C. Hart, W.J. Parton, et al. 2010. Cross-biome transplants of plant litter over a decade reveal both extension and limitation of the climate-litter quality paradigm. *Global Change Biology* 16:1744–1761.

Curtis, P.S. and X. Wang. 1998. A meta-analysis of elevated CO_2 effects on woody plant mass, form, and physiology. *Oecologia* 113:299–313.

Cyr, H. and M.L. Pace. 1993. Magnitude and patterns of herbivory in aquatic and terrestrial ecosystems. *Nature* 343:148–150.

D'Antonio, C.M. and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass-fire cycle, and global change. *Annual Review of Ecology and Systematics* 23:63–87.

Daily, G.C. 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington.

Daily, G.C., T. Soderqvist, S. Aniyar, K. Arrow, P. Dasgupta, et al. 2000. Ecology: The value of nature and the nature of value. *Science* 289:395–396.

Dale, V.H., S. Brown, R. Haeuber, N.T. Hobbs, N. Huntly, et al. 2000. Ecological principles and guidelines for managing the use of land. *Ecological Applications* 10:639–670.

Dasgupta, P. 2001. *Human Well-Being and the Natural Environment*. Oxford University Press, Oxford.

Davidson, E.A., P.A. Matson, P.M. Vitousek, R. Riley, K. Dunkin, et al. 1993. Process regulation of soil emissions of NO and N_2O in a seasonally dry tropical forest. *Ecology* 74:130–139.

Davidson, E.A., C.J.R. de Carvalho, I.C.G. Vieira, R.D. Figueiredo, P. Moutinho, et al. 2004. Nitrogen and phosphorus limitation of biomass growth in a tropical secondary forest. *Ecological Applications* 14: 150–163.

Davidson, E.A. and I.A. Janssens. 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature* 440:165–173.

Davies, W.J. and J. Zhang. 1991. Root signals and the regulation of growth and development of plants in drying soil. *Annual Review of Plant Physiology and Molecular Biology* 42:55–76.

Davis, M.B., R.R. Calcote, S. Sugita, and H. Takahara. 1998. Patchy invasion and the origin of a hemlock-hardwood forest mosaic. *Ecology* 79:2641–2659.

Davis, S.M. and J.C. Ogden, editors. 1994. *Everglades: The Ecosystem and Its Restoration*. St Lucie, Delray Beach, Florida.

Dawson, T.E. 1993. Water sources of plants as determined from xylem-water isotopic composition: Perspectives on plant competition, distribution, and water relations. Pages 465–496 *in* J.R. Ehleringer, A.E. Hall, and G.D. Farquhar, editors. *Stable Isotopes and Plant Carbon-Water Relations*. Academic Press, San Diego.

Dawson, T.E. and T.W. Siegwolf. 2007. *Stable Isotopes as Indicators of Ecological Change*. Academic Press-Elsevier, San Diego.

De Deyn, G.B., J.H.C. Cornelissen, and R.D. Bardgett. 2008. Plant functional traits and soil carbon sequestration in contrasting biomes. *Ecology Letters* 11:516–531.

de Vries, W., S. Solberg, M. Dobbertin, H. Sterba, D. Laubhann, et al. 2009. The impact of nitrogen deposition on carbon sequestration by European forests and heathlands. *Forest Ecology and Management* 258:1814–1823.

Dean, W.E. and E. Gorham. 1998. Magnitude and significance of carbon burial in lakes, reservoirs, and peatlands. *Geology* 26:535–538.

DeAngelis, D.L. and W.M. Post. 1991. Positive feedback and ecosystem organization. Pages 155–178 *in* M. Higashi and T.P. Burns, editors. *Theoretical Studies of Ecosystems: The Network Perspective*. Cambridge University Press, Cambridge.

DeAngelis, D.L., L.J. Gross, M.A. Huston, W.F. Wolff, D.M. Fleming, et al. 1998. Landscape modeling for Everglades ecosystem restoration. *Ecosystems* 1:64–75.

Del Grosso, S.J., W.J. Parton, A.R. Mosier, D.S. Ojima, A.E. Kulmala, et al. 2000. General model for N_2O and N_2 gas emissions from soils due to denitrification. *Global Biogeochemical Cycles* 14:1045–1060.

Delmas, R., C. Jambert, and Serga. 1997. Global inventory of NO_x sources. *Nutrient Cycling in Agroecosystems* 48:51–60.

Demming-Adams, B. and W.W. Adams. 1996. The role of xanthophyll cycle carotenoids in the protection of photosynthesis. *Trends in Plant Sciences* 1:21–26.

Detling, J.K., D.T. Winn, C. Procter-Gregg, and E.L. Painter. 1980. Effects of simulated grazing by belowground herbivores on growth, CO_2 exchange, and carbon allocation patterns of *Bouteloua gracilis*. *Journal of Applied Ecology* 17:771–778.

Detling, J.K. 1988. Grasslands and savannas: Regulation of energy flow and nutrient cycling by herbivores. Pages 131–148 *in* L.R. Pomeroy and J.J. Alberts, editors. *Concepts of Ecosystem Ecology*. Springer-Verlag, New York.

Díaz, R.J. and R. Rosenberg. 2008. Spreading dead zones and consequences for marine ecosystems. *Science* 321:926–929.

Díaz, S. and M. Cabido. 2001. Vive la différence: Plant functional diversity matters to ecosystem processes. *Trends in Ecology & Evolution* 16:646–655.

Díaz, S., J. Fargione, F.S. Chapin, III, and D. Tilman. 2006. Biodiversity loss threatens human well-being. *Plant Library of Science (PLoS)* 4:1300–1305.

Diener, E. and M.E.P. Seligman. 2004. Beyond money: Toward an economy of well-being. *Psychological Science in the Public Interest* 5:1–31.

Dietrich, W.E. and J.T. Perron. 2006. The search for a topographic signature of life. *Nature* 439:411–418.

Dietz, T., E. Ostrom, and P.C. Stern. 2003. The struggle to govern the commons. *Science* 302:1907–1912.

Dijkstra, F.A., J.B. West, S.E. Hobbie, and P.B. Reich. 2009. Antagonistic effects of species on C respiration and net N mineralization in soils from mixed coniferous plantations. *Forest Ecology and Management* 257:1112–1118.

Dimitrakopoulos, P.G. and B. Schmid. 2004. Biodiversity effects increase linearly with biotope space. *Ecology Letters* 7:574–583.

Dingman, S.L. 2001. *Physical Hydrology*. 2nd edition. Prentice Hall, Upper Saddle River, NJ.

Dirzo, R. and A. Miranda. 1991. Altered patterns of herbivory and diversity in the forest understory: A case study of the possible consequences of contemporary defaunation. Pages 273–287 *in* P.W. Price, T.M. Lewinsohn, G.W. Fernandes, and W.W. Benson, editors. *Plant-Animal Interactions: Evolutionary Ecology in Tropical and Temperate Regions*. Wiley, New York.

Dobson, A.P., A.D. Bradshaw, and A.J.M. Baker. 1997. Hopes for the future: Restoration ecology and conservation biology. *Science* 277:515–522.

Dokuchaev, V.V. 1879. Abridged historical account and critical examination of the principal soil classifications existing. *Transactions of the Petersburg Society of Naturalists* 1:64–67.

Doney, S.C., V.J. Fabry, R.A. Feely, and J.A. Kleypas. 2009. Ocean acidification: The other CO_2 problem. *Annual Review of Marine Science* 1:169–192.

Downing, J.A. and E. McCauley. 1992. The nitrogen: phosphorus relationship in lakes. *Limnology and Oceanography* 37:936–945.

Downing, J.A., Y.T. Prairie, J.J. Cole, C.M. Duarte, L.J. Tranvik, et al. 2006. The global abundance and size distribution of lakes, ponds, and impoundments. *Limnology and Oceanography* 51:2388–2397.

Drake, B.G., G. Peresta, E. Beugeling, and R. Matamala. 1996. Long-term elevated CO_2 exposure in a Chesapeake Bay wetland: Ecosystem gas exchange, primary production, and tissue nitrogen. Pages 197–214 *in* G.W. Koch and H.A. Mooney, editors. *Carbon Dioxide and Terrestrial Ecosystems*. Academic Press, San Diego.

Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, et al. 2001. Acidic deposition in the northeastern United States: Sources and inputs, ecosystem effects and management strategies. *BioScience* 51:180–198.

Driscoll, C.T., D. Whitall, J. Aber, E. Boyer, M. Castro, et al. 2003. Nitrogen pollution in the northeastern United States: Sources, effects, and management opitons. *BioScience* 53:357–374.

Dugdale, R.C. and J.J. Goering. 1967. Uptake of new and regenerated forms of nitrogen in primary productivity. *Limnology and Oceanography* 12:196–206.

Dugdale, R.C. 1976. Nutrient cycles. Pages 141–172 *in* D.H. Cushing and J.J. Walsh, editors. *The Ecology of the Seas*. W. B. Saunders, Philadelphia.

Dugdale, R.C., F.P. Wilkerson, and H.J. Minas. 1995. The role of a silicate pump in driving new production. *Deep Sea Research (Part I, Oceanographic Research Papers)* 42:697–719.

Dunne, T., L.A.K. Mertes, R.H. Meade, J.E. Richey, and B.R. Forsberg. 1998. Exchanges of sediment between the flood plain and channel of the Amazon River in Brazil. *Geological Society of America Bulletin* 110:450–467.

Easterlin, R.A. 2001. Income and happiness: Towards a unified theory. *The Economic Journal* 111:465–484.

Edwards, E.J. and S.A. Smith. 2010. Phylogenetic analyses reveal the shady history of C_4 grasses. *Proceedings of the National Academy of Sciences, USA* 107: 2532–2537.

Egler, F.E. 1954. Vegetation science concepts. I. Initial floristic composition, a factor in old-field vegetation development. *Vegetatio* 4:414–417.

Ehleringer, J.R. and H.A. Mooney. 1978. Leaf hairs: Effects on physiological activity and adaptive value to a desert shrub. *Oecologia* 37:183–200.

Ehleringer, J.R. and C.B. Osmond. 1989. Stable isotopes. Pages 281–300 *in* R.W. Pearcy, J. Ehleringer, H.A. Mooney, and P.W. Rundel, editors. *Plant Physiological Ecology: Field Methods and Instrumentation*. Chapman and Hall, London.

Ehleringer, J.R. 1993. Carbon and water relations in desert plants: An isotopic perspective. Pages 155–172 *in* J.R. Ehleringer, A.E. Hall, and G.D. Farquhar, editors. *Stable Isotopes and Plant Carbon-Water Relations*. Academic Press, San Diego.

Ehleringer, J.R. and C.B. Field, editors. 1993. *Scaling Physiological Processes: Leaf to Globe*. Academic Press, San Diego.

Ehleringer, J.R., A.E. Hall, and G.D. Farquhar, editors. 1993. *Stable Isotopes and Plant Carbon-Water Relations*. Academic Press, San Diego.

Ehleringer, J.R., N. Buchmann, and L.B. Flanagan. 2000. Carbon isotope ratios in belowground carbon cycle processes. *Ecological Applications* 10:412–422.

Ellenberg, H. 1978. *Vegetation von Mittleuropa*. Eugen Ulmer, Stuttgart.

Ellenberg, H. 1979. Man's influence on tropical mountain ecosystems in South-America: 2nd Tansley lecture. *Journal of Ecology* 67:401–416.

Ellis, E.C. and N. Ramankutty. 2008. Putting people on the map: Anthropogenic biomes of the world. *Frontiers in Ecology and the Environment* 6:439–447.

Elmqvist, T., C. Folke, M. Nyström, G. Peterson, J. Bengtsson, et al. 2003. Response diversity, ecosystem change, and resilience. *Frontiers in Ecology and the Environment* 1:488–494.

Elser, J.J., W.F. Fagan, R.F. Denno, D.R. Dobberfuhl, A. Folarin, et al. 2000. Nutritional constraints in terrestrial and freshwater food webs. *Nature* 408:578–580.

Elser, J.J., M.E.S. Bracken, E. Cleland, D.S. Gruner, W.S. Harpole, et al. 2007. Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. *Ecology Letters* 10:1135–1142.

Elton, C.S. 1927. *Animal Ecology*. Macmillan, New York.

Enquist, B.J., A.J. Kerkhoff, S.C. Stark, N.G. Swenson, M.C. McCarthy, et al. 2007. A general integrative model for scaling plant growth, carbon flux, and functional trait spectra. *Nature* 449:218–222.

Enríquez, S., C.M. Duarte, and K. Sand-Jensen. 1993. Patterns in decomposition rates among photosynthetic organisms: The importance of detritus C:N:P content. *Oecologia* 94:457–471.

Erisman, J.W., A. Bleeker, A. Hensen, and A. Vermeulen. 2008. Agricultural air quality in Europe and the future perspective. *Atmospheric Environment* 42: 3209–3217.

Estes, J.A. and J.F. Palmisano. 1974. Sea otters: Their role in structuring nearshore communities. *Science* 185: 1058–1060.

Estes, J.A., M.T. Tinker, T.M. Williams, and D.F. Doak. 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. *Science* 282: 473–476.

Eugster, W., W.R. Rouse, R.A. Pielke, J.P. McFadden, D.D. Baldocchi, et al. 2000. Land-atmosphere energy exchange in arctic tundra and boreal forest: Available data and feedbacks to climate. *Global Change Biology* 6 (Suppl. 1):84–115.

Euskirchen, E.S., A.D. McGuire, D.W. Kicklighter, Q. Zhuang, J.S. Clein, et al. 2006. Importance of recent shifts in soil thermal dynamics on growing season length, productivity, and carbon sequestration in terrestrial high-latitude ecosystems. *Global Change Biology* 12:731–750.

Euskirchen, E.S., A.D. McGuire, and F.S. Chapin, III. 2007. Energy feedbacks to the climate system due to reduced high latitude snow cover during 20th century warming. *Global Change Biology* 13: 2425–2438.

Euskirchen, E.S., A.D. McGuire, F.S. Chapin, III, S. Yi, and C.C. Thompson. 2009. Changes in vegetation in northern Alaska under scenarios of climate change, 2003–2100: Implications for climate feedbacks. *Ecological Applications* 19:1022–1043.

Evans, J.R. 1989. Photosynthesis and nitrogen relationships in leaves of C_3 plants. *Oecologia* 78:9–19.

Evans, L.T. 1980. The natural history of crop yield. *American Scientist* 68:388–397.

Eviner, V.T. and F.S. Chapin, III. 2001. Plant species provide vital ecosystem functions for sustainable agriculture, rangeland management and restoration. *California Agriculture* 55:54–59.

Eviner, V.T. and F.S. Chapin, III. 2003. Functional matrix: A conceptual framework for predicting multiple plant effects on ecosystem processes. *Annual Review of Ecology and Systematics* 34:455–485.

Eviner, V.T. and F.S. Chapin, III. 2005. Selective gopher disturbance influences plant species effects on nitrogen cycling. *Oikos* 109:154–166.

Eviner, V.T. and C.V. Hawkes. 2008. Embracing variability in the application of plant-soil interactions to the restoration of communities and ecosystems. *Restoration Ecology* 16:713–729.

Ewel, J.J. 1986. Designing agricultural ecosystems for the humid tropics. *Annual Review of Ecology and Systematics* 17:245–271.

Ewing, H.A., K.C. Weathers, P.H. Templer, T.E. Dawson, M.K. Firestone, et al. 2009. Fog water and ecosystem function: Heterogeneity in a California redwood forest. *Ecosystems* 12:417–433.

Fahey, T., C. Bledsoe, R. Day, R. Ruess, and A. Smucker. 1998. *Fine Root Production and Demography*. CRC Press, Boca Raton, FL.

Fahey, T.J., T.G. Siccama, C.T. Driscoll, G.E. Likens, J.L. Campbell, et al. 2005. The biogeochemistry of carbon at Hubbard Brook. *Biogeochemistry* 75:109–176.

Fahrig, L. and G. Merriam. 1985. Habitat patch connectivity and population survival. *Ecology* 66:1762–1768.

Falkenmark, M. and J. Rockström. 2004. *Balancing Water for Humans and Nature: The New Approach in Ecohydrology*. Earthscan, London.

Falkowski, P.G., R.T. Barber, and V. Smetacek. 1998. Biogeochemical controls and feedbacks on ocean primary production. *Science* 281:200–206.

Falkowski, P.G. 2000. Rationalizing elemental ratios in unicellular algae. *Journal of Phycology* 36:3–6.

Falkowski, P.G., R.J. Scholes, E. Boyle, J. Canadell, D. Canfield, et al. 2000. The global carbon cycle: A test of our knowlege of Earth as a system. *Science* 290:291–296.

Fan, S., M. Gloor, J. Mahlman, S. Pacala, J. Sarmiento, et al. 1998. A large terrestrial carbon sink in North America implied by atmospheric and oceanic carbon dioxide data and models. *Science* 282:442–446.

Fargione, J. and D. Tilman. 2005. Niche differences in phenology and rooting depth promote coexistence with a dominant C_4 bunchgrass *Oecologia* 143:598–606.

Farquhar, G.D. and T.D. Sharkey. 1982. Stomatal conductance and photosynthesis. *Annual Review of Plant Physiology* 33:317–345.

Fastie, C.L. 1995. Causes and ecosystem consequences of multiple pathways of primary succession at Glacier Bay, Alaska. *Ecology* 76:1899–1916.

Fasullo, J.T. and K.E. Trenberth. 2008. The annual cycle of the energy budget. Part II: Meridional structures and poleward transport. *Journal of Climate* 21:2313–2325.

Federov, A.V. and S.G. Philander. 2000. Is El Niño changing? *Science* 288:1997–2002.

Feely, R.A., C.L. Sabine, K. Lee, W. Berelson, J. Kleyas, et al. 2004. Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. *Science* 305:362–366.

Feeny, P.P. 1970. Seasonal changes in oak leaf tannins and nutrients as cause of spring feeding by winter moth caterpillars. *Ecology* 51:565–581.

Fenchel, T. 1994. Microbial ecology on land and sea. *Philosophical Transactions of the Royal Society of London, Series B* 343:51–56.

Feng, Z., R. Liu, D.L. DeAngelis, J.P. Bryant, K. Kielland, et al. 2009. Plant toxicity, adaptive herbivory, and plant community dynamics. *Ecosystems* 12:534–547.

Fenn, M.E., M.A. Poth, J.D. Aber, J.S. Baron, B.T. Bormann, et al. 1998. Nitrogen excess in North American ecosystems: Predisposing factors, ecosystem responses and management strategies. *Ecological Applications* 8:706–733.

Fenner, M. 1985. *Seed Ecology*. Chapman and Hall, London.

Field, C. 1983. Allocating leaf nitrogen for the maximization of carbon gain: Leaf age as a control on the allocation program. *Oecologia* 56:341–347.

Field, C. and H.A. Mooney. 1986. The photosynthesis-nitrogen relationship in wild plants. Pages 25–55 *in* T.J. Givnish, editor. *On the Economy of Plant Form and Function*. Cambridge University Press, Cambridge.

Field, C., F.S. Chapin, III, P.A. Matson, and H.A. Mooney. 1992. Responses of terrestrial ecosystems to the changing atmosphere: A resource-based approach. *Annual Review of Ecology and Systematics* 23:201–235.

Field, C.B. 1991. Ecological scaling of carbon gain to stress and resource availability. Pages 35–65 *in* H.A. Mooney, W.E. Winner, and E.J. Pell, editors. *Integrated Responses of Plants to Stress*. Academic Press, San Diego.

Field, C.B., D.B. Lobell, H.A. Peters, and N.R. Chiariello. 2007. Feedbacks of terrestrial ecosystems to climate change. *Annual Review of Environment and Resources* 32:1–29.

Fierer, N., J.M. Craine, K. McLauchghan, and J.P. Schimel. 2005. Litter quality and the temperature sensitivity of decomposition. *Ecology* 86:320–326.

Fierer, N., M. Breitbart, J. Nulton, P. Salamon, C. Lozupone, et al. 2007. Metagenomic and small-subunit rRNA analyses reveal the genetic diversity of bacteria, Archaea, fungi, and viruses in soil. *Applied & Environmental Microbiology* 73:7059–7066.

Fierer, N., A.S. Grandy, J. Six, and E.A. Paul. 2009a. Searching for unifying principles in soil ecology. *Soil Biology and Biochemistry* 41:2249–2256.

Fierer, N., M.S. Strickland, D. Liptzin, M.A. Bradford, and C.C. Cleveland. 2009b. Global patterns in belowground communities. *Ecology Letters* 12: 1238–1249.

Findlay, S.E.G., J.L. Tank, S. Dye, H.M. Valett, P.J. Mulholland, et al. 2002. A cross-system comparison of bacterial and fungal biomass in detritus pools of headwater streams. *Microbial Ecology* 43:55–66.

Finlay, J.C., S. Khandwala, and M.E. Power. 2002. Spatial scales of carbon flow in a river food web. *Ecology* 83:1845–1859.

Finlay, J.C. 2011. Stream size and human influences on ecosystem production in river networks. Ecosphere 2(7):artXX. doi:10.1890/ES11-00071.1.

Finlay, R.D. 2008. Ecological aspects of mycorrhizal symbiosis: With special emphasis on the functional diversity of interactions involving the extraradical mycelium. *Journal of Experimental Botany* 59:1115–1126.

Firestone, M.K. and E.A. Davidson. 1989. Microbiological basis of NO and N_2O production and consumption in soil. Pages 7–21 *in* M.O. Andreae and D.S. Schimel, editors. *Exchange of Trace Gases Between Terrestrial Ecosystems and the Atmosphere*. John Wiley and Sons, Ltd., New York.

Fisher, R.F. and D. Binkley. 2000. *Ecology and Management of Forest Soils*. 3rd edition. John Wiley & Sons, Inc., New York.

Fisher, S.G., L.J. Gray, N.B. Grimm, and D.E. Busch. 1982. Temporal succession in a desert stream ecosystem following flash flooding. *Ecological Monographs* 52:92–110.

Fisher, S.G., N.B. Grimm, E. Martí, R.M. Holmes, and J.B. Jones, Jr. 1998. Material spiraling in stream corridors: A telescoping ecosystem model. *Ecosystems* 1:19–34.

Flanagan, P.W. and A.K. Veum. 1974. Relationships between respiration, weight loss, temperature, and

moisture in organic residues on tundra. Pages 249–277 *in* A.J. Holding, O.W. Heal, S.F. Maclean, Jr., and P.W. Flanagan, editors. *Soil Organisms and Decomposition in Tundra*. Tundra Biome Steering Committee, Stockholm.

Flanagan, P.W. and K. Van Cleve. 1983. Nutrient cycling in relation to decomposition and organic matter quality in taiga ecosystems. *Canadian Journal of Forest Research* 13:795–817.

Flannery, T.F. 1994. *The Future Eaters*. Reed Books, Victoria.

Flynn, K.J. 2003. Do we need complex mechanistic phytoacclimation models for phytoplankton? *Limnology and Oceanography* 48:2243–2249.

Fog, K. 1988. The effect of added nitrogen on the rate of decomposition of organic matter. *Biological Review* 63:433–462.

Foley, J.A., J.E. Kutzbach, M.T. Coe, and S. Levis. 1994. Feedbacks between climate and boreal forests during the Holocene epoch. *Nature* 371:52–54.

Foley, J.A., I.C. Prentice, N. Ramankutty, S. Levis, D. Pollard, et al. 1996. An integrated biosphere model of land surface processes, terrestrial carbon balance, and vegetation dynamics. *Global Biogeochemical Cycles* 10:603–628.

Foley, J.A., M.T. Coe, M. Scheffer, and G. Wang. 2003a. Regime shifts in the Sahara and Sahel: Interactions between ecological and climatic systems in Northern Africa. *Ecosystems* 6:524–539.

Foley, J.A., M.H. Costa, C. Delire, N. Ramankutty, and P. Snyder. 2003b. Green surprise? How terrestrial ecosystems could affect earth's climate. *Frontiers of Ecology and the Environment* 1:38–44.

Foley, J.A., R. DeFries, G.P. Asner, C. Barford, G. Bonan, et al. 2005. Global consequences of land use. *Science* 309:570–574.

Folke, C., M. Hammer, R. Costanza, and A. Jansson. 1994. Investing in natural capital: Why, what, and how? Pages 1–20 *in* A. Jansson, M. Hammer, C. Folke, and R. Costanza, editors. *Investing in Natural Capital*. Island Press, Washington.

Folland, C.K., T.R. Karl, J.R. Christy, R.A. Clarke, G.V. Gruza, et al. 2001. Observed climate variability and change. Pages 99–181 *in* J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, et al., editors. *Climate Change 2001: The Scientific Basis*. Cambridge University Press, Cambridge.

Forman, R.T.T. 1995. *Land Mosaics: The Ecology of Landscapes and Regions*. Cambridge University Press, Cambridge.

Fornara, D.A. and D. Tilman. 2008. Plant functional composition influences rates of soil carbon and nitrogen accumulation. *Journal of Ecology* 96:314–322.

Foster, D.R. 1988. Disturbance history, community organization and vegetation dynamics of the old-growth Pisgah Forest, southwestern New Hampshire. *Journal of Ecology* 76:105–134.

Foster, D.R., D.A. Orwig, and J.S. McLachlan. 1996. Ecological and conservation insights from reconstructive studies of temperate old-growth forests. *Trends in Ecology & Evolution* 11:419–424.

Foster, D.R., B. Donahue, D. Kittredge, K.F. Lambert, M. Hunter, et al. 2010. *Wildlands and Woodlands: A Vision for the New England Landscape*. Harvard University, Petersham, MA.

Francis, R.C. 1990. Fisheries science and modeling: A look to the future. *Natural Resource Modeling* 4:1–10.

Frank, D.A. 2006. Large herbivores in heterogeneous grassland ecosystems. Pages 326–347 *in* K. Danell, R. Bergström, P. Duncan, and J. Pastor, editors. *Large Mammalian Herbivores, Ecosystem Dynamics, and Conservation*. Cambridge University Press, Cambridge.

Frank, D.A. 2008. Ungulate and topographic control of nitrogen:phosphorus stoichiometry in a temperate grassland: Soils, plants and mineralization rates. *Oikos* 117:591–601.

Frank, D.A., T. Depriest, K. McLauchlan, and A. Risch. 2011. Topographic and ungulate regulation of soil C turnover in a temperate trassland ecosystem. *Global Change Biology* 17:495–504.

Franklin, J.F., D.R. Berg, D.A. Thornburgh, and J.C. Tappeiner. 1997. Alternative silvicultural approaches to timber harvesting: Variable retention harvest systems. Pages 111–140 *in* K.A. Kohm and J.F. Franklin, editors. *Creating a Forestry for the 21st Century: The Science of Ecosystem Management*. Island Press, Washington.

Freemark, K.E. and H.G. Merriam. 1986. Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. *Biological Conservation* 31:95–105.

Frelich, L.E. and P.B. Reich. 2009. Will environmental change reinforce the impact of global warming on the prairie-forest border of central North America? *Frontiers in Ecology and the Environment*.

Freschet, G.T., J.H.C. Cornelissen, R.S.P. van Longtestijn, and R. Aerts. 2010. Evidence of the 'plant economics spectrum' in a subarctic flora. *Journal of Ecology* 98:362–373.

Fretwell, S.D. 1977. The regulation of plant communities by food chains exploiting them. *Perspectives in Biology and Medicine* 20:169–185.

Friedl, G. and A. Wüest. 2002. Disrupting biogeochemical cycles: Consequences of damming. *Aquatic Sciences* 64:55–65.

Frost, T.M., S.R. Carpenter, A.R. Ives, and T.K. Kratz. 1995. Species compensation and complementarity in ecosystem function. Pages 224–239 *in* C.G. Jones and J.H. Lawton, editors. *Linking Species and Ecosystems*. Chapman and Hall, New York.

Fung, I.Y., C.J. Tucker, and K.C. Prentice. 1987. Application of advanced very high resolution radiometer vegetation index to study atmosphere-biosphere exchange of CO_2. *Journal of Geophysical Research* 92D:2999–3015.

Gabriel, H.W. and G.F. Tande. 1983. *A Regional Approach to Fire History in Alaska*. BLM-Alaska Technical Report 9, U.S.D.I. Bureau of Land Management.

Galloway, J.N., W.H. Schlesinger, H. Levy, II, A. Michaels, and J.L. Schnoor. 1995. Nitrogen fixation: Anthropogenic enhancement-environmental response. *Global Biogeochemical Cycles* 9:235–252.

Galloway, J.N. 1996. Anthropogenic mobilization of sulfur and nitrogen: Immediate and delayed consequences. *Annual Review of Energy in the Environment* 21:261–292.

Galloway, J.N., J.D. Aber, J.W. Erisman, S.P. Seitzinger, R.W. Howarth, et al. 2003. The nitrogen cascade. *BioScience* 53:341–356.

Galloway, J.N., F.J. Dentener, D.G. Capone, E.W. Boyer, R.W. Howarth, et al. 2004. Nitrogen cycles: Past, present, and future. *Biogeochemistry* 70:153–226.

Gardner, R.H., B.T. Milne, M.G. Turner, and R.V. O'Neil. 1987. Neutral models for the analysis of broad-scale landscape pattern. *Landscape Ecology* 1:19–28.

Gardner, W.R. 1983. Soil properties and efficient water use: An overview. Pages 45–64 *in* H.M. Taylor, W.R. Jordan, and T.R. Sinclair, editors. *Limitations to Efficient Water Use in Crop Production*. American Society of Agronomy, Madison.

Garnier, E. 1991. Resource capture, biomass allocation and growth in herbaceous plants. *Trends in Ecology & Evolution* 6:126–131.

Gartner, T.B. and Z.G. Cardon. 2004. Decomposition dynamics in mixed-species leaf litter. *Oikos* 104:230–246.

Gessner, M.O., C.M. Swan, C.K. Dang, B.G. McKie, R.D. Bardgett, et al. 2010. Diversity meets decomposition. *Trends in Ecology & Evolution* 25:325–331.

Gholz, H.L., D.A. Wedin, S.M. Smitherman, M.E. Harmon, and W.J. Parton. 2000. Long-term dynamics of pine and hardwood litter in contrasting environments: Toward a global model of decomposition. *Global Change Biology* 6:751–765.

Gilichinsky, D., T. Vishnivetskaya, M. Petrova, E. Spirina, V. Mamykin, et al. 2008. Bacteria in permafrost. Pages 83–102 *in* R. Margesin, F. Schinner, J.-C. Marx, and C. Gerday, editors. *Psychrophiles: From Biodiversity to Biotechnology*. Springer-Verlag, Berlin.

Gill, J.L., J.W. Williams, S.T. Jackson, K.B. Lininger, and G.S. Robinson. 2009. Pleistocene megafaunal collapse, novel plant communities, and enhanced fire regimes in North America. *Science* 326: 1100–1103.

Giller, P.S. and B. Malmqvist. 1998. *The Biology of Streams and Rivers*. Oxford University Press, Oxford.

Gilliam, F.S., T.R. Seastedt, and A.K. Knapp. 1987. Canopy rainfall interception and throughfall in burned and unburned tallgrass prairie. *Southwestern Naturalist* 32:267–271.

Ginn, W.J. 2005. *Investing in Nature: Case Studies of Land Conservation in Collaboration with Business*. Island Press, Washington.

Gleason, H.A. 1926. The individualistic concept of the plant association. *Bulletin of the Torrey Botanical Club* 53:7–26.

Gleick, P.H. 1998. *The World's Water 1998–1999. The Biennial Report on Freshwater Resources*. Island Press, Washington.

Goetz, S.J., A.G. Bunn, G.A. Fiske, and R.A. Houghton. 2005. Satellite-observed photosynthetic trends across boreal North America associated with climate and fire disturbance. *Proceedings of the National Academy of Sciences, USA* 102:13521–13525.

Gollan, T., N.C. Turner, and E.D. Schulze. 1985. The responses of stomata and leaf gas exchange to vapor pressure deficits and soil water content. III. In the sclerophyllous woody species *Nerium oleander*. *Oecologia* 65:356–362.

Golley, F. 1961. Energy values of ecological materials. *Ecology* 42:581–584.

Golley, F.B. 1993. *A History of the Ecosystem Concept in Ecology: More than the Sum of the Parts*. Yale University Press, New Haven.

Goode, J.G., R.J. Yokelson, D.E. Ward, R.A. Susott, R.E. Babbitt, et al. 2000. Measurements of excess O_3, CO_2, CO, CH_4, C_2H_4, C_2H_2, HCN, NO, NH_3, HCOOH, CH_3COOH, HCHO, and CH_3OH in 1997 Alaskan biomass burning plumes by airborne Fourier transform infrared spectroscopy (AFTIR). *Journal of Geophysical Research* 105:22147–22166.

Gorham, E. 1991. Biogeochemistry: Its origins and development. *Biogeochemistry* 13:199–239.

Gosz, J.R. 1991. Fundamental ecological characteristics of landscape boundaries. Pages 8–30 *in* M.M. Holland, P.G. Risser, and R.J. Naiman, editors. *Ecotones: The Role of Landscape Boundaries in the Management and Restoration of Changing Environments*. Chapman and Hall, New York.

Goulden, M.L., J.W. Munger, S.-M. Fan, B.C. Daube, and S.C. Wofsy. 1996. CO_2 exchange by a deciduous forest: Response to interannual climate variability. *Science* 271:1576–1578.

Goulder, L.H. and D. Kennedy. 1997. Valuing ecosystem services: Philosophical bases and empirical methods. Pages 23–48 *in* G.C. Daily, editor. *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, D. C.

Gower, S.T., C.J. Kucharik, and J.M. Norman. 1999. Direct and indirect estimation of leaf area index, f(APAR), and net primary production of terrestrial ecosystems. *Remote Sensing of the Environment* 70:29–51.

Gower, S.T. 2002. Productivity of terrestrial ecosystems. Pages 516–521 *in* H.A. Mooney and J. Canadell, editors. *Encyclopedia of Global Change*. Blackwell Scientific, Oxford.

Graedel, T.E. and P.J. Crutzen. 1995. *Atmosphere, Climate, and Change*. Scientific American Library, New York.

Graetz, R.D. 1991. The nature and significance of the feedback of change in terrestrial vegetation on global atmospheric and climatic change. *Climatic Change* 18:147–173.

Graham, R.T. 2003. *Hayman Fire Case Study. General Technical Report RMRS-GTR-114*. U.S. Forest Service. Rocky Mountain Research Station, Ogden, UT.

Green, M.B. and J.C. Finlay. 2010. Patterns of hydrologic control over stream water total nitrogen to phosphorus ratios. *Biogeochemistry* 99:15–30.

Grigulis, K., S. Lavorel, I.D. Davies, A. Dossantos, F. Lloret, et al. 2005. Landscape-scale positive feedbacks

between fire and expansion of the large tussock grass, *Ampelodesmos mauritanica*, in Catalan shrublands. *Global Change Biology* 11:1042–1053.

Grim, R.E. 1968. *Clay Mineralogy*. McGraw-Hill, New York.

Grime, J.P. and R. Hunt. 1975. Relative growth rate: Its range and adaptive significance in a local flora. *Journal of Ecology* 63:393–422.

Grime, J.P., G. Mason, A.V. Curtis, J. Rodman, S.R. Band, et al. 1981. A comparative study of germination characteristics in a local flora. *Journal of Ecology* 69:1017–1059.

Grime, J.P. 1998. Benefits of plant diversity to ecosystems: Immediate, filter and founder effects. *Journal of Ecology* 86:902–910.

Grime, J.P., V.K. Brown, K. Thompson, G.J. Masters, S.H. Hillier, et al. 2000. The response of two contrasting limestone grasslands to simulated climate change. *Science* 289:762–765.

Grime, J.P. 2001. *Plant Strategies, Vegetation Processes, and Ecosystem Properties*. John Wiley & Sons, Chichester, UK.

Grime, J.P., J.D. Fridley, A.P. Askew, K. Thompson, J.G. Hodgson, et al. 2008. Long-term resistance to simulated climate change in an infertile grassland. *Proceedings of the National Academy of Sciences, USA* 105:10029–10032.

Grimm, N.B. and K.C. Petrone. 1997. Nitrogen fixation in a desert stream ecosystem. *Biogeochemistry* 37:33–61.

Groendahl, L., T. Fribort, and H. Soegaard. 2007. Temperature and snow-melt controls on interannual variability in carbon exchange in the high Arctic. *Theoretical and Applied Climatology* 88:111–125.

Gross, M.R., R.M. Coleman, and R.M. McDowell. 1988. Aquatic productivity and the evolution of diadromous fish migration. *Science* 239:1291–1293.

Grove, J.M. 2009. Cities: Managing densely settled social-ecological systems. Pages 281–294 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Gruber, N. and J.N. Galloway. 2008. An Earth-system perspective of the global nitrogen cycle. *Nature* 451: 293–296.

Guenther, A., C. Hewitt, D. Erickson, R. Fall, C. Geron, et al. 1995. A global model of natural volatile organic compound emissions. *Journal of Geophysical Research* 100D:8873–8892.

Guildford, S.J. and R.E. Hecky. 2000. Total nitrogen, total phosphorus, and nutrient limitation in lakes and oceans: Is there a common relationship? *Limnology and Oceanography* 45:1213–1223.

Gulis, V. and K. Suberkropp. 2003. Effect of inorganic nutrients on relative contributions of fungi and bacteria to carbon flow from submerged decomposing leaf litter. *Microbial Ecology* 45:11–19.

Gulledge, J., A. Doyle, and J. Schimel. 1997. Different NH_4^+-inhibition patterns of soil CH_4 consumption: A result of distinct CH_4 oxidizer populations across sites? *Soil Biology and Biochemistry* 29:13–21.

Gulmon, S.L. and H.A. Mooney. 1986. Costs of defense on plant productivity. Pages 681–698 *in* T.J. Givnish, editor. *On the Economy of Plant Form and Function*. Cambridge University Press, Cambridge, U.K.

Gurney, K.R., R.M. Law, A.S. Denning, P.J. Rayner, D. Baker, et al. 2002. Towards robust regional estimates of CO_2 sources and sinks using atmospheric transport models. *Nature* 415:626–630.

Güsewell, S. 2004. N:P ratios in terrestrial plants: Variation and functional significance. *New Phytologist* 164: 243–266.

Gutierrez, J.R. and W.G. Whitford. 1987. Chihuahuan desert annuals: Importance of water and nitrogen. *Ecology* 68:2032–2045.

Haberl, H., K.H. Erb, F. Krausmann, V. Gaube, A. Bondeau, et al. 2007. Quantifying and mapping the human appropriation of net primary production in Earth's terrestrial ecosystems. *Proceedings of the National Academy of Sciences, USA* 104:12942–12945.

Hagen, J.B. 1992. *An Entangled Bank: The Origins of Ecosystem Ecology*. Rutgers University Press, New Brunswick, New Jersey.

Hairston, N.G., F.E. Smith, and L.B. Slobodkin. 1960. Community structure, population control and competition. *American Naturalist* 94:421–425.

Hall, S.J. and P.A. Matson. 1998. Nitrogen oxide emissions after nitrogen additions in tropical forests. *Nature* 400:152–155.

Hall, S.J. and G.P. Asner. 2007. Biological invasions alter regional N-oxide emissions in Hawaiian rain forests. *Global Change Biology* 13:2143–2160.

Hallbacken, L. 1992. *The Nature and Importance of Long-Term Soil Acidification in Swedish Forest Ecosystems*. Swedish University of Agricultural Sciences, Department of Ecology and Environmental Research, Uppsala.

Hanski, I., L. Hansson, and H. Henttonen. 1991. Specialist predators, generalist predators, and the microtine rodent cycle. *Journal of Animal Ecology* 60:353–367.

Hanski, I. 1999. *Metapopulation Ecology*. Oxford University Press, Oxford.

Hanski, I., H. Henttonen, E. Korpimäki, L. Oksanen, and P. Turchin. 2001. Small-rodent dynamics and predation. *Ecology* 82:1505–1520.

Harden, J.W., S.E. Trumbore, B.J. Stocks, A. Hirsch, S.T. Gower, et al. 2000. The role of fire in the boreal carbon budget. *Global Change Biology* 6 (Suppl. 1): 174–184.

Hardin, G. 1968. The tragedy of the commons. *Science* 162:1243–1248.

Harmon, M.E., W.L. Silver, B. Fasth, H. Chen, I.C. Burke, et al. 2009. Long-term patterns of mass loss during the decomposition of leaf and fine root litter: An intersite comparison. *Global Change Biology* 15:1320–1338.

Harpole, W.S. and D. Tilman. 2007. Grassland species loss resulting from reduced niche dimension. *Nature* 446:791–793.

Harris, J.A., R.J. Hobbs, E. Higgs, and J. Aronson. 2006. Ecological restoration and global climate change. *Restoration Ecology* 14:170–176.

Hartshorn, G.S. 1980. Neotropical forest dynamics. *Biotroprica* 12:23–30.

Hay, M.E. and W. Fenical. 1988. Marine plant-herbivore interactions: The ecology of chemical defense. *Annual Review of Ecology and Systematics* 19:111–145.

Haynes, R.J. 1986. The decomposition process: Mineralization, immobilization, humus formation, and degradation. Pages 52–126 *in* R.J. Haynes, editor. *Mineral Nitrogen in the Plant-Soil System*. Academic Press, Orlando.

Heal, G. 2000. *Nature and the Marketplace: Capturing the Value of Ecosystem Services*. Island Press, Washington.

Heal, O.W. and J. MacLean, S. F. 1975. Comparative productivity in ecosystems: Secondary productivity. Pages 89–108 *in* W.H. van Dobben and R.H. Lowe-McConnell, editors. *Unifying Concepts in Ecology*. Junk, The Hague.

Hedin, L.O., J.J. Armesto, and A.H. Johnson. 1995. Patterns of nutrient loss from unpolluted, old-growth temperate forests: Evaluation of biogeochemical theory. *Ecology* 76:493–509.

Hedin, L.O., E.N.J. Brookshire, D.N.L. Menge, and A.R. Barron. 2009. The nitrogen paradox in tropical forest ecosystems. *Annual Review of Ecology and Systematics* 40:613–635.

Heijmans, M.M.P.D., W.J. Arp, and F.S. Chapin, III. 2004. Controls on moss evaporation in a boreal black spruce forest. *Global Biogeochemical Cycles* 18:GB2004, doi:2010.1029/2003GB002128.

Heinsch, F.A., M. Zhao, S.W. Running, J.S. Kimball, R.R. Nemani, et al. 2006. Evaluation of remote sensing based terrestrial productivity from MODIS using regional tower eddy flux network observations. *IEEE Transactions on Geoscience and Remote Sensing* 44:1908–1925.

Helfield, J.M. and R.J. Naiman. 2001. Effects of salmon-derived nitrogen on riparian forest growth and implications for stream productivity. *Ecology* 82:2403–2409.

Herms, D.A. and W.J. Mattson. 1992. The dilemma of plants: To grow or defend. *Quarterly Review of Biology* 67:283–335.

Heywood, V.H. and R.T. Watson, editors. 1995. *Global Biodiversity Assessment*. Cambridge University Press, Cambridge.

Hibbert, A.R. 1967. Forest treatment effects on water yield.*in* W.E. Sopper and H.W. Lull, editors. *International Symposium on Forest Hydrology*. Pergamon Press, New York.

Hicks, W.T. and M.E. Harmon. 2002. Diffusion and seasonal dynamics of O_2 in woody debris from the Pacific Northwest, USA. *Plant and Soil* 243:67–79.

Hilborn, R., C.J. Walters, and D. Ludwig. 1995. Sustainable exploitation of renewable resources. *Annual Review of Ecology and Systematics* 26:45–67.

Hirose, T. and M.J.A. Werger. 1987. Maximizing daily canopy photosynthesis with respect to the leaf nitrogen allocation pattern in the canopy. *Oecologia* 72:520–526.

Hobbie, S.E. 1992. Effects of plant species on nutrient cycling. *Trends in Ecology & Evolution* 7:336–339.

Hobbie, S.E. 1995. Direct and indirect effects of plant species on biogeochemical processes in arctic ecosystems. Pages 213–224 *in* F.S. Chapin, III and C. Körner, editors. *Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences*. Springer-Verlag, Berlin.

Hobbie, S.E. and P.M. Vitousek. 2000. Nutrient regulation of decomposition in Hawaiian montane forests: Do the same nutrients limit production and decomposition? *Ecology* 81:1867–1877.

Hobbie, S.E. 2008. Nitrogen effects on litter decomposition: A five-year experiment in eight temperate grassland and forest sites. *Ecology* 89:2633–2644.

Hobbs, N.T. 1996. Modification of ecosystems by ungulates. *Journal of Wildlife Management* 60:695–713.

Hobbs, R.J. and H.A. Mooney. 1991. Effects of rainfall variability and gopher disturbance on serpentine annual grassland dynamics. *Ecology* 72:59–68.

Hobbs, R.J., S. Yates, and H.A. Mooney. 2007. Long-term data reveal complex dynamics in grassland in relation to climate and long-term disturbance. *Ecological Monographs* 77:545–568.

Hobbs, R.J. and V.A. Cramer. 2008. Restoration ecology: Interventionist approaches for restoring and maintaining ecosystem function in the face of rapid environmental change. *Annual Review of Environment and Resources* 33:39–61.

Hobbs, R.J., E. Higgs, and J.A. Harris. 2009. Novel ecosystems: Implications for conservation and restoration. *Trends in Ecology & Evolution* 24:599–605.

Hobbs, R.J., D.N. Cole, L. Yung, E.S. Zavaleta, G.H. Aplet, et al. 2010. Guiding concepts for park and wilderness stewardship in an era of global environmental change. *Frontiers in Ecology and the Environment* 8:483–490.

Hodge, A., D. Robinson, B. Griffiths, and A. Fitter. 1999. Why plants bother: Root proliferation results in increased nitrogen capture from an organic patch when two grasses compete. *Plant, Cell and Environment* 22: 811–820.

Högberg, P. and I.J. Alexander. 1995. Roles of root symbioses in African woodland and forest: Evidence from ^{15}N abundance and foliar nutrient concentrations. *Journal of Ecology* 83:217–224.

Högberg, P., A. Nordgren, N. Buchmann, A.F.S. Taylor, A. Ekblad, et al. 2001. Large-scale forest girdling experiment demonstrates that current photosynthesis drives soil respiration. *Nature* 411:789–792.

Holdridge, L.R. 1947. Determination of world plant formations from simple climatic data. *Science* 105:367–368.

Holland, E.A., F.J. Dentener, B.H. Braswell, and J.M. Sulzman. 1999. Contemporary and pre-industrial global reactive nitrogen budgets. *Biogeochemistry* 46:1–37.

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4:1–23.

Holling, C.S. 1986. Resilience of ecosystems: Local surprise and global change. Pages 292–317 *in* W.C. Clark and R.E. Munn, editors. *Sustainable Development and the Biosphere*. Cambridge University Press, Cambridge.

Holling, C.S. 1992. The role of forest insects in structuring the boreal landscape. Pages 170–191 *in* H.H. Shugart, R. Leemans, and G.B. Bonan, editors. *A Systems Analysis of the Global Boreal Forest*. Cambridge University Press, Cambridge.

Holling, C.S. and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology* 10:328–337.

Holling, C.S. and L.H. Gunderson. 2002. Resilience and adaptive cycles. Pages 25–62 *in* L.H. Gunderson and C.S. Holling, editors. *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington.

Hollinger, D.Y., S.V. Ollinger, A.D. Richardson, T.P. Meyers, D.B. Dail, et al. 2010. Albedo estimates for land surface models and support for a new paradigm based on foliage nitrogen concentration. *Global Change Biology* 16:696–710.

Holloway, J.M., R.A. Dahlgren, B. Hansen, and W.H. Casey. 1998. Contribution of bedrock nitrogen to high nitrate concentrations in stream water. *Nature* 395:785–788.

Hooper, D.U. and P.M. Vitousek. 1998. Effects of plant composition and diversity on nutrient cycling. *Ecological Monographs* 68:121–149.

Hooper, D.U., F.S. Chapin, III, J.J. Ewel, A. Hector, P. Inchausti, et al. 2005. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge and needs for future research. *Ecological Applications* 75:3–35.

Horne, A.J. and C.R. Goldman. 1994. *Limnology*. McGraw-Hill, New York.

Houghton, R.A. 2004. The contemporary carbon cycle. Pages 473–513 *in* W.H. Schlesinger, editor. *Biogeochemistry*. Elsevier, Amsterdam.

Houlton, B.Z., Y.-P. Wang, P.M. Vitousek, and C.B. Field. 2008. A unifying framework for dinitrogen fixation in the terrestrial biosphere. *Nature* 454:327–330.

Houlton, B.Z. and E. Bai. 2009. Imprint of denitrifying bacteria on the global terrestrial biosphere. *Proceedings of the National Academy of Sciences, USA* 106:21713–21716.

Howarth, R.W. 1984. The ecological significance of sulfur in the energy dynamics of salt marsh and marine sediments. *Biogeochemistry* 1:5–27.

Howarth, R.W., H. Jensen, R. Marino, and H. Postma. 1995. Transport and processing of phosphorus in nearshore and oceanic waters. Pages 323–345 *in* H. Tiessen, editor. *Phosphorus in the Global Environment: Transfers, Cycles, and Management*. John Wiley & Sons, Chichester.

Howarth, R.W., G. Billen, D. Swaney, A. Townsend, N. Jaworski, et al. 1996a. Regional nitrogen budgets and N and P fluxes for the drainages to the North Atlantic Ocean: Natural and human influences. *Biogeochemistry* 35:75–139.

Howarth, R.W., R. Schneider, and D. Swaney. 1996b. Metabolism and organic carbon fluxes in the tidal, freshwater Hudson River. *Estuaries* 19:848–865.

Howarth, R.W. and R. Marino. 2006. Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: Evolving views over three decades. *Limnology and Oceanography* 51:364–376.

Howarth, R.W., F. Chan, D.J. Conley, J. Garnier, S.C. Doney, et al. 2011. Coupled biogeochemical cycles: Eutrophication and hypoxia in temperate estuaries and coastal marine ecosystems. *Frontiers in Ecology and the Environment* 9:18–26.

Hu, S., F.S. Chapin, III, M.K. Firestone, C.B. Field, and N.R. Chiariello. 2001. Nitrogen limitation of microbial decomposition in a grassland under elevated CO_2. *Nature* 409:188–191.

Huante, P., E. Rincón, and F.S. Chapin, III. 1998. Effect of changing light availability on nutrient foraging in tropical deciduous tree-seedlings. *Oikos* 82:449–458.

Humphreys, W.F. 1979. Production and respiration in animal populations. *Journal of Animal Ecology* 48:427–454.

Hunt, H.W., D.C. Coleman, E.R. Ingham, E.T. Elliott, J.C. Moore, et al. 1987. The detrital food web in a shortgrass prairie. *Biology and Fertility of Soils* 3:57–68.

Hutley, L.B., D. Doley, D.J. Yates, and A. Boonsaner. 1997. Water-balance of an Australian subtropical rainforest at altitude: The ecological and physiological significance of intercepted cloud and fog. *Australian Journal of Botany* 45:311–329.

Huxman, T.E., M.D. Smith, P.A. Fay, A.K. Knapp, M.R. Shaw, et al. 2004. Convergence across biomes to a common rain-use efficiency. *Nature* 429:651–654.

Ingestad, T. and G.I. Ågren. 1988. Nutrient uptake and allocation at steady-state nutrition. *Physiologia Plantarum* 72:450–459.

Insam, H. 1990. Are the soil microbial biomass and basal respiration governed by the climatic regime? *Soil Biology and Biochemistry* 22:525–532.

IPCC. 2007. *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge.

Irons, J.G., III, J.P. Bryant, and M.W. Oswood. 1991. Effects of moose browsing on decomposition rates of birch leaf litter in a subarctic stream. *Canadian Journal of Fisheries and Aquatic Science* 48:442–444.

Jackson, R.B., J. Canadell, J.R. Ehleringer, H.A. Mooney, O.E. Sala, et al. 1996. A global analysis of root distributions for terrestrial biomes. *Oecologia* 108:389–411.

Jackson, R.B., J.S. Sperry, and T.E. Dawson. 2000. Root water uptake and transport: Using physiological processes in global predictions. *Trends in Plant Science* 5:482–488.

Jackson, R.B., E.G. Jobbágy, R. Avissar, S.B. Roy, D.J. Barrett, et al. 2005. Trading water for carbon with biological carbon sequestration. *Science* 310:1944–1947.

Jaeger, C.H., III, S.E. Lindow, W. Miller, E. Clark, and M.K. Firestone. 1999. Mapping sugar and amino acid availability in soil around roots with bacterial sensors of sucrose and tryptophan. *Applied and Environmental Microbiology* 65:2685–2690.

Janssens, I.A., W. Dieleman, S. Luyssaert, J.-A. Subke, M. Reichstein, et al. 2010. Reduction of forest soil respiration in response to nitrogen deposition. *Nature Geoscience* 3:315–322.

Jarvis, P.G. 1976. The interpretation of the variations in leaf water potential and stomatal conductance found in canopies in the field. *Philosophical Transactions of the Royal Society of London, Series B* 273:593–610.

Jarvis, P.G. and J.W. Leverenz. 1983. Productivity of temperate, deciduous and evergreen forests. Pages 233–280 *in* O.L. Lange, P.S. Nobel, C.B. Osmond, and H. Ziegler, editors. *Encyclodedia of Plant Physiology, New Series*. Springer-Verlag, Berlin.

Jarvis, P.G. and K.G. McNaughton. 1986. Stomatal control of transpiration: Scaling up from leaf to region. *Advances in Ecological Research* 15:1–49.

Jefferies, R.L. 1988. Vegetation mosaics, plant-animal interactions, and resources for plant growth. Pages 341–369 *in* L. Gottlieb and S.K. Kain, editors. *Plant Evolutionary Biology*. Chapman and Hall, London.

Jefferies, R.L. and J.P. Bryant. 1995. The plant-vertebrate herbivore interface in arctic ecosystems. Pages 271–281 *in* F.S. Chapin, III and C. Körner, editors. *Arctic and Alpine Biodiversity: Patterns, Causes, and Ecosystem Consequences*. Springer-Verlag, Berlin.

Jenny, H. 1941. *Factors of Soil Formation*. McGraw-Hill, New York.

Jenny, H. 1980. *The Soil Resources: Origin and Behavior*. Springer-Verlag, New York.

Jenny, H., R.J. Arkley, and A.M. Schultz. 1969. The pigmy forest-podsol ecosystem and its dune associates of the Mendocino Coast. *Madroño*. 20:60–74.

Jobbágy, E.G. and R.B. Jackson. 2000. The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological Applications* 10:423–436.

Johnson, E.A. 1992. *Fire and Vegetation Dynamics. Studies from the North American Boreal Forest*. Cambridge University Press, Cambridge.

Johnson, M.D., J. Völker, H.V. Moeller, E. Laws, K.J. Breslauer, et al. 2009. Universal constant for heat production in protists. *Proceedings of the National Academy of Sciences, USA* 106:6696–6699.

Johnstone, J.F., T.N. Hollingsworth, F.S. Chapin, III, and M.C. Mack. 2010. Changes in fire regime break the legacy lock on successional trajectories in the Alaskan boreal forest. *Global Change Biology* 16:1281–1295.

Jonasson, S. and F.S. Chapin, III. 1985. Significance of sequential leaf development for nutrient balance of the cotton sedge, *Eriophorum vaginatum* L. *Oecologia* 67:511–518.

Jonasson, S., A. Michelsen, and I.K. Schmidt. 1999. Coupling of nutrient cycling and carbon dynamics in the Arctic: Integration of soil microbial and plant processes. *Applied Soil Ecology* 11:135–146.

Jones, C.G., J.H. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. *Oikos* 69: 373–386.

Jones, H.G. 1992. *Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology*. 2nd edition. Cambridge University Press, Cambridge.

Jones, J.A. 2000. Hydrologic processes and peak discharge response to forest removal, regrowth, and roads in ten small experimental basins, western Cascades, Oregon. *Water Resources Research* 36:2621–2642.

Jones, J.A. and D.A. Post. 2004. Seasonal and successional streamflow response to forest cutting and regrowth in the northwest and eastern United States. *Water Resources Research* 40:W05203, doi: 05210.01029/02003WR002952.

Jones, J.B., J.D. Schade, S.G. Fisher, and N.B. Grimm. 1997. Organic matter dynamics in Sycamore Creek, a desert stream in Arizona, USA. *Journal of the North American Benthological Society* 16:78–82.

Jonsson, M. and D.A. Wardle. 2008. Context dependency of litter-mixing effects on decomposition and nutrient release across a long-term chronosequence. *Oikos* 117:1674–1682.

Ju, X.-T., G.-X. Xing, X.-P. Chen, S.-L. Zhang, L.-J. Zhang, et al. 2009. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proceedings of the National Academy of Sciences, USA* 106:3041–3046

Juice, S.M., T.J. Fahey, T.G. Siccama, C.T. Driscoll, E.G. Denny, et al. 2006. Response of sugar maple to calcium addition to northern hardwood forest at Hubbard Brook, NH. *Ecology* 87:1267–1280.

Kahmen, A., W. Wanek, and N. Buchmann. 2008. Foliar $\delta^{15}N$ values characterize soil N cycling and reflect nitrate or ammonium preference of plants along a temperate grassland gradient. *Oecologia* 156:861–870.

Kalff, J. 2002. *Limnology*. Prentice-Hall, Upper Saddle River, NJ.

Kaplan, L.A. and T.L. Bott. 1989. Diel fluctuations in bacterial activity on streambed substrata during vernal alagal blooms: Effects of temperature, water chemistry, and habitat. *Limnology and Oceanography* 34:718–733.

Karlsson, O.M., J.S. Richardson, and P.A. Kiffney. 2005. Modeling organic matter dynamics in headwater streams of south-western British Columbia, Canada. *Ecological Modelling* 183:463–476.

Kates, R.W., C.E. Colten, S. Laska, and S.P. Leatherman. 2006. Reconstruction of New Orleans after Hurricane Katrina: A research perspective. *Proceedings of the National Academy of Sciences, USA* 103: 14653–14660.

Keeley, J.E. 1990. Photosynthetic pathways in freshwater aquatic plants. *Trends in Ecology & Evolution* 5: 330–333.

Keeling, C.D., J.F.S. Chin, and T.P. Whorf. 1996a. Increased activity of northern vegetation inferred from atmospheric CO_2 measurements. *Nature* 382: 146–149.

Keeling, R.F., S.C. Piper, and M. Heimann. 1996b. Global and hemispheric CO_2 sinks deduced from changes in atmospheric O_2 concentration. *Nature* 381:218–221.

Kelliher, F.M., R. Leuning, M.R. Raupach, and E.-D. Schulze. 1995. Maximum conductances for evaporation from global vegetation types. *Agricultural and Forest Meteorology* 73:1–16.

Kelliher, F.M. and R. Jackson. 2001. Evaporation and the water balance. Pages 206–217 *in* A. Sturman and R. Spronken-Smith, editors. *The Physical Environment: A New Zealand Perspective*. Oxford University Press, Melbourne, Australia.

Kellner, J.R. and G.P. Asner. 2009. Convergent structural responses of tropical forests to diverse disturbance regimes. *Ecology Letters* 12:887–897.

Kellner, J.R., D.B. Clark, and S.P. Hubbell. 2009. Pervasive canopy dynamics produce short-term stability in a tropical rain forest landscape. *Ecology Letters* 12:155–164.

Kelly, D. and J.J. Sullivan. 2010. Life histories, dispersal, invasions, and global change: Progress and prospects in New Zealand ecology, 1989–2029. *New Zealand Journal of Ecology* 34:207–217.

Kemmitt, S., C.V. Lanyon, I.S. Waite, Q. Wen, A.G. O'Donnell, et al. 2008. Mineralization of native soil organic matter is not regulated by the size, activity or composition of the soil microbial biomass – a new perspective. *Soil Biology and Biochemistry* 40:61–73.

Kerkhoff, A.J., B.J. Enquist, J.J. Elser, and W.F. Fagan. 2005. Plant allometry, stoichiometry and the temperature-dependence of primary productivity. *Global Ecology and Biogeography* 14:585–598.

Kielland, K. 1994. Amino acid absorption by arctic plants: Implications for plant nutrition and nitrogen cycling. *Ecology* 75:2373–2383.

Kielland, K. 1997. Role of free amino acids in the nitrogen economy of arctic cryptogams. *Ecoscience* 4:75–79.

Kielland, K. and J. Bryant. 1998. Moose herbivory in taiga: Effects on biogeochemistry and vegetation dynamics in primary succession. *Oikos* 82:377–383.

Kielland, K., J.W. McFarland, and K. Olson. 2006. Amino acid uptake in deciduous and coniferous taiga ecosystems. *Plant and Soil* 288:297–307.

Killingbeck, K.T. and W.G. Whitford. 1996. High foliar nitrogen in desert shrubs: An important ecosystem trait or defective desert doctrine? *Ecology* 77:1728–1737.

Kitchell, J.F., editor. 1992. *Food Web Management: A Case Study of Lake Mendota*. Springer-Verlag, New York.

Kleiden, A. and H.A. Mooney. 2000. A global distribution of biodiversity inferred from climatic constraints: Results from a process-based modelling study. *Global Change Biology* 6:507–523.

Klein, D.R. 1982. Fire, lichens, and caribou. *Journal of Range Management* 35:390–395.

Kling, G.W., G.W. Kipphut, and M.C. Miller. 1991. Arctic lakes and streams as gas conduits to the atmosphere: Implications for tundra carbon budgets. *Science* 251: 298–301.

Knapp, A.K., J.M. Briggs, D.C. Hartnett, and S.L. Collins, editors. 1998. *Grassland Dynamics: Konza Prairie, and Long-Term Ecological Research in Tallgrass Prairie*. Oxford University Press, New York.

Knapp, A.K. and M.D. Smith. 2001. Variation among biomes in temporal dynamics of aboveground primary production. *Science* 291:481–484.

Knorr, M., S.D. Frey, and P.S. Curtis. 2005. Nitrogen additions and litter decomposition: A meta-analysis. *Ecology* 86:3252–3257.

Kobe, R.K., C.A. Lepczyk, and M. Iyer. 2005. Resorption efficiency decreases with increasing green leaf nutrients in a global data set. *Ecology* 86:2780–2792.

Koerselman, W. and A.F.M. Mueleman. 1996. The vegetation N:P ratio: A new tool to detect the nature of nutrient limitation. *Journal of Applied Ecology* 33:1441–1450.

Kofinas, G.P. 2009. Adaptive co-management in social-ecological governance. Pages 77–101 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Koide, R.T. 1991. Nutrient supply, nutrient demand and plant response to mycorrhizal infection. *New Phytologist* 117:365–386.

Körner, C., J.A. Scheel, and H. Bauer. 1979. Maximum leaf diffusive conductance in vascular plants. *Photosynthetica* 13:45–82.

Körner, C. and W. Larcher. 1988. Plant life in cold climates. *Symposium of the Society of Experimental Biology* 42:25–57.

Körner, C. 1994. Leaf diffusive conductances in the major vegetation types of the globe. Pages 463–490 *in* E.-D. Schulze and M.M. Caldwell, editors. *Ecophysiology of Photosynthesis*. Springer-Verlag, Berlin.

Körner, C. 1999. *Alpine Plant Life*. Springer-Verlag, Berlin.

Kortelainen, P., M. Rantakari, J.T. Huttunen, T. Mattsson, J. Alm, et al. 2006. Sediment respiration and lake trophic state are important predictors of large CO_2 evasion from small boreal lakes. *Global Change Biology* 12:1554–1567.

Kozlovsky, D.G. 1968. A critical evaluation of the trophic level concept. I. Ecological efficiencies. *Ecology* 49:48–60.

Kozlowski, T.T., P.J. Kramer, and S.G. Pallardy. 1991. *The Physiological Ecology of Woody Plants*. Academic Press, San Diego.

Kramer, P.J. and J.S. Boyer. 1995. *Water Relations of Plants and Soils*. Academic Press, San Diego.

Kremen, C.K., A.M. Merenlender, and D.D. Murphy. 1994. Ecological monitoring: A vital need for integrated conservation and development programs in the tropics. *Conservation Biology* 8:388–397.

Kremen, C.K., I. Raymond, and K. Lance. 1998. An interdisciplinary tool for monitoring conservation impacts in Madagascar. *Conservation Biology* 12: 549–563.

Kristjanson, P., R.S. Reid, N.M. Dickson, W.C. Clark, D. Romney, et al. 2009. Linking international agricultural research knowledge with action for sustainable development. *Proceedings of the National Academy of Sciences, USA* 106:5047–5052.

Kroehler, C.J. and A.E. Linkins. 1991. The absorption of inorganic phosphate from ^{32}P-labeled inositol hexaphosphate by *Eriophorum vaginatum*. *Oecologia* 85:424–428.

Kronzucker, H.J., M.Y. Siddiqi, and A.M. Glass. 1997. Conifer root discrimination against soil nitrate and the ecology of forest succession. *Nature* 385:59–61.

Kucharik, C.J., J.A. Foley, C. Delire, V.A. Fisher, M.T. Coe, et al. 2000. Testing the performance of a dynamic global ecosystem model: Water balance, carbon balance and vegetation structure. *Global Biogeochemical Cycles* 14:795–825.

Kummerow, J., B.A. Ellis, S. Kummerow, and F.S. Chapin, III. 1983. Spring growth of shoots and roots in shrubs of an Alaskan muskeg. *American Journal of Botany* 70:1509–1515.

Kursar, T.A. and P.D. Coley. 2003. Convergence in defense syndromes of young leaves in tropical rainforests. *Biochemical Systematics and Ecology* 31: 929–949.

Kurz, W.A., C.C. Dymond, G. Stinson, G.J. Rampley, E.T. Neilson, et al. 2008. Mountain pine beetle and forest carbon feedback to climate change. *Nature* 452:987–990.

Kuzyakov, Y., J.K. Friedel, and K. Stahr. 2000. Review of mechanisms and quantification of priming effects. *Soil Biology and Biochemistry* 32:1485–1498.

Lafleur, P.M. and E.R. Humphreys. 2007. Spring warming and carbon dioxide exchange over low Arctic tundra in central Canada. *Global Change Biology* 14:740–756.

Lafont, S., L. Kergoat, G. Dedieu, A. Chevillard, U. Karstens, et al. 2002. Spatial and temporal variability of land CO_2 fluxes estimated with remote sensing and analysis data over western Eurasia. *Tellus B* 4:820–833.

Laiho, R., H. Vasander, T. Penttila, and J. Laine. 2003. Dynamics of plant-mediated organic matter and nutrient cycling following water-level draw-down in boreal peatlands. *Global Biogeochemical Cycles* 17:17:1053. doi:1010.1029/2002GB002015.

Laine, K. and H. Henttonen. 1983. The role of plant production in microtine cycles in northern Fennoscandia. *Oikos* 40:407–418.

Lajtha, K. and M. Klein. 1988. The effect of varying phosphorus availability on nutrient use by *Larrea tridentata*, a desert evergreen shrub. *Oecologia* 75:348–353.

Lambers, H. and H. Poorter. 1992. Inherent variation in growth rate between higher plants: A search for physiological causes and ecological consequences. *Advances in Ecological Research* 23:187–261.

Lambers, H., O.K. Atkin, and I. Scheurwater. 1996. Respiratory patterns in roots in relation to their functioning. Pages 323–362 *in* Y. Waisel, A. Eshel, and U. Kafkaki, editors. *Plant Roots: The Hidden Half*. Marcel Dekker, New York.

Lambers, H., F.S. Chapin, III, and T.L. Pons. 2008. *Plant Physiological Ecology*. 2nd edition. Springer, New York.

Lambin, E.F., H.J. Geist, and E. Lepers. 2003. Dynamics of land use and land cover in tropical regions. *Annual Review of Environment and Resources* 28:205–241.

Landsberg, J.J. and S.T. Gower. 1997. *Applications of Physiological Ecology to Forest Management*. Academic Press, San Diego.

Larcher, W. 2003. *Physiological Plant Ecology: Ecophysiology and Stress Physiology of Functional Groups*. 4th edition. Springer-Verlag, Berlin.

Lauenroth, W.K., J.L. Dodd, and P.L. Simms. 1978. The effects of water- and nitrogen-induced stresses on plant community structure in a semiarid grassland. *Oecologia* 36:211–222.

Lauenroth, W.K. and O.E. Sala. 1992. Long-term forage production of North American shortgrass steppe. *Ecological Applications* 2:397–403.

Laurance, W.F. and R.O. Bierregaard, editors. 1997. *Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Forests*. University of Chicago Press, Chicago.

Lavelle, P., D. Bignell, and M. Lepage. 1997. Soil function in a changing world: The role of invertebrate ecosystem engineers. *European Journal of Soil Biology* 33:159–193.

Law, B.E., E. Falge, L. Gu, D.D. Baldocchi, P. Bakwin, et al. 2002. Environmental controls over carbon dioxide and water vapor exchange of terrestrial vegetation. *Agricultural and Forest Meteorology* 113:97–120.

Lawton, J.H. and C.G. Jones. 1995. Linking species and ecosystems: Organisms as ecosystem engineers. Pages 141–150 *in* C.G. Jones and J.H. Lawton, editors. *Linking species and ecosystems*. Chapman and Hall, New York.

Le Quéré, C., C. Rödenbeck, E. T. Buitenhuis, T. J. Conway, R. L. Langenfelds, et al. 2007. Saturation of the Southern Ocean CO_2 sink due to recent climate change. *Science* 316:1735–1738.

Le Quéré, C., M.R. Raupach, J.G. Canadell, G. Marland, L. Bopp, et al. 2009. Trends in the sources and sinks of carbon dioxide. *Nature Geoscience* 2:831–836.

LeBauer, D.S. and K.K. Treseder. 2008. Nitrogen limitation of net primary production in terrestrial ecosystems is globally distributed. *Ecology* 89:371–379.

Lee, R.B. 1982. Selectivity and kinetics of ion uptake by barley plants following nutrient deficiency. *Annals of Botany* 50:429–449.

Lee, R.B. and K.A. Rudge. 1987. Effects of nitrogen deficiency on the absorption of nitrate and ammonium by barley plants. *Annals of Botany* 57:471–486.

Lekberg, Y. and R.T. Koide. 2005. Is plant performance limited by abundance of arbuscular mycorrhizal fungi? A meta-analysis of studies published between 1988 and 2003. *New Phytologist* 168:189–204.

Levick, S.R., G.P. Asner, O.A. Chadwick, L.M. Khomo, K.H. Rogers, et al. 2010. Regional insight into savanna hydrogeomorphology from termite mounds. *Nature Communications* 1:doi:10.1038/ncomms1066.

Levin, S.A. 1999. *Fragile Dominion: Complexity and the Commons*. Perseus Books, Reading, MA.

Lewis, W.M., Jr., S.K. Hamilton, M.A. Rodriguez, J.F. Saunders, and M.A. Lasi. 2001. Foodweb analysis of the Orinoco floodplain based on production estimates and stable isotope data. *Journal of the North American Benthological Society* 20:241–254.

Lieth, H. 1975. Modeling the primary productivity of the world. Pages 237–263 *in* H. Lieth and R.H. Whittaker, editors. *Primary Productivity of the Biosphere*. Springer-Verlag, Berlin.

Likens, G.E., F.H. Bormann, R.S. Pierce, J.S. Eaton, and N.M. Johnson. 1977. *Biogeochemistry of a Forested Ecosystem*. Springer-Verlag, New York.

Likens, G.E., C.T. Driscoll, and D.C. Buso. 1996. Long-term effects of acid rain: Response and recovery of a forest ecosystem. *Science* 272:244–246.

Limm, E.B., K.A. Simonin, A.G. Bothman, and T.E. Dawson. 2009. Foliar water uptake: A common water acquisition strategy for plants of the redwood forest. *Oecologia* 161:449–459.

Lindeman, R.L. 1942. The trophic-dynamic aspects of ecology. *Ecology* 23:399–418.

Lindroth, R.L. 1996. CO_2-mediated changes in tree chemistry and tree-Lepidopteran interactions. Pages 105–120 *in* G.W. Koch and H.A. Mooney, editors. *Carbon Dioxide and Terrestrial Ecosystems*. Academic Press, San Diego.

Lipson, D.A., S.K. Schmidt, and R.K. Monson. 1999. Links between microbial population dynamics and nitrogen availability in an alpine ecosystem. *Ecology* 80:1623–1631.

Lipson, D.A., T.K. Raab, S.K. Schmidt, and R.K. Monson. 2001. An empirical model of amino acid transformations in an alpine soil. *Soil Biology and Biochemistry* 33:189–198.

Liston, G.E. and M. Sturm. 1998. A snow-transport model for complex terrain. *Journal of Glaciology* 44:498–516.

Liu, J., S.X. Li, Z.Y. Ouyang, C. Tam, and X. Chen. 2008. Ecological and socioeconomic effects of China's policies for ecosystem services. *Proceedings of the National Academy of Sciences, USA* 105:9477–9482.

Liu, L. and T.L. Greaver. 2009. A review of nitrogen enrichment effects on three biogenic GHGs: The CO_2 sink may be largely offset by stimulated N_2O and CH_4 emission. *Ecology Letters* 12:1103–1117.

Livingston, G.P. and G.L. Hutchinson. 1995. Enclosure-based measurement of trace gas exchange: Applications and sources of error. Pages 14–51 *in* P.A. Matson and R.C. Harriss, editors. *Biogenic Trace Gases: Measuring Emissions from Soil and Water*. Blackwell Scientific, Oxford.

Lloyd, J. and J.A. Taylor. 1994. On the temperature dependence of soil respiration. *Functional Ecology* 8:315–323.

Lohrenz, S.E., G.L. Fahnenstiel, D.G. Redalje, G.A. Lang, M.J. Dagg, et al. 1999. Nutrients, irradiance, and mixing as factors regulating primary production in coastal waters impacted by the Mississippi River plume. *Continental Shelf Research* 19:1113–1141.

Long, S.P., E.A. Ainsworth, A.D.B. Leakey, J. Nosberger, and D.R. Ort. 2006. Food for thought: Lower-than-expected crop yield stimulation with rising CO_2 concentrations. *Science* 312:1918–1921.

Longhurst, A.R. 1998. *Ecological Geography of the Sea*. Academic Press, San Diego.

Lorio, P.L., Jr. 1986. Growth-differentiation balance: A basis for understanding southern pine beetle-tree interactions. *Forest Ecology and Management* 14:259–273.

Los, S.O., G.J. Collatz, P.J. Sellers, C.M. Malmström, N.H. Pollack, et al. 2000. A global 9-yr biophysical land surface dataset from NOAA AVHRR data. *Journal of Hydrometeorology* 1:183–199.

Lousier, J.D. and S.S. Bamforth. 1990. Soil protozoa. Pages 97–136 *in* D.L. Dindal, editor. *Soil Biology Guide*. John Wiley and Sons, New York.

Lovett, G.M. 1994. Atmospheric deposition of nutrients and pollutants in North America: An ecological perspective. *Ecological Applications* 4:629–650.

Lovett, G.M., K.C. Weathers, and W.V. Sobczak. 2000. Nitrogen saturation and retention in forested watersheds of the Catskill Mountains, New Hampshire. *Ecological Applications* 10:73–84.

Lowrance, R., L.S. Altier, J.D. Newbold, R.R. Schnabel, P.M. Groffman, et al. 1997. Water quality functions of riparian forest buffer systems in the Chesapeake Bay watershed. *Environmental Management* 21:687–712.

Ludwig, D., R. Hilborn, and C. Walters. 1993. Uncertainty, resource exploitation, and conservation: Lessons from history. *Science* 260:17, 36.

Lu, M., Y. Yang, Y. Luo, C. Fang, X. Zhou, et al. 2010. Responses of ecosystem nitrogen cycle to nitrogen addition: A meta-analysis. New Phytologist:doi: 10.1111/j.1469-8137.2010.03563.x.

Ludwig, J.A. and D.J. Tongway. 1995. Spatial organisation of landscapes and its function in semi-arid woodlands, Australia. *Landscape Ecology* 10:51–63.

Luo, Y., S. Wan, D. Hui, and L.L. Wallace. 2001. Acclimatization of soil respiration to warming in a tall grass prairie. *Nature* 413:622–625.

Luo, Y. 2007. Terrestrial carbon-cycle feedback to climate warming. *Annual Review of Ecology, Evolution and Systematics* 38:683–712.

Luyssaert, S., I. Inglima, M. Jung, A.D. Richardson, M. Reichstein, et al. 2007. CO_2 balance of boreal, temperate, and tropical forests derived from a global database. *Global Change Biology* 13:2509–2537.

Luyssaert, S., E.-D. Schulze, A. Börner, A. Knohl, D. Hessenmöller, et al. 2008. Old-growth forests as global carbon sinks. *Nature* 455:213–215.

Lytle, D.A. and N.L. Poff. 2004. Adaptation to natural flow regimes. *Trends in Ecology & Evolution* 19:94–100.

Lyver, P.O.B., H. Moller, and C. Thompson. 1999. Changes in sooty shearwater *Puffinus griseus* chick production and harvest precede ENSO events. *Marine Ecology Progress Series* 188:237–248.

MacArthur, R.H. and E.O. Wilson. 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton.

Mace, G., H. Masundire, J. Baillie, T. Ricketts, T. Brooks, et al. 2005. Biodiversity. Pages 77–122 *in* R. Hassan,

R.J. Scholes, and N. Ash, editors. *Ecosystems and Human Well-Being: Current State and Trends, Volume 1*. Island Press, Washington.

Mack, M.C., C.M. D'Antonio, and R.E. Ley. 2001. Pathways through which exotic grasses alter N cycling in a seasonally dry Hawaiian woodland. *Ecological Applications* 11:1323–1335.

MacLean, D.A. and R.W. Wein. 1978. Weight loss and nutrient changes in decomposing litter and forest floor material in New Brunswick forest stands. *Canadian Journal of Botany* 56:2730–2749.

Magill, A.H., J.D. Aber, J.J. Hendricks, R.D. Bowden, J.M. Melillo, et al. 1997. Biogeochemical response of forest ecosystems to simulated chronic nitrogen deposition. *Ecological Applications* 7:402–415.

Magnani, F., M. Mencuccini, M. Borghetti, P. Berbigier, F. Berninger, et al. 2007. The human footprint in the carbon cycle of temperate and boreal forests. *Nature* 447:849–851.

Mann, K.H. and J.R.N. Lazier. 2006. *Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans*. 3rd edition. Blackwell Publishing, Victoria, Australia.

Manzoni, S., R.B. Jackson, J.A. Trofymow, and A. Porporato. 2008. The global stoichiometry of litter nitrogen mineralization. *Science* 321:684–686.

Margalef, R. 1968. *Perspectives in Ecological Theory*. University of Chicago Press, Chicago.

Margolis, H., R. Oren, D. Whitehead, and M.R. Kaufmann. 1995. Leaf area dynamics of conifer forests. Pages 181–223 *in* W.K. Smith and T.M. Hinckley, editors. *Ecophysiology of Coniferous Forests*. Academic Press, San Diego.

Mark, A.F., K.S. Turner, and C.J. West. 2001. Integrating nature conservation with hydro-electric development: Conflict resolution with Lakes Manapouri and Te Anau, Fiordland National Park, New Zealand. *Lake and Reservoir Management* 17:1–16.

Mark, A.F. and K.J.M. Dickinson. 2008. Maximizing water yield with indigenous non-forest vegetation: A New Zealand perspective. *Frontiers in Ecology and the Environment* 6:25–34.

Marschner, H. 1995. *Mineral Nutrition in Higher Plants*. 2nd edition. Academic Press, London.

Martin, J.H. 1990. Glacial-interglacial CO_2 exchange: The iron hypothesis. *Paleoceanography* 5:1–13.

Marvier, M., C. McCreedy, J. Regetz, and P. Kareiva. 2007. A meta-analysis of effects of Bt cotton and maize on nontarget invertebrates. *Science* 316: 1475–1477.

Mary, B., S. Recous, D. Darwis, and D. Robin. 1996. Interactions between decomposition of plant residues and nitrogen cycling in soil. *Plant and Soil* 181:71–82.

Maslow, A.H. 1943. A theory of human motivation. *Psychological Review* 50:370–396.

Matson, P.A. and P.M. Vitousek. 1981. Nitrogen mineralization and nitrification potentials following clearcutting in the Hoosier National Forest, Indiana. *Forest Science* 27:781–791.

Matson, P.A. and R.D. Boone. 1984. Natural disturbance and nitrogen mineralization: Wave-form dieback of mountain hemlock in the Oregon Cascades. *Ecology* 65:1511–1516.

Matson, P.A. and R.H. Waring. 1984. Effects of nutrient and light limitation on mountain hemlock: Susceptibility to laminated root rot. *Ecology* 65: 1517–1524.

Matson, P.A. and P.M. Vitousek. 1987. Cross-system comparisons of soil nitrogen transformations and nitrous oxide flux in tropical forest ecosystems. *Global Biogeochemical Cycles* 1:163–170.

Matson, P.A., P.M. Vitousek, J. Ewel, M. Mazzarino, and G. Robertson. 1987. Nitrogen transformations following tropical forest felling and burning on a volcanic soil. *Ecology* 68:491–502.

Matson, P.A. and R.C. Harriss. 1988. Prospects for aircraft-based gas exchange measurements in ecosystem studies. *Ecology* 69:1318–1325.

Matson, P.A., C. Volkmann, K. Coppinger, and W.A. Reiners. 1991. Annual nitrous oxide flux and soil nitrogen characteristics in sagebrush steppe ecosystems. *Biogeochemistry* 14:1–12.

Matson, P.A., W.J. Parton, A.G. Power, and M.J. Swift. 1997. Agricultural intensification and ecosystem properties. *Science* 227:504–509.

Matson, P.A., R.L. Naylor, and I. Ortiz-Monasterio. 1998. The integration of environmental, agronomic, and economic aspects of fertilizer management. *Science* 280:112–115.

Matson, P.A., W.H. McDowell, A.R. Townsend, and P.M. Vitousek. 1999. The globalization of N deposition: Ecosystem consequences in tropical environments. *Biogeochemistry* 46:67–83.

Matson, P.A. 2009. The sustainability transition. *Issues in Science and Technology* 25:39–42.

McAndrews, J.H. 1966. Postglacial history of prairie, savanna, and forest in northwestern Minnesota. *Torrey Botanical Club Memoir* 22:1–72.

McCoy, E.D., S.S. Bell, and K. Walters. 1986. Identifying biotic boundaries along environmental gradients. *Ecology* 67:749–759.

McCulley, R.L., I.C. Burke, and W.K. Lauenroth. 2009. Conservation of nitrogen increases with precipitation across a major grassland gradient in the Central Great Plains of North America. *Oecologia* 159:571–581.

McDowell, N., W.T. Pockman, C.D. Allen, D.D. Breshears, N. Cobb, et al. 2008. Mechanisms of plant survival and mortality during drought: Why do some plants survive while others succumb to drought? *New Phytologist* 178:719–739.

McElroy, M.B. 2002. *The Atmospheric Environment: Effects of Human Activity*. Princeton University Press, Princeton.

McGill, W. and C.V. Cole. 1981. Comparative aspects of cycling of organic C, N, S, and P through soil organic matter. *Geoderma* 26:267–286.

McGroddy, M., T. Deaufresne, and L.O. Hedin. 2004. Scaling of C:N:P stoichiometry in forests worldwide:

Implications of terrestrial Redfield-type ratios. *Ecology* 85:2390–2401.

McGuire, A.D., J.M. Melillo, and L.A. Joyce. 1995a. The role of nitrogen in the response of forest net primary production to elevated atmospheric carbon dioxide. *Annual Review of Ecology and Systematics* 26:473–503.

McGuire, A.D., J.W. Melillo, D.W. Kicklighter, and L.A. Joyce. 1995b. Equilibrium responses of soil carbon to climate change: Empirical and process-based estimates. *Journal of Biogeography* 22:785–796.

McGuire, A.D., S. Sitch, J.S. Clein, R. Dargaville, G. Esser, et al. 2001. Carbon balance of the terrestrial biosphere in the twentieth century: Analyses of CO_2, climate and land-use effects with four process-based models. *Global Biogeochemical Cycles* 15:183–206.

McGuire, A.D., L.G. Anderson, T.R. Christensen, S. Dallimore, L. Guo, et al. 2009. Sensitivity of the carbon cycle in the Arctic to climate change. *Ecological Monographs* 79:523–555.

McGuire, A.D., D.J. Hayes, D.W. Kicklighter, M. Manizza, Q. Zhuang, et al. 2010. An analysis of the carbon balance of the Arctic Basin from 1997 to 2006. *Tellus Series B: Chemical and Physical Meteorology*.

McKane, R.B., E.B. Rastetter, G.R. Shaver, K.J. Nadelhoffer, A.E. Giblin, et al. 1997. Climatic effects on tundra carbon storage inferred from experimental data and a model. *Ecology* 78:1170–1187.

McKane, R.B., L.C. Johnson, G.R. Shaver, K.J. Nadelhoffer, E.B. Rastetter, et al. 2002. Resource-based niches provide a basis for plant species diversity and dominance in arctic tundra. *Nature* 415:68–71.

McKey, D., P.G. Waterman, C.N. Mbi, J.S. Gartlan, and T.T. Struhsaker. 1978. Phenolic content of vegetation in two African rain forests: Ecological implications. *Science* 202:61–63.

McLachlan, J.S., J. Hellmann, and M. Schwartz. 2007. A framework for debate of assisted migration in an era of climate change. *Conservation Biology* 21:297–302.

McNaughton, K.G. 1976. Evaporation and advection I: Evaporation from extensive homogeneous surfaces. *Quarterly Journal of the Royal Meteorological Society* 102:181–191.

McNaughton, K.G. and P.G. Jarvis. 1991. Effects of spatial scale on stomatal control of transpiration. *Agricultural and Forest Meteorology* 54:279–302.

McNaughton, S.J. 1977. Diversity and stability of ecological communities: A comment on the role of empiricism in ecology. *American Naturalist* 111:515–525.

McNaughton, S.J. 1979. Grazing as an optimization process: Grass-ungulate relationships in the Serengeti. *American Naturalist* 113:691–703.

McNaughton, S.J. 1985. Ecology of a grazing ecosystem: The Serengeti. *Ecological Monographs* 53:259–294.

McNaughton, S.J. 1988. Mineral nutrition and spatial concentrations of African ungulates. *Nature* 334:343–345.

McNaughton, S.J., M. Oesterheld, D.A. Frank, and K.J. Williams. 1989. Ecosystem-level patterns of primary productivity and herbivory in terrestrial habitats. *Nature* 341:142–144.

McNulty, S.G., J.D. Aber, T.M. McLellan, and S.M. Katt. 1990. Nitrogen cycling in high elevation forests of the northeastern U.S. in relation to nitrogen deposition. *Ambio* 19:38–40.

McTammany, M.E., J.R. Webster, E.F. Benfield, and M.A. Neatrour. 2003. Longitudinal patterns of metabolism in a southern Appalachian river. *Journal of the North American Benthological Society* 22:359–370.

MEA (Millennium Ecosystem Assessment). 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington.

Meffe, G.K., L.A. Nielsen, R.L. Knight, and D.A. Schenborn. 2002. *Ecosystem Management: Adaptive, Community-Based Conservation* Island Press, Washington.

Melillo, J.M., J.D. Aber, and J.F. Muratore. 1982. Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. *Ecology* 63:621–626.

Meyer, J.L. and R.T. Edwards. 1990. Ecosystem metabolism and turnover of organic carbon along a blackwater river continuum. *Ecology* 71:668–677.

Meyer, W.B. and B.L. Turner, III. 1992. Human population growth and global land-use/cover change. *Annual Review of Ecology and Systematics* 23:39–61.

Migliavacca, M., M. Reichstein, A.D. Richardson, R. Colombo, M.A. Sutton, et al. 2010. Semiempirical modeling of abiotic and biotic factors controlling ecosystem respiration across eddy covariance sites. *Global Change Biology* 16:187–208.

Milchunas, D.G. and W.K. Lauenroth. 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological Monographs* 63:327–366.

Millar, C.I., N.L. Stephenson, and S.L. Stephens. 2007. Climate change and forests of the future: Managing in the face of uncertainty. *Ecological Applications* 17:2145–2151.

Miller, J.R., M.G. Turner, E.A.H. Smithwick, C.L. Dent, and E.H. Stanley. 2004. Spatial extrapolation: The science of predicting ecological patterns and processes. *BioScience* 54:310–320.

Miller, R.W. and R.L. Donahue. 1990. *Soils. An Introduction to Soils and Plant Growth*. 6th edition. Prentice Hall, Englewood, USA.

Milliman, J.D. and J.P.M. Syvitski. 1992. Geomorphic/tectonic control of sediment discharge to the ocean: The importance of small mountains and rivers. *Journal of Geology* 100:525–544.

Milner, A.M., C. Fastie, F.S. Chapin, III, D.R. Engstrom, and L. Sharman. 2007. Interactions and linkages among ecosystems during landscape evolution. *BioScience* 57:237–247.

Minkkinen, K., R. Korhonen, I. Savolainen, and J. Laine. 2002. Carbon balance and radiative forcing of Finnish peatlands 1900–2100: The impact of forestry drainage. *Global Change Biology* 8:785–799.

Minshall, G.W., C.T. Robinson, and D.E. Lawrence. 1997. Postfire responses of lotic ecosystems in Yellowstone National Park, U.S.A. *Canadian Journal of Fisheries and Aquatic Sciences* 54:2509–2525.

Moen, R., Y. Cohen, and J. Pastor. 1998. Linking moose population and plant growth models with a moose energetics model. *Ecosystems* 1:52–63.

Monserud, R.A. and J.D. Marshall. 1999. Allometric crown relations in three northern Idaho conifer species. *Canadian Journal of Forest Research* 29:521–535.

Monteith, J.L. and M.H. Unsworth. 2008. *Principles of Environmental Physics*. 3rd edition. Elsevier, Amsterdam.

Mooney, H.A. and E.L. Dunn. 1970. Convergent evolution of mediterranean-climate evergreen sclerophyll shrubs. *Evolution* 24:292–303.

Mooney, H.A. 1972. The carbon balance of plants. *Annual Review of Ecology and Systematics* 3:315–346.

Mooney, H.A. 1986. Photosynthesis. Pages 345–373 *in* M.J. Crawley, editor. *Plant Ecology*. Blackwell, Oxford.

Mooney, H.A., J. Canadell, F.S. Chapin, III, J.R. Ehleringer, C. Körner, et al. 1999. Ecosystem physiology responses to global change. Pages 141–189 *in* B. Walker, W. Steffen, J. Canadell, and J. Ingram, editors. *The Terrestrial Biosphere and Global Change: Implications for Natural and Managed Ecosystems*. Cambridge University Press, Cambridge.

Moore, J.C. and H.W. Hunt. 1988. Resource compartmentation and the stability of real ecosystems. *Nature* 333:261–263.

Moore, J.C. and P.C. de Ruiter. 2000. Invertebrates in detrital food webs along gradients of productivity *in* D.C. Coleman and P.F. Hendrix, editors. *Invertebrates as Webmasters in Ecosystems*. CABI Publishing, Oxford.

Moore, J.C., K. McCann, H. Setälä, and P.C. de Ruiter. 2003. Top-down is bottom-up: Does predation in the rhizosphere regulate aboveground dynamics? *Ecology* 84:846–857.

Moore, R.D. and S.M. Wondzell. 2005. Physical hydrology and the effects of forest harvesting in the Pacific Northwest: A review. *Journal of the American Water Resources Association* 41:763–784.

Morris, J.T. 1980. The nitrogen uptake kinetics of *Spartina alterniflora* in culture. *Ecology* 61:1114–1121.

Moss, B. 1998. *Ecology of Fresh Waters: Man and Medium, Past to Future*. 3rd edition. Blackwell Scientific, Oxford.

Motzkin, G., D. Foster, A. Allen, J. Harrod, and R. Boone. 1996. Controlling site to evaluate history: Vegetation patterns of a New England sand plain. *Ecological Monographs* 66:345–365.

Mulder, C.P.H., D.D. Uliassi, and D.F. Doak. 2001. Physical stress and diversity-productivity relationships: The role of positive interactions. *Proceedings of the National Academy of Sciences, USA* 98:6704–6708.

Mulholland, P.J., C.S. Fellows, J.L. Tank, N.B. Grimm, J.R. Webster, et al. 2001. Inter-biome comparison of factors controlling stream metabolism. *Freshwater Biology* 46:1503–1517.

Mulholland, P.J., A.M. Helton, G.C. Poole, R.O. Hall, Jr., S.K. Hamilton, et al. 2008. Stream denitrification across biomes and its response to anthropogenic nitrate loading. *Nature* 452:202–205.

Mullon, C., P. Freon, and P. Cury. 2005. The dynamics of collapse in world fisheries. *Fish and Fisheries* 6:111–120.

Nadelhoffer, K.J., A.E. Giblin, G.R. Shaver, and A.E. Linkins. 1992. Microbial processes and plant nutrient availability in arctic soils. Pages 281–300 *in* F.S. Chapin, III, R.L. Jefferies, J.F. Reynolds, G.R. Shaver, and J. Svoboda, editors. *Arctic Ecosystems in a Changing Climate: An Ecophysiological Perspective*. Academic Press, San Diego.

Nadkarni, N. 1981. Canopy roots: Convergent evolution in rainforest nutrient cycles. *Science* 214:1023–1024.

Naeem, S., D.E. Bunker, A. Hector, M. Loreau, and C. Perrings, editors. 2009. *Biodiversity, Ecosystem Functioning, and Human Well-being: An Ecological and Economic Perspective*. Oxford University Press, Oxford.

Naiman, R.J. and H. Décamps. 1997. The ecology of interfaces: Riparian zones. *Annual Review of Ecology and Systematics* 28:621–658.

Naiman, R.J., H. Décamps, and M.E. McClain. 2005. *Riparia: Ecology, Conservation, and Management of Streamside Communities*. Elsevier, Amsterdam.

Näsholm, T., A. Ekblad, A. Nordin, R. Giesler, M. Högberg, et al. 1998. Boreal forest plants take up organic nitrogen. *Nature* 392:914–916.

Näsholm, T., K. Huss-Danell, and P. Högberg. 2000. Uptake of organic nitrogen in the field by four agriculturally important plant species. *Ecology* 81:1155–1161.

Naylor, R.L. 2009. Managing food production systems for resilience. Pages 259–280 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Neff, J.C., E.A. Holland, F.J. Dentener, W.H. McDowell, and K.M. Russell. 2002. The origin, composition and rates of organic nitrogen deposition: A missing piece of the nitrogen cycle? *Biogeochemistry* 57:99–136.

Neff, J.C. and D.U. Hooper. 2002. Vegetation and climate controls on potential CO_2, DOC and DON production in northern latitude soils. *Global Change Biology* 8:872–884.

Neff, J.C., A.P. Ballantyne, G.L. Famer, N.M. Mahowald, J.L. Conroy, et al. 2008. Recent increase in eolian dust deposition related to human activity in the Western United States. *Nature Geosciences* 1:189–195.

Nepstad, D.C., C.R. deCarvalho, E.A. Davidson, P.H. Jipp, P.A. Lefebvre, et al. 1994. The role of deep roots in the hydrological and carbon cycles of Amazonian forests and pastures. *Nature* 372:666–669.

New, M.G., M. Hulme, and P.D. Jones. 1999. Representing 20th century space-time climate variability, I: Development of a 1961–1990 mean monthly terrestrial climatology. *Journal of Climate* 12:829–856.

New, M.G., D. Lister, M. Hulme, and I. Makin. 2002. A high-resolution data set of surface climate over global land areas. *Climate Research* 21:1–25.

Newman, E.I. 1985. The rhizosphere: Carbon sources and microbial populations. Pages 107–121 *in* A.H. Fitter, D. Atkinson, D.J. Read, and M. Busher, editors. *Ecological Interactions in Soil*. Blackwell, Oxford.

Niemelä, P., F.S. Chapin, III, K. Danell, and J.P. Bryant. 2001. Animal-mediated responses of boreal forest to climatic change. *Climatic Change* 48:427–440.

Nippert, J.B. and A.K. Knapp. 2007a. Linking water uptake with rooting patterns in grassland species. *Oecologia* 153:261–272.

Nippert, J.B. and A.K. Knapp. 2007b. Soil water partitioning contributes to species coexistence in tallgrass prairie. *Oikos* 116:1017–1029.

Nixon, S.W. 1988. Physical energy inputs and the comparative ecology of lake and marine ecosystems. *Limnology and Oceanography* 33:1005–1025.

Nixon, S.W., J.W. Ammerman, L.P. Atkinson, V.M. Berounsky, G. Billen, et al. 1996. The fate of nitrogen and phosphorus at the land-sea margin of the North Atlantic Ocean. *Biogeochemistry* 35:141–180.

Noble, I.R. and R.O. Slatyer. 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetatio* 43:5–21.

Norby, R.J., E.H. DeLucia, B. Gielen, C. Calfapietra, C.P. Giardina, et al. 2005. Forest response to elevated CO_2 is conserved across a broad range of productivity. *Proceedings of the National Academy of Sciences, USA* 102:18052–18056.

Norby, R.J., J.M. Warren, C.M. Iversen, B.E. Medlyn, and R.E. McMurtrie. 2010. CO_2 enhancement of forest productivity constrained by limited nitrogen availability. *Proceedings of the National Academy of Sciences USA* 107:19368–19373.

Northup, R.R., Z. Yu, R.A. Dahlgren, and K.A. Vogt. 1995. Polyphenol control of nitrogen release from pine litter. *Nature* 377:227–229.

Norton, J.M., J.L. Smith, and M.K. Firestone. 1990. Carbon flow in the rhizosphere of Ponderosa pine seedlings. *Soil Biology and Biochemistry* 22:449–445.

Norton, J.M. and M.K. Firestone. 1991. Metabolic status of bacteria and fungi in the rhizosphere of ponderosa pine seedlings. *Applied and Environmental Microbiology* 57:1161–1167.

Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology* 4: 355–364.

NRC (National Research Council). 2000. *Watershed Management for Potable Water Supply: Assessing New York City's Approach*. National Academies Press, Washington.

NRC (National Research Council). 2006. *Drawing Louisiana's New Map: Addressing Land Loss in Coastal Louisiana*. National Academies Press, Washington.

NRC (National Research Council). 2008. *Hydrologic Effects of a Changing Forest Landscape*. National Academies Press, Washington.

NRC (National Research Council). 2010. *America's Climate Choices: Adapting to the Impacts of Climate Change*. National Academies Press, Washington.

Nulsen, R.A., K.J. Bligh, I.N. Baxter, E.J. Solin, and D.H. Imrie. 1986. The fate of rainfall in a mallee and heath vegetated catchment in southern Western Australia. *Australian Journal of Ecology* 11:361–371.

Nye, P.H. and P.B. Tinker. 1977. *Solute Movement in the Soil-Root System*. University of California Press, Berkeley.

O'Leary, M.H. 1988. Carbon isotopes in photosynthesis. *BioScience* 38:325–336.

O'Neill, R.V., D.L. DeAngelis, J.B. Waide, and T.F.H. Allen. 1986. *A Hierarchical Concept of Ecosystems*. Princeton University Press, Princeton.

Oades, J.M. 1989. An introduction to organic matter in mineral soils. Pages 89–160 *in* J.B. Dixon and S.B. Weed, editors. *Minerals in Soil Environments*. Soil Science Society of America, Madison.

Odum, E.P. 1959. *Fundamentals of Ecology*. W. B. Saunders, Philadelphia.

Odum, E.P. 1969. The strategy of ecosystem development. *Science* 164:262–270.

Oechel, W.C., G.L. Vourlitis, S.J. Hastings, R.C. Zulueta, L. Hinzman, et al. 2000. Acclimation of ecosystem CO_2 exchange in the Alaskan Arctic in response to decadal climate warming. *Nature* 406:978–981.

Oke, T.R. 1987. *Boundary Layer Climates*. 2nd edition. Methuen, London.

Oki, T. and S. Kanae. 2006. Global hydrological cycles and world water resources. *Science* 313:1068–1072.

Okin, G.S., N.M. Mahowald, O.A. Chadwick, and P. Artaxo. 2004. Impact of desert dust on the biogeochemistry of phosphorus in terrestrial ecosystems. *Global Biogeochemical Cycles* 18:GB2005, doi:2010.1029/2003GB002145.

Oksanen, L. 1990. Predation, herbivory, and plant strategies along gradients of primary productivity. Pages 445–474 *in* J.B. Grace and D. Tilman, editors. *Perspectives on Plant Competition*. Academic Press, San Diego.

Olander, L.P. and P.M. Vitousek. 2000. Asymmetry in N and P mineralization: Regulation of extracellular phosphatase and chitinase activity by N and P availability. *Biogeochemistry* 49:175–190.

Olsen, J.S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. *Ecology* 44:322–331.

Olsson, A.D., M.P. McClaran, J. Betancourt, and S.E. Marsh. In press. Sonoran Desert ecosystem transformation by a C_4 grass without the grass-fire cycle. *Diversity and Distributions*.

Onipchenko, V.G., M. Makarov, R.S.P. van Logtestijn, V. Ivanov, A.A. Akhmetzhanova, et al. 2009. New nitrogen uptake strategy: Specialized snow roots. *Ecology Letters* 12:758–764.

Orlove, B.S., J.C.H. Chiang, and M.A. Cane. 2000. Forecasting Andean rainfall and crop yield from the influence of El Niño on Pleiades visibility. *Nature* 403:68–71.

Orr, J.C., V.J. Fabry, O. Aumont, L. Bopp, S.C. Doney, et al. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437:681–686.

Osborne, C.P. and R.P. Freckleton. 2009. Ecological selection pressures for C_4 photosynthesis. *Proceedings of The Royal Society, Series B* 276:1753–1760.

Osterheld, M., O.E. Sala, and S.J. McNaughton. 1992. Effect of animal husbandry on herbivore-carrying capacity at a regional scale. *Nature* 356:234–236.

Ostfeld, R.S. and F. Keesing. 2000. Biodiversity and disease risk: The case of Lyme disease. *Conservation Biology* 14:722–728.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge.

Ostrom, E. 2007. A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences, USA* 104:15181–15187.

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325:419–422.

Ovington, J.D. 1962. Quantitative ecology and the woodland ecosystem concept. *Advances in Ecological Research* 1:103–192.

Owen-Smith, R.N. 1988. *Megaherbivores: The Influence of Very Large Body Size on Ecology*. Cambridge University Press, Cambridge.

Pace, M.L., J.J. Cole, S.R. Carpenter, and J.F. Kitchell. 1999. Trophic cascades revealed in diverse ecosystems. *Trends in Ecology & Evolution* 14:483–488.

Paine, R.T. 1980. Food webs: Linkage, interaction strength and community infrastructure. *Journal of Animal Ecology* 49:667–685.

Paine, R.T. 2000. Phycology for the mammalogist: Marine rocky shores and mammal-dominated communities. How different are the structuring processes? *Journal of Mammalogy* 81:637–648.

Painter, T.H., A.P. Barrett, C.C. Landry, J.C. Neff, M.P. Cassidy, et al. 2007. Impact of disturbed desert soils on duration of mountain snowcover. *Geophysical Research Letters* 34:12, L12502, 12510.11029/12007GL030208.

Palm, C.A., S.A. Vosti, P.A. Sanchez, and P.J. Ericksen. 2005. *Slash-and-Burn Agriculture: The Search for Alternatives*. Columbia University Press, New York.

Palmer, M., E. Bernhardt, E. Chornesky, S. Collins, A. Dobson, et al. 2004. Ecology for a crowded planet. *Science* 304:1251–1252.

Parker, I.M., D. Simberloff, W.M. Lonsdale, K. Goodell, M. Wonham, et al. 1999. Impact: Toward a framework for understanding the ecological effects of invaders. *Biological Invasions* 1:3–19.

Parton, W.J., D.S. Schimel, C.V. Cole, and D.S. Ojima. 1987. Analysis of factors controlling soil organic matter levels in Great Plains grasslands. *Soil Science Society of America Journal* 51:1173–1179.

Parton, W.J., J.M.O. Scurlock, D.S. Ojima, T.G. Gilmanov, R.J. Scholes, et al. 1993. Observations and modeling of biomass and soil organic matter dynamics for the grassland biome worldwide. *Global Biogeochemical Cycles* 7:785–809.

Parton, W.J., W.L. Silver, I.C. Burke, L. Grassens, M.E. Harmon, et al. 2007. Global-scale similarities in nitrogen release patterns during long-term decomposition. *Science* 315:361–364.

Passioura, J.B. 1988. Response to Dr. P. J. Kramer's article, 'Changing concepts regarding plant water relations'. *Plant, Cell and Environment* 11:569–571.

Pastor, J., J.D. Aber, C.A. McClaugherty, and J.M. Melillo. 1984. Aboveground primary production and N and P cycling along a nitrogen mineralization gradient on Blackhawk Island, Wisconsin. *Ecology* 65:256–268.

Pastor, J., R.J. Naiman, B. Dewey, and P. McInnes. 1988. Moose, microbes, and the boreal forest. *BioScience* 38:770–777.

Pastor, J., Y. Cohen, and N.T. Hobbs. 2006. The roles of large herbivores in ecosystem nutrient cycles. Pages 289–325 *in* K. Danell, editor. *Large Herbivore Ecology, Ecosystem Dynamics and Conservation*. Cambridge University Press, Cambridge.

Paton, T.R., G.S. Humphreys, and P.B. Mitchell. 1995. *Soils: A New Global View*. Yale University Press, New Haven.

Patz, J.A., U.E.C. Confalonieri, F.P. Amerasinghe, K.B. Chua, P. Daszak, et al. 2005. Human health: Ecosystem regulation of infectious diseases. Pages 391–415 *in* R. Hassan, R.J. Scholes, and N. Ash, editors. *Ecosystems and Well-Being: Current State and Trends, Volume 1*. Island Press, Washington.

Paul, E.A. and F.E. Clark. 1996. *Soil Microbiology and Biochemistry*. 2nd edition. Academic Press, San Diego.

Pauly, D. and V. Christensen. 1995. Primary production required to sustain global fisheries. *Nature* 374: 255–257.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres, Jr. 1998. Fishing down marine food webs. *Science* 279:860–863.

Pauly, D., J. Alder, A. Bakun, S. Heileman, K.-H. Kock, et al. 2005. Marine fisheries systems. Pages 477–511 *in* R. Hassan, R.J. Scholes, and N. Ash, editor. *Ecosystems and Human Well-Being: Current State and Trends*. Island Press, Washington.

Payette, S. and L. Filion. 1985. White spruce expansion at the tree line and recent climatic change. *Canadian Journal of Forest Research* 15:241–251.

Pearcy, R.W. 1990. Sunflecks and photosynthesis in plant canopies. *Annual Review of Plant Physiology* 41:421–453.

Pearson, P.N. and M.R. Palmer. 2000. Atmosphere carbon dioxide concentrations over the past 60 million years. *Nature* 406:695–699.

Peltzer, D.A., P.J. Bellingham, H. Kurokawa, L.R. Walker, D.A. Wardle, et al. 2009. Punching above their weight: Low-biomass non-native plant species alter soil properties during primary succession. *Oikos* 118: 1001–1014.

Penning de Vries, F.W.T., A.H.M. Brunsting, and H.H. van Laar. 1974. Products, requirements, and efficiency of biosynthesis: A quantitative approach. *Journal of Theoretical Biology* 45:339–377.

Penning de Vries, F.W.T. 1975. The cost of maintenance processes in plant cells. *Annals of Botany* 39:77–92.

Perakis, S.S. and L.O. Hedin. 2002. Nitrogen loss from unpolluted South American forests mainly via dissolved organic compounds. *Nature* 415:416–419.

Perez-Harguindeguy, N., S. Díaz, J.H.C. Cornelissen, F. Vendramini, M. Cabido, et al. 2000. Chemistry and toughness predict leaf litter decomposition rates over a wide spectrum of functional types and taxa in central Argentina. *Plant and Soil* 218:21–30.

Perry, G.L.W. and N.J. Enright. 2006. Spatial modelling of vegetation change in dynamic landscapes: A review of methods and applications. *Progress in Physical Geography* 30:43–72.

Peters, D.P.C., R.A. Pielke, Sr., B.T. Bestelmeyer, C.D. Allen, S. Munson-McGee, et al. 2004. Cross-scale interactions, nonlinearities, and forecasting catastrophic events. *Proceedings of the National Academy of Sciences, USA* 101:15130–15135.

Peters, D.P.C., J.R. Gosz, and S.L. Collins. 2009. Boundary dynamics in landscapes. Pages 458–463 *in* S.A. Levin, S.R. Carpenter, H.C.J. Godfray, A.P. Kinzig, M. Loreau, et al., editors. *Princeton Guide to Ecology*. Princeton University Press, Princeton.

Peters, D.P.C., A.E. Lugo, F.S. Chapin, III, S.T.A. Pickett, M. Duniway, et al. 2011. Cross-system comparisons elucidate disturbance complexities and generalities. *Ecosphere* 2(7):art81. doi:10-1890/ES11-00115.1.

Peterson, B.J., J.E. Hobbie, and T.J. Corliss. 1986. Carbon flow in a tundra stream ecosystem. *Canadian Journal of Fisheries and Aquatic Sciences* 43:1259–1270.

Peterson, B.J., W.M. Wolheim, P.J. Mujlholland, J.R. Webster, J.L. Meyer, et al. 2001. Control of nitrogen export from watersheds by headwater streams. *Science* 292:86–90.

Peterson, G.D., C.R. Allen, and C.S. Holling. 1998. Ecological resilience, biodiversity, and scale. *Ecosystems* 1:6–18.

Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: A tool for conservation in an uncertain world. *Conservation Biology* 17:358–366.

Petit, J.R., J. Jouzel, D. Raynaud, N.I. Barkov, J.M. Barnola, et al. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature* 399:429–436.

Piao, S., P. Ciais, P. Friedlingstein, P. Peylin, M. Reichstein, et al. 2008. Net carbon dioxide losses of northern ecosystems in response to autumn warming. *Nature* 451:49–53.

Piao, S., P. Friedlingstein, P. Ciais, P. Peylin, B. Zhu, et al. 2009. Footprint of temperature changes in the temperate and boreal forest carbon balance. *Geophysical Research Letters* 36:L07404, doi:07410.01029/02009GL037381.

Pickett, S.T.A. and P.S. White. 1985. *The Ecology of Natural Disturbance as Patch Dynamics*. Academic Press, New York.

Pickett, S.T.A., S.L. Collins, and J.J. Armesto. 1987. A hierarchical consideration of causes and mechanisms of succession. *Vegetatio* 69:109–114.

Pickett, S.T.A., J. Kolasa, and C.G. Jones. 1994. *Ecological Understanding. The Nature of Theory and the Theory of Nature*. Academic Press, New York.

Pielke, R.A., Sr. and R. Avisar. 1990. Influence of landscape structure on local and regional climate. *Landscape Ecology* 4:133–156.

Pimm, S.L. 1982. *Food Webs*. Chapman and Hall, New York.

Pimm, S.L. 1984. The complexity and stability of ecosystems. *Nature* 307:321–326.

Pimm, S.L., G.J. Russell, J.L. Gittleman, and T.M. Brooks. 1995. The future of biodiversity. *Science* 269:347–350.

Pires, M. 2004. Watershed protection for a world city: The case of New York. *Land Use Policy* 21:161–175.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, et al. 1997. The natural flow regime: A paradigm for river conservation and restoration. *BioScience* 47:769–784.

Polis, G.A. 1991. Complex trophic interactions in deserts: An empirical critique of food-web theory. *American Naturalist* 138:123–155.

Polis, G.A. and S.D. Hurd. 1996. Linking marine and terrestrial food webs: Allochthonous input from the ocean supports high secondary productivity on small islands and coastal land communities. *American Naturalist* 147:396–423.

Polis, G.A. 1999. Why are parts of the world green? Multiple factors control productivity and the distribution of biomass. *Oikos* 86:3–15.

Pomeroy, J., N. Hedstrom, and J. Parviainen. 1999. The snow mass balance of Wolf Creek, Yukon: Effects of snow sublimation and redistribution. Pages 15–30 *in* J.W. Pomeroy and R.J. Granger, editors. *Wolf Creek Research Basin: Hydrology, Ecology, Environment*. National Water Research Institute, Environment Canada, Saskatoon.

Pons, T.L., K. Perreijn, C. van Kessel, and M.J.A. Werger. 2006. Symbiotic nitrogen fixation in a tropical rainforest: ^{15}N natural abundance measurements supported by experimental isotopic enrichment. *New Phytologist* 173:154–167.

Poorter, H. 1994. Construction costs and payback time of biomass: A whole-plant perspective. Pages 111–127 *in* J. Roy and E. Garnier, editors. *A Whole-Plant Perspective on Carbon-Nitrogen Interactions*. SPB Academic Publishing, The Hague.

Porder, S., A. Paytan, and P.M. Vitousek. 2005. Erosion and landscape development affect plant nutrient status in the Hawaiian Islands. *Oecologia* 142:440–449.

Post, D.M., M.L. Pace, and N.G. Hairston. 2000. Ecosystem size determines food-chain length in lakes. *Nature* 405:1047–1049.

Post, W.M., W.R. Emanuel, P.J. Zinke, and A.G. Stangenberger. 1982. Soil carbon pools and world life zones. *Nature* 298:156–159.

Postel, S.L., G.C. Daily, and P.R. Ehrlich. 1996. Human appropriation of renewable fresh water. *Science* 271:785–788.

Postel, S.L. and B. Richter. 2003. *Rivers for Life: Managing Water for People and Nature*. Island Press, Washington.

Potter, C.S., J.T. Randerson, C.B. Field, P.A. Matson, P.M. Vitousek, et al. 1993. Terrestrial ecosystem production:

A process model based on global satellite and surface data. *Global Biogeochemical Cycles* 7:811–841.

Power, M.E. 1990. Effects of fish in river food webs. *Science* 250:411–415.

Power, M.E. 1992a. Hydrologic and trophic controls of seasonal algal blooms in northern California rivers. *Archivs fur Hydrobiologie* 125:385–410.

Power, M.E. 1992b. Top-down and bottom-up forces in food webs: Do plants have primacy? *Ecology* 73:733–746.

Power, M.E., D. Tilman, J.A. Estes, B.A. Menge, W.J. Bond, et al. 1996. Challenges in the quest for keystones. *BioScience* 46:609–620.

Prentice, I.C., W. Cramer, S.P. Harrison, R. Leemans, R.A. Monserud, et al. 1992. A global biome model based on plant physiology and dominance, soil properties and climate. *Journal of Biogeography* 19:117–134.

Prentice, I.C., G.D. Farquhar, M.J.R. Fasham, M.L. Goulden, M. Heimann, et al. 2001. The carbon cycle and atmospheric carbon dioxide. Pages 183–237 *in* J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, et al., editors. *Climate Change 2001: The Scientific Basis*. Cambridge University Press, Cambridge.

Prescott, C.E. 1995. Does nitrogen availability control rates of litter decomposition in forests? *Plant and Soil* 168–169:83–88.

Prescott, C.E., R. Kabzems, and L.M. Zabek. 1999. Effects of fertilization on decomposition rate of *Populus tremuloides* foliar litter in a boreal forest. *Canadian Journal of Forest Research* 29:393–397.

Press, F. and R. Siever. 1986. *Earth*. 4th edition. W. H. Freeman and Company, New York.

Pugnaire, F.I. and F.S. Chapin, III. 1992. Environmental and physiological factors governing nutrient resorption efficiency in barley. *Oecologia* 90:120–126.

Raab, T.K., D.A. Lipson, and R.K. Monson. 1999. Soil amino acid utilization among species of the Cyperaceae: Plant and soil processes. *Ecology* 80:2408–2419.

Rabalais, N.N., R.E. Turner, and W.J. Wiseman, Jr. 2002. Gulf of Mexico hypoxia, A.K.A. "The dead zone". *Annual Review of Ecology and Systematics* 33: 235–263.

Raffa, K.F., B.H. Aukema, B.J. Bentz, A.L. Carroll, J.A. Hicke, et al. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions. *BioScience* 58:501–517.

Raich, J.W. and W.H. Schlesinger. 1992. The global carbon dioxide flux in soil respiration and its relationship to climate. *Tellus* 44B:81–99.

Raich, J.W., A.E. Russell, and P.M. Vitousek. 1997. Primary production and ecosystem development along an elevational gradient in Hawaii. *Ecology* 78:707–721.

Ramakrishnan, P.S. 1992. *Shifting Agriculture and Sustainable Development: An Interdisciplinary Study from North-Eastern India*. Parthenon Publishing Group, Park Ridge, NJ.

Randerson, J.T., F.S. Chapin, III, J. Harden, J.C. Neff, and M.E. Harmon. 2002. Net ecosystem production: A comprehensive measure of net carbon accumulation by ecosystems. *Ecological Applications* 12:937–947.

Raper, C.D., Jr., D.L. Osmond, M. Wann, and W.W. Weeks. 1978. Interdependence of root and shoot activities in determining nitrogen uptake rate of roots. *Botanical Gazette* 139:289–294.

Rastetter, E.B. and G.R. Shaver. 1992. A model of multiple-element limitation for acclimating vegetation. *Ecology* 73:1157–1174.

Read, D.J. and R. Bajwa. 1985. Some nutritional aspects of the biology of ericaceous mycorrhizas. *Proceedings of the Royal Society of Edinburgh* 85B:317–332.

Read, D.J. 1991. Mycorrhizas in ecosystems. *Experientia* 47:376–391.

Redfield, A.C. 1958. The biological control of chemical factors in the environment. *American Scientist* 46:205–221.

Reeburgh, W.S. 1997. Figures summarizing the global cycles of biogeochemically important elements. *Bulletin of the Ecological Society of America* 78:260–267.

Reich, P.B., M.B. Walters, and D.S. Ellsworth. 1997. From tropics to tundra: Global convergence in plant functioning. *Proceedings of the National Academy of Sciences, USA* 94:13730–13734.

Reich, P.B., D.S. Ellsworth, M.B. Walters, J.M. Vose, C. Gresham, et al. 1999. Generality of leaf trait relationships: A test across six biomes. *Ecology* 80: 1955–1969.

Reich, P.B. and J. Oleksyn. 2004. Global patterns of plant leaf N and P in relation to temperature and latitude. *Proceedings of the National Academy of Sciences, USA* 101:11001–11006.

Reich, P.B., S.E. Hobbie, T. Lee, D.W. Ellsworth, J.B. West, et al. 2006. Nitrogen limitation constrains sustainability of ecosystem response to CO_2. *Nature* 440:922–925.

Reichstein, M., D. Papale, R. Valentini, M. Aubinet, C. Bernhofer, et al. 2007. Determinants of terrestrial ecosystem carbon balance inferred from European eddy covariance flux sites. *Geophysical Research Letters* 34:L01402, doi:01410.01029/02006GL027880.

Reiners, W.A. 1986. Complementary models for ecosystems. *American Naturalist* 127:59–73.

Reynolds, J.F. and J.H.M. Thornley. 1982. A shoot:root partitioning model. *Annals of Botany* 49:585–597.

Reynolds, J.F., D.W. Hilbert, and P.R. Kemp. 1993. Scaling ecophysiology from the plant to the ecosystem: A conceptual framework. Pages 127–140 *in* J.R. Ehleringer and C.B. Field, editors. *Scaling Physiological Processes: Leaf to Globe*. Academic Press, San Diego.

Reynolds, J.F. and D.M. Stafford Smith, editors. 2002. *Global Desertification: Do Humans Cause Deserts?* Dahlem University Press, Berlin.

Rice, E.L. 1979. Allelopathy: An update. *Botanical Review* 45:15–109.

Richardson, A.E., T.S. George, I. Jakobsen, and R.J. Simpson. 2007. Plant utilization of inositol phosphates. Pages 242–260 *in* B.L. Turner, A.E. Richardson, and E.J. Mullaney, editors. *Inositol Phosphates: Linking Agriculture and the Environment*. CABI Publishing, Wallingford.

Richter, D.D., Jr. and D. Markewitz. 2001. *Understanding Soil Change: Soil Sustainability over Millennia, Centuries, and Decades*. Cambridge University Press, Cambridge.

Ricketts, T.H., G.C. Daily, P.R. Ehrlich, and C.D. Michener. 2004. Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences, USA* 101:12579–12582.

Ritchie, M.E., D. Tilman, and J.M.H. Knops. 1998. Herbivore effects on plant and nitrogen dynamics in oak savanna. *Ecology* 79:165–177.

Robertson, G.P. 1989. Nitrification and denitrification in humid tropical ecosystems: Potential controls on nitrogen retention. Pages 55–69 *in* J. Proctor, editor. *Mineral Nutrients in Tropical Forest and Savanna Ecosystems*. Blackwell Scientific, Oxford.

Robertson, G.P., K.M. Klingensmith, M.J. Klug, E.A. Paul, J.R. Crum, et al. 1997. Soil resources, microbial activity, and primary production across an agricultural ecosystem. *Ecological Applications* 7:158–170.

Robertson, G.P. and E.A. Paul. 2000. Decomposition and soil organic matter dynamics. Pages 104–116 *in* O.E. Sala, R.B. Jackson, H.A. Mooney, and R.W. Howarth, editors. *Methods in Ecosystem Science*. Springer-Verlag, New York.

Robertson, G.P. and P.M. Vitousek. 2009. Nitrogen in agriculture: Balancing the cost of an essential resource. *Annual Review of Environment and Resources* 34:97–125.

Robinson, D. 1994. The responses of plants to non-uniform supplies of nutrients. *New Phytologist* 127:635–674.

Robles, M. and F.S. Chapin, III. 1995. Comparison of the influence of two exotic species on ecosystem processes in the Berkeley Hills. *Madrono* 42: 349–357.

Rockström, J., L. Gordon, C. Folke, M. Falkenmark, and M. Engvall. 1999. Linkages among water vapor flows, food production, and terrestrial ecosystem services. *Conservation Ecology* 3:[online] http://www.consecol.org/vol3/iss2/art5.

Rockström, J., W. Steffen, K. Noone, Å. Persson, F.S. Chapin, III, et al. 2009. A safe operating space for humanity. *Nature* 461:472–475.

Rodin, L.E. and N.I. Bazilevich. 1967. *Production and Mineral Cycling in Terrestrial Vegetation*. Oliver and Boyd, Edinburgh, Scotland.

Rosenberg, A.A., M.J. Fogarty, M.P. Sissenwine, J.R. Beddington, and J.G. Shepherd. 1993. Achieving sustainable use of renewable resources. *Science* 262:828–829.

Rosenberg, D.K., B.R. Noon, and E.C. Meslow. 1997. Biological corridors: Form, function, and efficacy. *BioScience* 47:677–687.

Roulet, N.T., P.M. Crill, N.T. Comer, A. Dove, and R.A. Boubonniere. 1997. CO_2 and CH_4 flux between a boreal beaver pond and the atmosphere. *Journal of Geophysical Research* 102:29313–29319.

Rovira, A.D. 1969. Plant root exudates. *Botanical Review* 35:35–56.

Rudel, T.K., O.T. Coomes, E. Moran, F. Achard, A. Angelsen, et al. 2005. Forest transitions: Towards a global understanding of land use change. *Global Environmental Change* 15:23–31.

Ruess, R.W. and S.J. McNaughton. 1987. Grazing and the dynamics of nutrient and energy regulated microbial processes in the Serengeti grasslands. *Oikos* 49:101–110.

Ruess, R.W., D.S. Hik, and R.L. Jefferies. 1989. The role of lesser snow geese as nitrogen processors in a subarctic salt marsh. *Oecologia* 89:23–29.

Ruess, R.W., K. Van Cleve, J. Yarie, and L.A. Viereck. 1996. Contributions of fine root production and turnover to the carbon and nitrogen cycling in taiga forests of the Alaskan interior. *Canadian Journal of Forest Research* 26:1326–1336.

Ruess, R.W., R.L. Hendrick, and J.P. Bryant. 1998. Regulation of fine root dynamics by mammalian browsers in early successional Alaskan taiga forests. *Ecology* 79:2706–2720.

Ruimy, A., P.G. Jarvis, D.D. Baldocchi, and B. Saugier. 1995. CO_2 fluxes over plant canopies and solar radiation: A review. *Advances in Ecological Research* 26:1–53.

Running, S.W., R.R. Nemani, D.L. Peterson, L.E. Band, D.F. Potts, et al. 1989. Mapping regional forest evapotranspiration and photosynthesis by coupling satellite data with ecosystem simulation. *Ecology* 70:1090–1101.

Running, S.W., P.E. Thornton, R.R. Nemani, and J.M. Glassy. 2000. Global terrestrial gross and net primary productivity from the earth observing system. Pages 44–57 *in* O. Sala, R.B. Jackson, and H.A. Mooney, editors. *Methods in Ecosystem Science*. Springer-Verlag, New York.

Running, S.W., R.R. Nemani, F.A. Heinsch, M. Zhao, M. Reeves, et al. 2004. A continuous satellite-derived measure of global terrestrial primary production. *BioScience* 54:547–560.

Rupp, T.S., A.M. Starfield, and F.S. Chapin, III. 2000. A frame-based spatially explicit model of subarctic vegetation response to climatic change: Comparison with a point model. *Landscape Ecology* 15:383–400.

Ruttenberg, K.C. 2004. The global phosphorus cycle. Pages 585–643 *in* W.H. Schlesinger, editor. *Biogeochemistry*. Elsevier, Amsterdam.

Rutter, A.J., P.C. Robins, A.J. Morton, and K.A. Kershaw. 1971. Predictive model of rainfall interception in forests, 1. Derivation of the model from observations in a plantation of Corsican pine. *Agricultural Meteorology* 9:367–384.

Ryan, M.G., S. Linder, J.M. Vose, and R.M. Hubbard. 1994. Respiration of pine forests. *Ecological Bulletin* 43:50–63.

Ryan, M.G., D. Binkley, and J.H. Fownes. 1997. Age-related decline in forest productivity: Pattern and process. *Advances in Ecological Research* 27:213–262.

Sabine, C.L., M. Heiman, P. Artaxo, D.C.E. Bakker, C.-T.A. Chen, et al. 2004. Current status and past trends of the carbon cycle. Pages 17–44 *in* C.B. Field and M.R. Raupach, editors. *The Global Carbon Cycle:*

Integrating Humans, Climate and the Natural World. Island Press, Washington.

Sage, R.F. 2004. The evolution of C_4 photosynthesis. *New Phytologist* 161:341–370.

Sala, O.E., W.K. Lauenroth, S.J. McNaughton, G. Rusch, and X. Zhang. 1996. Biodiversity and ecosystem functioning in grasslands. Pages 129–149 *in* H.A. Mooney, J.H. Cushman, E. Medina, O.E. Sala, and E.-D. Schulze, editors. *Functional Role of Biodiversity: A Global Perspective*. John Wiley & Sons, Chichester.

Sala, O.E., R.B. Jackson, H.A. Mooney, and R.W. Howarth, editors. 2000. *Methods in Ecosystem Science*. Springer-Verlag, New York.

Saleska, S.R., K. Didan, A.R. Huete, and H.R. da Rocha. 2007. Amazon forests green-up during 2005 drought. *Science* 318:612.

Sampson, R.N., N. Bystriakova, S. Brown, P. Gonzalez, L. C. Irland, et al. 2005. Timber, fuel, and fiber. Pages 585–621 *in* R. Hassan, R. J. Scholes, and N. Ash, editors. Ecosystems and Human Well-Being: Current State and Trends. Cambridge University Press, Cambridge.

Sanchez, P.A. 2010. Tripling crop yields in tropical Africa. *Nature Geoscience* 3:299–300.

Sarmiento, J.L. and N. Gruber. 2006. *Ocean Biogeochemical Dynamics*. Princeton University Press, Princeton.

Saugier, B., J. Roy, and H.A. Mooney. 2001. Estimations of global terrestrial productivity: Converging toward a single number? Pages 543–557 *in* J. Roy, B. Saugier, and H.A. Mooney, editors. *Terrestrial Global Productivity*. Academic Press, San Diego.

Saura, S. and L. Pascual-Hortal. 2007. A new habitat availability index to integrate connectivity in landscape conservation planning: comparison with existing indices and application to a case study. *Landscape and Urban Planning* 83:91–103.

Sayre, N. 2005. *Working Wilderness: The Malpai Borderlands Group Story and the Future of the Western Range*. Rio Nuevo Press, Tucson, AZ.

Scatena, F.N., S. Moya, C. Estrada, and J.D. Chinea. 1996. The first five years in the reorganization of aboveground biomass and nutrient use following Hurricane Hugo in the Bisley Experimental Watersheds, Luquillo Experimental Forest, Puerto Rico. *Biotropica* 28:424–440.

Schaefer, D.A., W.H. McDowell, F.N. Scatena, and C.E. Asbury. 2000. Effects of hurricane disturbance on stream water concentrations and fluxes in eight tropical forest watersheds of the Luquillo Experimental Forest, Puerto Rico. *Journal of Tropical Ecology* 16:189–207.

Scheffer, M. and S.R. Carpenter. 2003. Catastrophic regime shifts in ecosystems: Linking theory to observation. *Trends in Ecology & Evolution* 18:648–656.

Scheffer, M., G.J. van Geest, K. Zimmer, E. Jeppsen, M. Sondergaard, et al. 2006. Small habitat size and isolation can promote species richness: Second-order effects on biodiversity in shallow lakes and ponds. *Oikos* 112:227–231.

Schenk, H.J. and R.B. Jackson. 2002. Rooting depths, lateral root spreads and below-ground/above-ground allometries of plants in water-limited ecosystems. *Journal of Ecology* 90:480–494.

Schimel, D.S. 1995. Terrestrial ecosystems and the carbon cycle. *Global Change Biology* 1:77–91.

Schimel, D.S., J.I. House, K.A. Hibbard, P. Bousquet, P. Ciais, et al. 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. *Nature* 414:169–172.

Schimel, J.P., K. Van Cleve, R.G. Cates, T.P. Clausen, and P.B. Reichardt. 1996. Effects of balsam poplar *(Populus balsamifera)* tannins and low molecular weight phenolics on microbial activity in taiga floodplain soil: Implications for changes in N cycling during succession. *Canadian Journal of Botany* 74:84–90.

Schimel, J.P. 2001. Biogeochemical models: Implicit vs. explicit microbiology. Pages 177–183 *in* E.-D. Schulze, S.P. Harrison, M. Heimann, E.A. Holland, J.J. Lloyd, et al., editors. *Global Biogeochemical Cycles in the Climate System*. Academic Press, San Diego.

Schimel, J.P. and J. Bennett. 2004. Nitrogen mineralization: Challenges of a changing paradigm. *Ecology* 85:591–602.

Schimper, A.F.W. 1898. *Pflanzengeographie auf Physiologischer Grundlage*. Fisher, Jena, Germany.

Schindler, D.W. 1971. Carbon, nitrogen, and phosphorus and the eutrophication of freshwater lakes. *Journal of Phycology* 7:321–329.

Schindler, D.W. 1974. Eutrophication and recovery in experimental lakes: Implications for lake management. *Science* 184:897–899.

Schindler, D.W. 1978. Factors regulating phytoplankton production and standing crop in the world's lakes. *Limnology and Oceanography* 23:478–486.

Schindler, D.W. 1985. The coupling of elemental cycles by organisms: Evidence from whole-lake chemical perturbations. Pages 225–250 *in* W. Stumm, editor. *Chemical Processes in Lakes*. Wiley Press, New York.

Schindler, D.W., R.E. Hecky, D.L. Findlay, M.P. Stainton, B.R. Parker, et al. 2008. Eutrophication of lakes cannot be controlled by reducing nitrogen inputs: Results of a 37-year whole-ecosystem experiment. *Proceedings of the National Academy of Sciences, USA* 105: 11254–11258.

Schippers, P., M. Lurling, and M. Scheffer. 2004. Increase in atmospheric CO_2 promotes phytoplankton productivity. *Ecology Letters* 7:446–451.

Schlesinger, W.H. 1977. Carbon balance in terrestrial detritus. *Annual Review of Ecology and Systematics* 8:51–81.

Schlesinger, W.H., J.F. Reynolds, G.L. Cunningham, L.F. Huenneke, W.M. Jarrell, et al. 1990. Biological feedbacks in global desertification. *Science* 247: 1043–1048.

Schlesinger, W.H. 1997. *Biogeochemistry: An Analysis of Global Change*. 2nd edition. Academic Press, San Diego.

Schlesinger, W.H. 2000. Carbon sequestration in soils: Some cautions amidst optimism. *Agriculture, Ecosystems and Environment* 82:121–127.

Schmidt, M.W.I., M.S. Torn, S. Abiven, T. Dittmar, G. Guggenberger, et al. in press. Environment as a dominant control in soil organic matter dynamics. *Nature*.

Schmitz, O.A., P.A. Hambäck, and A.P. Beckerman. 2000. Trophic cascades in terrestrial systems: A review of the effects of carnivore removals on plants. *American Naturalist* 155:141–153.

Schmitz, O.J. 2009. Effects of predator functional diversity on grassland ecosystem function. *Ecology* 90:2339–2345.

Schoennagel, T., T.T. Veblen, and W.H. Romme. 2004. The interaction of fire, fuels, and climate across Rocky Mountain forests. *BioScience* 54:661–676.

Schubert, S.D., M.J. Suarez, P.J. Pegion, R.D. Koster, and J.T. Bacmeister. 2004. On the cause of the 1930s dust bowl. *Science* 303:1855–1859.

Schuh, A.E., A.S. Denning, K.D. Corbin, I.T. Baker, M. Uliasz, et al. 2010. A regional high-resolution carbon flux inversion of North America for 2004. *Biogeosciences* 7:1625–1644.

Schulze, E.-D. and F.S. Chapin, III. 1987. Plant specialization to environments of different resource availability. Pages 120–148 *in* E.-D. Schulze and H. Zwolfer, editors. *Potentials and Limitations in Ecosystem Analysis*. Springer-Verlag, Berlin.

Schulze, E.-D., R.H. Robichaux, J. Grace, P.W. Rundel, and J.R. Ehleringer. 1987. Plant water balance. *BioScience* 37:30–37.

Schulze, E.-D. 1989. Air pollution and forest decline in a spruce (*Picea abies*) forest. *Science* 244:776–783.

Schulze, E.-D., F.M. Kelliher, C. Körner, J. Lloyd, and R. Leuning. 1994. Relationship among maximum stomatal conductance, ecosystem surface conductance, carbon assimilation rate, and plant nitrogen nutrition: A global ecology scaling exercise. *Annual Review of Ecology and Systematics* 25:629–660.

Schuur, E.A.G. 2003. Productivity and global climate revisited: The sensitivity of tropical forest growth to precipitation. *Ecology* 84:1165–1170.

Schuur, E.A.G., J. Bockheim, J. Canadell, E.S. Euskirchen, C. Field, et al. 2008. The vulnerability of permafrost carbon to climate change: Implications for the global carbon cycle. *BioScience* 58:701–714.

Schuur, E.A.G., J.G. Vogel, K.G. Crummer, H. Lee, J.O. Sickman, et al. 2009. The effect of permafrost thaw on old carbon release and net carbon exchange from tundra. *Nature* 459:556–559.

Schwoerbel, J. 1987. *Handbook of Limnology*. 5th edition. Halsted Press, New York.

Scurlock, J.M.O. and R.J. Olson. 2002. Terrestrial net primary productivity: A brief history and a new worldwide database. *Environmental Reviews* 10: 91–109.

Seagle, S.W. 2003. Can deer foraging in multiple-use landscapes alter forest nitrogen budgets? *Oikos* 103:230–234.

Seastedt, T.R. 1985. Canopy interception of nitrogen in bulk precipitation by annually burned and unburned tallgrass prairie. *Oecologia* 66:88–92.

Seitzinger, S.P., J.A. Harrison, E. Dumont, A.H.W. Beusen, and A.F. Bouwman. 2005. Sources and delivery of carbon, nitrogen, and phosphorus to the coastal zone: An overview of Global Nutrient Export from Watersheds (NEWS) models and their application. *Global Biogeochemical Cycles* 19:GB4S01, doi: 10.1029/2005GB002606.

Selby, M.J. 1993. *Hillslope Materials and Processes*. 2nd edition. Oxford University Press, Oxford.

Semikhatova, O.A. 2000. Ecological physiology of plant dark respiration: Its past, present and future. *Botanishcheskii Zhurnal* 85:15–32.

Serreze, M.C. 2010. Understanding recent climate change. *Conservation Biology* 24:10–17.

Shaver, G.R., K.J. Nadelhoffer, and A.E. Giblin. 1991. Biogeochemical diversity and element transport in a heterogeneous landscape, the North Slope of Alaska. Pages 105–126 *in* M.G. Turner and R.H. Gardner, editors. *Quantitative Methods in Landscape Ecology*. Springer-Verlag, New York.

Shaver, G.R., W.D. Billings, F.S. Chapin, III, A.E. Giblin, K.J. Nadelhoffer, et al. 1992. Global change and the carbon balance of arctic ecosystems. *BioScience* 61:415–435.

Shaver, G.R., J. Canadell, F.S. Chapin, III, J. Gurevitch, J. Harte, et al. 2000. Global warming and terrestrial ecosystems: A conceptual framework for analysis. *BioScience* 50:871–882.

Shiro, T. and R. del Moral. 1995. Species attributes in early primary succession on volcanoes. *Journal of Vegetation Science* 6:517–522.

Shvidenko, A., D.V. Barber, and R. Persson. 2005. Forest and woodland systems. Pages 585–621 *in* R. Hassan, R.J. Scholes, and N. Ash, editors. *Ecosystems and Human Well-Being: Current State and Trends, Volume 1*. Island Press, Washington.

Sigman, D.M. and E.A. Boyle. 2000. Glacial/interglacial variations in atmospheric carbon dioxide. *Nature* 407:859–869.

Silver, W.L., D.J. Herman, and M.K. Firestone. 2001. Dissimilatory nitrate reduction to ammonium in upland tropical rain forest soils. *Ecology* 82:2410–2416.

Silvola, J., J. Alm, U. Ahlholm, H. Nykanen, and P.J. Martikainen. 1996. CO_2 fluxes from peat in boreal mires under varying temperature and moisture conditions. *Journal of Ecology* 84:219–228.

Simard, M., W.H. Romme, J.M. Griffin, and M.G. Turner. 2011. Do mountain pine beetle outbreaks change the probability of active crown fire in lodgepole pine forests? *Ecological Monographs* 81:3–24.

Simard, S.W., D.A. Perry, M.D. Jones, D.D. Myrold, D.M. Durall, et al. 1997. Net transfer of carbon between ectomycorrhizal tree species in the field. *Nature* 388:579–582.

Sinclair, A.R.E. 1979. The eruption of the ruminants. Pages 82–103 *in* A.R.E. Sinclair and M. Norton-Griffiths, editors. *Serengeti: Dynamics of an Ecosystem*. University of Chicago Press, Chicago.

Sinclair, A.R.E. and M. Norton-Griffiths. 1979. Dynamics of the Serengeti Ecosystem. Pages 1–30 *in* A.R.E. Sinclair

and M. Norton-Griffiths, editors. *Serengeti: Dynamics of an Ecosystem*. University of Chicago, Chicago.

Singer, F., W. Swank, and E. Clebsch. 1984. Effects of wild pig rooting in a deciduous forest. *Journal of Wildlife Management* 48:464–473.

Sinsabaugh, R.L., C.L. Lauber, M.N. Weintraub, B. Ahmed, S.D. Allison, et al. 2008. Stoichiometry of soil enzyme activity at global scale. *Ecology Letters* 11:1252–1264.

Smart, D.R. and A.J. Bloom. 1988. Kinetics of ammonium and nitrate uptake among wild and cultivated tomatoes. *Oecologia* 76:336–340.

Smil, V. 2000. Phosphorus in the environment: Natural flows and human interferences. *Annual Review of Energy in the Environment* 25:53–88.

Smirnoff, N., P. Todd, and G.R. Stewart. 1984. The occurrence of nitrate reduction in the leaves of woody plants. *Annals of Botany* 54:363–374.

Smit, B. and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16:282–292.

Smith, J.L. and E.A. Paul. 1990. The significance of soil microbial biomass estimations. Pages 357–396 *in* J. Bollag and G. Stotsky, editors. *Soil Biochemistry*. Marcel Dekker, New York.

Smith, S.E. and D.J. Read. 1997. *Mycorrhizal Symbiosis*. Academic Press, London.

Smithwick, E.A.H., M.C. Mack, M.G. Turner, F.S. Chapin, III, J. Zhu, et al. 2005. Spatial heterogeneity and soil nitrogen dynamics in a burned black spruce forest stand: Distinct controls at different scales. *Biogeochemistry* 76:517–537.

Solomon, S., G.-K. Plattner, R. Knutti, and P. Friedlingstein. 2009. Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences, USA* 106:1704–1709.

Soluck, D.A. and J.S. Richardson. 1997. The role of stoneflies in enhancing growth of trout: A test of the importance of predator-predator facilitation within a stream community. *Oikos* 80:214–219.

Sowden, F., Y. Chen, and M. Schnitzer. 1977. The nitrogen distribution in soils formed under widely differing climatic conditions. *Geochimica et Cosmochimica Acta* 41:1524–1526.

Sperry, J.S. 1995. Limitations on stem water transport and their consequences. Pages 105–124 *in* B.L. Gartner, editor. *Plant Stems: Physiology and Functional Morphology*. Academic Press, San Diego.

Sperry, J.S., F.C. Meinzer, and K.A. McCulloh. 2008. Safety and efficiency conflicts in hydraulic architecture: Scaling from tissues to trees. *Plant, Cell & Environment* 31:632–635.

Sprugel, D.G. 1976. Dynamic structure of wave-generated *Abies balsamea* forests in the northeastern United States. *Journal of Ecology* 64:880–911.

St. Louis, V.L., C.A. Kelly, E. Duchemin, J.W.M. Rudd, and D.M. Rosenberg. 2000. Reservoir surfaces as sources of greenhouse gases to the atmosphere: A global estimate. *BioScience* 50:766–775.

Stafford Smith, D.M., N. Abel, B. Walker, and F.S. Chapin, III. 2009. Drylands: Coping with uncertainty, thresholds, and changes in state. Pages 171–195 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New Work.

Stanford, G. and E. Epstein. 1974. Nitrogen mineralization-water relations in soils. *Soil Science Society of America Journal* 38:103–107.

Starfield, A.M. 1991. Qualitative rule-based modeling. *BioScience* 40:601–604.

Starfield, A.M. and A.L. Bleloch. 1991. *Building Models for Conservation and Wildlife Management*. 2nd edition. Burgess Press, Edina, MN.

Stark, J.M. and M.K. Firestone. 1995. Mechanisms for soil moisture effects on nitrifying bacteria. *Applied Environmental Microbiology* 61:218–221.

Stark, J.M. and S.C. Hart. 1997. High rates of nitrification and nitrate turnover in undisturbed coniferous forests. *Nature* 385:61–64.

Steele, J.H. 1991. Can ecological theory cross the land-sea boundary? *Journal of Theoretical Biology* 153:425–436.

Steffen, W.L., A. Sanderson, P.D. Tyson, J. Jäger, P.A. Matson, et al. 2004. *Global Change and the Earth System: A Planet under Pressure*. Springer-Verlag, New York.

Steiner, K. 1982. *Intercropping in Tropical Smallholder Agriculture with Special Reference to West Africa*. German Agency for Technical Cooperation (GTZ), Eschborn, Germany.

Stephens, B.B. and R.F. Keeling. 2000. The influence of Antarctic sea ice on glacial-interglacial CO_2 variations. *Nature* 404:171–174.

Stern, N. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge.

Sterner, R.W. and J.J. Elser. 2002. *Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere*. Princeton University Press, Princeton.

Sterner, R.W. 2008. On the phosphorus limitation paradigm for lakes. *International Review of Hydrobiology* 93:433–445.

Stevenson, F.J. 1994. *Humus Chemistry: Genesis, Composition, Reactions*. 2nd edition. Wiley, New York.

Still, C.J., J.A. Berry, G.J. Collatz, and R.S. DeFries. 2003. Global distribution of C_3 and C_4 vegetation: Carbon cycle implications. *Global Biogeochemical Cycles* 17:doi:10.1029/2001GB001807.

Stock, W.D. and O.A.M. Lewis. 1984. Uptake and assimilation of nitrate and ammonium by an evergreen Fynbos shrub species *Protea repens* L. (Proteaceae). *New Phytologist* 97:261–268.

Stocker, R., J.R. Seymour, A. Samadani, D.E. Hunt, and M.F. Polz. 2008. Rapid chemotactic response enables marine bacteria to exploit microscale nutrient patches. *Proceedings of the National Academy of Sciences, USA* 105:4209–4214.

Stokes, D.E. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Brookings Institution Press, Washington.

Stramma, L., G.C. Johnson, J. Sprintal, and V. Mohrholz. 2008. Expanding oxygen-minimum zones in the tropical oceans. *Science* 320:655–658.

Strayer, D.L., N.F. Caraco, J.J. Cole, S. Findlay, and M.L. Pace. 1999. Transformation of freshwater ecosystems by bivalves. *BioScience* 49:19–27.

Strayer, D.L., R.E. Beighley, L.C. Thompson, A. Brooks, C. Nilsson, et al. 2003. Effects of land cover on stream ecosystems: Roles of empirical models and scaling issues. *Ecosystems* 6:407–423.

Strong, D.R. 1992. Are trophic cascades all wet? Differentiation and donor-control in speciose ecosystems. *Ecology* 73:747–754.

Sturm, M., J.P. McFadden, G.E. Liston, F.S. Chapin, III, J. Holmgren, et al. 2001. Snow-shrub interactions in arctic tundra: A feedback loop with climatic implications. *Journal of Climate* 14:336–344.

Sturman, A.P. and N.J. Tapper. 1996. *The Weather and Climate of Australia and New Zealand*. Oxford University Press, Oxford.

Sucoff, E. 1972. Water potential in red pine: Soil moisture, evapotranspiration, crown position. *Ecology* 52:681–686.

Suding, K.N., S. Lavorel, F.S. Chapin, III, J.H.C. Cornelissen, S. Díaz, et al. 2008. Scaling environmental change through the community level: A trait-based response- and-effect framework for plants. *Global Change Biology* 14:1125–1140.

Sun, J.M., K.E. Kohfield, and S.P. Harrison. 2000. *Records of aeolian dust deposition on the Chinese Loess Plateau during the Quaternary*. Max-Planck Instutut für Biogeochemie Technical Reports.

Sundquist, E.T. and K. Visser. 2004. The geologic history of the carbon cycle. Pages 425–472 *in* W.H. Schlesinger, editor. *Biogeochemistry*. Elsevier, Amsterdam.

Sutherland, W.J. 2000. *The Conservation Handbook: Research, Management and Policy*. Blackwell Scientific, Oxford.

Sutton, M.A., D. Smpson, P.E. Levy, R.I. Smith, S. Fres, et al. 2008. Uncertainties in the relationship between atmospheric nitrogen deposition and forest carbon sequestration. *Global Change Biology* 14:2057–2063.

Swank, W.T. and J.E. Douglass. 1974. Streamflow greatly reduced by converting deciduous hardwood stands to pine. *Science* 185:857–859.

Swanson, F.J. and F.S. Chapin, III. 2009. Forest Systems: Living with long-term change. Pages 149–170 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Swift, M.J., O.W. Heal, and J.M. Anderson. 1979. *Decomposition in Terrestrial Ecosystems*. Blackwell Scientific Publications, Ltd., Oxford.

Syvitski, J.P.M., C.J. Vörösmarty, A.J. Kettner, and P.A. Green. 2005. Impact of humans on the flux of terrestrial sediment to the global coastal ocean. *Science* 308:376–380.

Szaro, R.C., N.D. Johnson, W.T. Sexton, and A.J. Malk, editors. 1999. *Ecological Stewardship: A Common Reference for Ecosystem Management*. Elsevier Science Ltd, Oxford.

Tallis, H., P. Kareiva, M. Marvier, and A. Chang. 2008. An ecosystem services framework to support both practical conservation and economic development. *Proceedings of the National Academy of Sciences, USA* 105:9457–9464.

Tans, P.P., I.Y. Fung, and T. Takahashi. 1990. Observational constraints on the global CO_2 budget. *Science* 247:1431–1438.

Tansley, A.G. 1935. The use and abuse of vegetational concepts and terms. *Ecology* 16:284–307.

Tarnocai, C., J.G. Canadell, E.A.G. Schuur, P. Kuhry, G. Mazhitova, et al. 2009. Soil organic carbon pools in the northern circumpolar permafrost region. Global Biogeochemical Cycles 23:GB2023, doi:2010.1029/2008GB003327.

Taylor, B.R., D. Parkinson, and W.F.J. Parsons. 1989. Nitrogen and lignin as predictors of litter decay rates: A microcosm test. *Ecology* 70:97–104.

Taylor, D.L., I.C. Herriott, K.E. Stone, J.W. McFarland, M.G. Booth, et al. 2010. Structure and resilience of fungal communities in Alaskan boreal forest soils. *Canadian Journal of Forest Research* 40: 1288–1301.

Tengö, M., K. Johansson, F. Rakotongrasoa, J. Lundberg, J.-A. Andriamaherilala, et al. 2007. Taboos and forest governance: Informal protection of hot spot dry forest in Southern Madagascar. *Ambio* 36:683–691.

Tennyson, A.J.D. 2010. The origin and history of New Zealand's terrestrial vertebrates. *New Zealand Journal of Ecology* 34:6–27.

Terashima, I. and K. Hikosaka. 1995. Comparative ecophysiology of leaf and canopy photosynthesis. *Plant, Cell and Environment* 18:1111–1128.

Teskey, R.O., D.W. Sheriff, and D.Y. Hollinger. 1995. External and internal factors regulating photosynthesis *in* W.K. Smith and T.M. Hinkley, editors. *Resources and Physiology of Conifers: Acquisition, Allocation, and Utilization*. Academic Press, San Diego.

Thiet, R.K., S.D. Frey, and J. Six. 2006. Do growth yield efficiencies differ between soil microbial communities differing in fungal: bacterial ratios? Reality check and methodological issues. *Soil Biology and Biochemistry* 38:837–844.

Thomas, W.A. 1969. Accumulation and cycling of calcium by dogwood trees. *Ecological Monographs* 39:101–120.

Thompson, R.M., C.R. Townsend, D. Craw, R. Frew, and R. Riley. 2001. (Further) links from rocks to plants. *Trends in Ecology & Evolution* 16:543.

Thornton, K.W., B.L. Kimmel, and F.E. Payne. 1990. *Reservoir Limnology: Ecological Perspectives*. John Wiley and Sons, New York.

Thorp, J.H. and A.P. Covich, editors. 2001. *Ecology and Classification of North American Freshwater Invertebrates*. Academic Press, San Diego.

Thurman, H.V. 1991. *Introductory Oceanography*. 6th edition. MacMillan Publishing Company, New York.

Tiessen, H. 1995. Introduction and synthesis. Pages 1–6 *in* H. Tiessen, editor. *Phosphorus in the Global Environment: Transfers, Cycles and Management*. John Wiley & Sons, Chichester.

Tietema, A. and C. Beier. 1995. A correlative evaluation of nitrogen cycling in the forest ecosystems of the EC projects NITREX and EXMAN. *Forest Ecology and Management* 71:143–151.

Tilman, D. 1985. The resource-ratio hypothesis of plant succession. *American Naturalist* 125:827–852.

Tilman, D. 1988. *Plant Strategies and the Dynamics and Function of Plant Communities*. Princeton University Press, Princeton.

Tilman, D. and D. Wedin. 1991. Dynamics of nitrogen competition between successional grasses. *Ecology* 72:1038–1049.

Tilman, D., D. Wedin, and J. Knops. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature* 379:718–720.

Tilman, D., P.B. Reich, and J.M.H. Knops. 2006. Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature* 441:629–632.

Tjoelker, M.G., J.M. Craine, D. Wedin, P.B. Reich, and D. Tilman. 2005. Linking leaf and root trait syndromes among 39 grassland and savannah species. *New Phytologist* 167:493–508.

Towns, D.R., I.A.E. Atkinson, and C.H. Daugherty. 2006. Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions* 8:863–891.

Townsend, A.R., P.M. Vitousek, and S.E. Trumbore. 1995. Soil organic matter dynamics along gradients in temperature and land use on the island of Hawaii. *Ecology* 76:721–733.

Townsend, A.R., C.C. Cleveland, G.P. Asner, and M.M.C. Bustamante. 2007. Controls of foliar N:P ratios in tropical rain forests. *Ecology* 88:107–118.

Trenberth, K.E., and T.J. Haar. 1996. The 1990–1995 El Niño - Southern Oscillation event: Longest on record. *Geophysical Research Letters* 23:57–60.

Trenberth, K.E. and D.P. Stepaniak. 2003. Coveriability of components of poleward atmospheric energy transports on seasonal and interannual timescales. *Journal of Climate* 16:3691–3705.

Trenberth, K.E., J.T. Fasullo, and J. Kiehl. 2009. Earth's global energy budget. *Bulletin of the American Meteorological Society*.

Treseder, K.K. 2008. Nitrogen additions and microbial biomass: A meta-analysis of ecosystem studies. *Ecology Letters* 11:1111–1120.

Trimble, S.W., F.H. Weirich, and B.L. Hoag. 1987. Reforestation reduces stream flow in the southeastern United States. *Water Resource Research* 23:425–437.

Trumbore, S.E. 1993. Comparison of carbon dynamics in tropical and temperate soils using radiocarbon measurements. *Global Biogeochemical Cycles* 7:275–290.

Trumbore, S.E. and J.W. Harden. 1997. Accumulation and turnover of carbon in organic and mineral soils of the BOREAS northern study area. *Journal of Geophysical Research* 102:28817–28830.

Turetsky, M.R., M.C. Mack, T.N. Hollingsworth, and J.W. Harden. 2010. The role of mosses in ecosystem succession and function in Alaska's boreal forest. *Canadian Journal of Forest Research* 40:1237–1264.

Turner, B.L., II, W.C. Clark, R.W. Kates, J.F. Richards, J.T. Mathews, et al., editors. 1990. *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years*. Cambridge University Press, Cambridge.

Turner, B.L., II, R.E. Kasperson, P.A. Matson, J.J. McCarthy, R.W. Corell, et al. 2003a. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences, USA* 100:8074–8079.

Turner, D.P., S. Urbanski, D. Bremer, S.C. Wofsy, T. Meyers, et al. 2003b. A cross-biome comparison of daily light use efficiency for gross primary production. *Global Change Biology* 9:383–395.

Turner, D.P., W.D. Ritts, W.B. Cohen, T.K. Maeirsperger, S.T. Gower, et al. 2005. Site-level evaluation of satellite-based global terrestrial primary production and net primary production monitoring. *Global Change Biology* 11:666–684.

Turner, M.G., R.V. O'Neill, R.H. Gardner, and B.T. Milne. 1989. Effects of changing spatial scale on the analysis of landscape pattern. *Landscape Ecology* 3:153–162.

Turner, M.G., W.H. Romme, R.H. Gardner, R.V. O'Neill, and T.K. Kratz. 1993. A revised concept of landscape equilibrium: Disturbance and stability on scaled landscapes. *Landscape Ecology* 8:213–227.

Turner, M.G., W.H. Hargrove, R.H. Gardner, and W.H. Romme. 1994. Effects of fire on landscape heterogeneity in Yellowstone National Park, Wyoming. *Journal of Vegetation Science* 5:731–742.

Turner, M.G., W.H. Romme, R.H. Gardner, and W.W. Hargrove. 1997. Effects of fire size and pattern on early succession Yellowstone National Park. *Ecological Monographs* 67:411–433.

Turner, M.G., W.H. Romme, and R.H. Gardner. 1999. Prefire heterogeneity, fire severity and plant reestablishment in subalpine forests of Yellowstone National Park, Wyoming. *International Journal of Wildland Fire* 9:21–36.

Turner, M.G., R.H. Gardner, and R.V. O'Neill. 2001. *Landscape Ecology in Theory and Practice: Pattern and Process*. Springer-Verlag, New York.

Turner, M.G. 2005. Landscape ecology: What is the state of the science? *Annual Review of Ecology, Evolution, and Systematics* 36:319–344.

Turner, M.G. and F.S. Chapin, III. 2005. Causes and consequences of spatial heterogeneity in ecosystem function. Pages 9–30 *in* G.M. Lovett, C.G. Jones, M.G. Turner, and K.C. Weathers, editors. *Ecosystem Function in Heterogeneous Landscapes*. Springer, New York.

Turner, M.G. 2010. Disturbance and landscape dynamics in a changing world. *Ecology* 91:2833–2849.

Tyrrell, T. 1999. The relative influences of nitrogen and phosphorus on oceanic primary production. *Nature* 400:525–531.

Uehara, G. and G. Gillman. 1981. *The Minerology, Chemistry, and Physics of Tropical Soils with Variable Charge Clays*. Westview Press, Boulder.

Ugolini, F.C. 1968. Soil development and alder invasion in a recently deglaciated area of Glacier Bay, Alaska. Pages 115–148 *in* J.M. Trappe, F.F. Franklin, R.F. Tarrant, and G.M. Hansen, editors. *Biology of Alder*. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland.

Ugolini, F.C. and H. Spaltenstein. 1992. Pedosphere. Pages 123–153 *in* S.S. Butcher, R.J. Charlson, G.H. Orians, and G.V. Wolfe, editors. *Global Biogeochemical Cycles*. Academic Press, London.

Ulrich, A. and J.J. Hills. 1973. Plant analysis as an aid in fertilizing sugar crops: Part I. Sugar beets. Pages 271–288 *in* L.M. Walsh and J.D. Beaton, editors. *Soil Testing and Plant Analysis*. Soil Science Society of America, Madison, WI.

Urban, D.L., R.V. O'Neill, and H.H. Shugart. 1987. Landscape ecology. *BioScience* 37:119–127.

Vadeboncoeur, Y., M.J. Vander Zanden, and D.M. Lodge. 2002. Putting the lake back together: Reintegrating benthic pathways into lake food web models. *BioScience* 52:44–54.

Vadeboncoeur, Y., G.D. Peterson, M.J. Vander Zanden, and J. Kalff. 2008. Benthic algal production across lake size gradients: Interactions among morphometry, nutrients, and light. *Ecology* 89:2542–2552.

Valentini, R., G. Matteucci, A.J. Dolman, E.-D. Schulze, C. Rebmann, et al. 2000. Respiration as the main determinant of carbon balance in European forests. *Nature* 404:861–864.

Valiela, I. 1995. *Marine Ecological Processes*. 2nd edition. Springer-Verlag, New York.

Van Breemen, N. and A.C. Finzi. 1998. Plant-soil interactions: Ecological aspects and evolutionary implications. *Biogeochemistry* 42:1–19.

Van Cleve, K., W.C. Oechel, and J.L. Hom. 1990. Response of black spruce (*Picea mariana*) ecosystems to soil temperature modification in interior Alaska. *Canadian Journal of Forest Research* 20:1530–1535.

Van Cleve, K., F.S. Chapin, III, C.T. Dyrness, and L.A. Viereck. 1991. Element cycling in taiga forest: State-factor control. *BioScience* 41:78–88.

Van Cleve, K., C.T. Dyrness, G.M. Marion, and R. Erickson. 1993. Control of soil development on the Tanana River floodplain, interior Alaska. *Canadian Journal of Forest Research* 23:941–955.

van Ruijven, J. and F. Berendse. 2003. Positive effects of plant species diversity on productivity in the absence of legumes. *Ecology Letters* 6:170–175.

Vance, E.D. and F.S. Chapin, III. 2001. Substrate-environment interactions: Multiple limitations to microbial activity in taiga forest floors. *Soil Biology and Biochemistry* 33:173–188.

Vander Zanden, M.J., T.E. Essington, and Y. Vadeboncoeur. 2005. Is pelagic top-down control in lakes augmented by benthic energy pathways? *Canadian Journal of Fisheries and Aquatic Sciences* 62:1422–1431.

Vander Zanden, M.J., S. Chandra, S.-K. Park, Y. Vadeboncoeur, and C.R. Goldman. 2006. Efficiencies of benthic and pelagic trophic pathways in a subalpine lake. *Canadian Journal of Fisheries and Aquatic Sciences* 63:2608–2620.

Vandermeer, J.H. 1990. Intercropping. Pages 481–516 *in* C.R. Carrol, J.H. Vandermeer, and P.M. Rosset, editors. *Agroecology*. McGraw Hill, New York.

Vandermeer, J.H. 1995. The ecological basis of alternative agriculture. *Annual Review of Ecology and Systematics* 26:201–224.

Vannote, R.I., G.W. Minshall, K.W. Cummings, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences* 37:120–137.

VEMAP-Members. 1995. Vegetation/ecosystem modeling and analysis project: Comparing biogeography and biogeochemistry models in a continental-scale study of terrestrial ecosystem responses to climate change and CO_2 doubling. *Global Biogeochemical Cycles* 9:407–437.

Verbyla, D.L. 1995. *Satellite Remote Sensing of Natural Resources*. CRC Press, Boca Raton, Florida.

Verhoef, H.A. and L. Brussaard. 1990. Decomposition and nitrogen mineralization in natural and agro-ecosystems: The contribution of soil animals. *Biogeochemistry* 11:175–211.

Villar, R., J.R. Robleto, Y. De Jong, and H. Poorter. 2006. Differences in construction costs and chemical composition between deciduous and evergreen woody species are small as compared to differences among families. *Plant, Cell and Environment* 29:1629–1643.

Violle, C., M.-L. Navas, D. Vile, E. Kazakou, C. Fortunel, et al. 2007. Let the concept of trait be functional! *Oikos* 116:882–892.

Vitousek, P.M. and W.A. Reiners. 1975. Ecosystem succession and nutrient retention: A hypothesis. *BioScience* 25:376–381.

Vitousek, P.M. 1982. Nutrient cycling and nutrient use efficiency. *American Naturalist* 119:553–572.

Vitousek, P.M., J.R. Gosz, C.C. Grier, J.M. Melillo, and W.A. Reiners. 1982. A comparative analysis of potential nitrification and nitrate mobility in forest ecosystems. *Ecological Monographs* 52:155–177.

Vitousek, P.M. 1984. Litterfall, nutrient cycling, and nutrient limitation in tropical forests. *Ecology* 65: 285–298.

Vitousek, P.M. and P.A. Matson. 1984. Mechanisms of nitrogen retention in forest ecosystems: A field experiment. *Science* 225:51–52.

Vitousek, P.M., L.R. Walker, L.D. Whiteaker, D. Mueller-Dombois, and P.A. Matson. 1987. Biological invasion by *Myrica faya* alters ecosystem development in Hawai'i. *Science* 238:802–804.

Vitousek, P.M. and P.A. Matson. 1988. Nitrogen transformations in a range of tropical forest soils. *Soil Biology and Biochemistry* 20:361–367.

Vitousek, P.M. 1990. Biological invasions and ecosystem processes: Towards an integration of population biology and ecosystem studies. *Oikos* 57:7–13.

Vitousek, P.M. and R.W. Howarth. 1991. Nitrogen limitation on land and in the sea: How can it occur? *Biogeochemistry* 13:87–115.

Vitousek, P.M., G. Aplet, D. Turner, and J.J. Lockwood. 1992. The Mauna Loa environmental matrix: Foliar and soil nutrients. *Oecologia* 89:372–382.

Vitousek, P.M. and D.U. Hooper. 1993. Biological diversity and terrestrial ecosystem biogeochemistry. Pages 3–14 *in* E.-D. Schulze and H.A. Mooney, editors. *Biodiversity and Ecosystem Function*. Springer-Verlag, Berlin.

Vitousek, P.M. 1994. Beyond global warming: Ecology and global change. *Ecology* 75:1861–1876.

Vitousek, P.M., J.D. Aber, R.W. Howarth, G.E. Likens, P.A. Matson, et al. 1997a. Human alteration of the global nitrogen cycle: Sources and consequences. *Ecological Applications* 7:737–750.

Vitousek, P.M. and H. Farrington. 1997. Nitrogen limitation and soil development: Experimental test of a biogeochemical theory. *Biogeochemistry* 37:63–75.

Vitousek, P.M., H.A. Mooney, J. Lubchenco, and J.M. Melillo. 1997b. Human domination of Earth's ecosystems. *Science* 277:494–499.

Vitousek, P.M. and C.B. Field. 1999. Ecosystem constraints to symbiotic nitrogen fixers: A simple model and its implications. *Biogeochemistry* 46:179–202.

Vitousek, P.M., K. Cassman, C.C. Cleveland, T. Crews, C.B. Field, et al. 2002. Towards an ecological understanding of biological nitrogen fixation. *Biogeochemistry* 57/58:1–45.

Vitousek, P.M. 2004. *Nutrient Cycling and Limitation: Hawai'i as a Model System*. Princeton University Press, Princeton.

Vitousek, P.M., G.P. Asner, O.A. Chadwick, and S. Hotchkiss. 2009a. Landscape-level variation in forest structure and biogeochemistry across a substrate age gradient in Hawai'i. *Ecology* 90:3074–3086.

Vitousek, P.M., R.L. Naylor, T. Crews, M.B. David, L.E. Drinkwater, et al. 2009b. Agriculture: Nutrient imbalances in agricultural development. *Science* 324: 1519–1520.

Vitousek, P.M., S. Porder, B.Z. Houlton, and O.A. Chadwick. 2010. Terrestrial phosphorus limitation: Mechanisms, implications, and nitrogen-phosphorus interactions. *Ecological Applications* 20:5–15.

Vogt, K.A., C.C. Grier, and D.J. Vogt. 1986. Production, turnover, and nutrient dynamics in above- and belowground detritus of world forests. *Advances in Ecological Research* 15:303–377.

Vörösmarty, C.J., C. Leveque, C. Revenga, R. Bos, C. Caudill, et al. 2005. Fresh water. Pages 165–207 *in* R. Hassan, R.J. Scholes, and N. Ash, editors. *Ecosystems and Human Well-Being: Current State and Trends, Volume 1*. Island Press, Washington.

Vrba, E.S. and S.J. Gould. 1986. The hierarchical expansion of sorting and selection: Sorting and selection cannot be equated. *Paleobiology* 12:217–228.

Vukicevic, T., B.H. Braswell, and D. Schimel. 2001. A diagnostic study of temperature controls on global terrestrial carbon exchange. *Tellus* 53B:150–170.

Wagener, S.M., M.W. Oswood, and J.P. Schimel. 1998. Rivers and soils: Parallels in carbon and nutrient processing. *BioScience* 48:104–108.

Waldrop, M.P. and D.R. Zak. 2006. Response of oxidative enzyme activities to nitrogen deposition affects soil concentrations of dissolved organic carbon. *Ecosystems* 9:921–933.

Walker, B.H. 1992. Biodiversity and ecological redundancy. *Conservation Biology* 6:18–23.

Walker, B.H. 1995. Conserving biological diversity through ecosystem resilience. *Conservation Biology* 9:747–752.

Walker, B.H., A. Kinzig, and J. Langridge. 1999. Plant attribute diversity, resilience, and ecosystem function: The nature and significance of dominant and minor species. *Ecosystems* 2:95–113.

Walker, B.H., C.S. Holling, S.R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability, and transformability in social-ecological systems. *Ecology and Society* 9:http://www.ecologyandsociety.org/vol9/iss2/art5.

Walker, D.A., J.G. Bockheim, F.S. Chapin, III, W. Eugster, J.Y. King, et al. 1998. A major arctic soil pH boundary: Implications for energy and trace-gas fluxes. *Nature* 394:469–472.

Walker, L.R., J.C. Zasada, and F.S. Chapin, III. 1986. The role of life history processes in primary succession on an Alaskan floodplain. *Ecology* 67:1243–1253.

Walker, L.R. 1993. Nitrogen fixers and species replacements in primary succession. Pages 249–272 *in* J. Miles and D.W.H. Walton, editors. *Primary succession on land*. Blackwell, Oxford.

Walker, L.R. 1999. Patterns and processes in primary succession. Pages 585–610 *in* L.R. Walker, editor. *Ecosystems of Disturbed Ground*. Elsevier, Amsterdam.

Walker, L.R. and R. del Moral. 2003. *Primary Succession and Ecosystem Rehabilitation*. Cambridge University Press, Cambridge.

Walker, T.W. and J.K. Syers. 1976. The fate of phosphorus during pedogenesis. *Geoderma* 15:1–19.

Wall, D.H., G. Adams, and A.N. Parsons. 2001. Soil biodiversity. Pages 47–82 *in* F.S. Chapin, III, O.E. Sala, and E. Huber-Sannwald, editors. *Global Biodiversity in a Changing Environment: Scenarios for the 21st century*. Springer-Verlag, New York.

Wall, D.H., M.A. Bradford, M.G. St. John, J.A. Trofymow, V. Behan-Pelletier, et al. 2008. Global decomposition experiment shows soil animal impacts on decomposition are climate-dependent. *Global Change Biology* 14:2661–2677.

Wallwork, J.A. 1976. *The Distribution and Diversity of Soil Fauna*. Academic Press, New York.

Walter, K.M., L.C. Smith, and F.S. Chapin, III. 2007. Methane bubbling from northern lakes: Present and future contributions to the global methane budget. *Philosophical Transactions of the Royal Society of London* A365:1657–1676.

Walter, M.K., S.A. Zimov, J.P. Chanton, D. Verbyla, and F.S. Chapin, III. 2006. Methane bubbling from Siberian

thaw lakes as a positive feedback to climate warming. *Nature* 443:71–75.

Walters, C.J. and S.J.D. Martell. 2004. *Fisheries Ecology and Management*. Princeton University Press, Princeton.

Walters, C.J. and R. Ahrens. 2009. Oceans and estuaries: Managing the commons. Pages 221–240 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Manangement in a Changing World*. Springer, New York.

Walters, M.B. and P.B. Reich. 1999. Low-light carbon balance and shade tolerance in the seedlings of woody plants: Do winter deciduous and broad-leaved evergreen species differ? *New Phytologist* 143: 143–154.

Wan, S., D. Hui, and Y. Luo. 2001. Fire effects on nitrogen pools and dynamics in terrestrial ecosystems: A meta-analysis. *Ecological Applications* 11:1349–1365.

Wang, J.S., J.A. Logan, M.B. McElroy, B.N. Duncan, I.A. Megretskaia, et al. 2004. A 3-D model analysis of the slowdown and interannual variability in the methane growth rate from 1988 to 1997. *Global Biogeochemical Cycles* 18:GB3011, doi:3010.1029/3003GB002180.

Waring, R.H., J.J. Landsberg, and M. Williams. 1998. Net primary production of forests: A constant fraction of gross primary production? *Tree Physiology* 18:129–134.

Waring, R.H. and S.W. Running. 2007. *Forest Ecosystems: Analysis at Multiple Scales*. 3rd edition. Academic Press, San Diego.

WCED. 1987. *Our Common Future*. World Commission on Environment and Development, Oxford University Press, Oxford.

Weaver, C.P. and R. Avissar. 2001. Atmospheric disturbances caused by human modification of the landscape. *Bulletin of the American Meteorological Society* 82:269–281.

Webb, T. and P.J. Bartlein. 1992. Global changes during the last three million years: Climatic controls and biotic responses. *Annual Review of Ecology and Systematics* 23:141–173.

Webster, J.R. and E.F. Benfield. 1986. Vascular plant breakdown in freshwater ecosystems. *Annual Review of Ecology and Systematics* 17:567–594.

Webster, J.R., S.W. Golliday, E.F. Benfield, D.J. D'Angelo, and G.T. Peters. 1990. Effects of forest disturbance on particulate organic matter budgets of small streams. *Journal of the North American Benthological Society* 9:120–140.

Webster, J.R., J.B. Wallace, and E.F. Benfield. 1995. Organic processes in streams of the eastern United States.*in* C.E. Cushing, G.W. Minshall, and K.W. Cummins, editors. *Ecosystems of the World 22: River and Stream Ecosystems*. Elsevier, Amsterdam.

Webster, J.R. and J.L. Meyer. 1997. Organic matter budgets for streams: A synthesis. *Journal of the North American Benthological Society* 16:141–161.

Webster, J.R. 2007. Spiraling down the river continuum: Stream ecology and the U-shaped curve. *Journal of the North American Benthological Society* 26:375–389.

Webster, K.E., T.K. Kratz, C.J. Bowser, and J.J. Magnuson. 1996. The influence of landscape position on lake chemical responses to drought in northern Wisconsin. *Limnology and Oceanography* 41:977–984.

Webster, P.J. and T.N. Palmer. 1997. The past and future of El Niño. *Nature* 390:562–564.

Wedin, D.A. and D. Tilman. 1990. Species effects on nitrogen cycling: A test with perennial grasses. *Oecologia* 84:433–441.

Wells, M.P. and K.E. Brandon. 1993. The principles and practice of buffer zones and local participation in biodiversity conservation. *Ambio* 22:157–162.

West, T.O. and W.M. Post. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. *Soil Science Society of America Journal* 66:1930–1946.

Westley, F., B. Zimmerman, and M.Q. Patton. 2006. *Getting to Maybe: How the World is Changed*. Random House, Toronto.

Westman, W.E. 1978. Patterns of nutrient flow in the pygmy forest region of northern California. *Vegetatio* 36:1–15.

Whalen, S.C. and J.C. Cornwell. 1985. Nitrogen, phosphorus, and organic carbon cycling in an arctic lake. *Canadian Journal of Fisheries and Aquatic Sciences* 42:797–808.

Whisenant, S. 1999. *Repairing Damaged Ecosystems*. Cambridge University Press, New York.

White, M.A., P.E. Thornton, S.W. Running, and R.R. Nemani. 2000. Parameterization and sensitivity analysis of the BIOME-BGC terrestrial ecosystem model: Net primary production controls. *Earth Interactions* 4:1–85.

White, P.S. and S.T.A. Pickett. 1985. Natural disturbance and patch dynamics: An introduction. Pages 3–13 *in* S.T.A. Pickett and P.S. White, editors. *The Ecology of Natural Disturbance and Patch Dynamics*. Academic Press, New York.

Whiteman, G., B.C. Forbes, J. Niemelä, and F.S. Chapin, III. 2004. Bringing feedback and resilience of high-latitude ecosystems into the corporate boardroom. *Ambio* 33:371–376.

Whittaker, R.H. and W.A. Niering. 1965. Vegetation of the Santa Catalina Mountains, Arizona. (II) A gradient analysis of the south slope. *Ecology* 46:429–452.

Whittaker, R.H. 1975. *Communities and Ecosystems*. 2nd edition. Macmillan, New York.

Wiegert, R.G. and D.F. Owen. 1971. Trophic structure, available resources and population density in terrestrial versus aquatic ecosystems. *Journal of Theoretical Biology* 30:69–81.

Wiens, J.A. 1996. Wildlife in patchy environments: Metapopulations, mosaics, and management. Pages 53–84 *in* D.R. McCullough, editor. *Metapopulations and Wildlife Conservation*. Island Press, Washington.

Wilcox, H.E. 1991. Mycorrhizae. Pages 731–765 *in* Y. Waisel, A. Eshel, and U. Kafkaki, editors. *Plant Roots: The Hidden Half*. Marcel Dekker, New York.

Williams, J.W. and S.T. Jackson. 2007. Novel climates, no-analog communities, and ecological surprises. *Frontiers in Ecology and the Environment* 5:475–482.

Williamson, C.E., R.S. Sternberger, D.P. Morris, T.M. Frost, and S.G. Paulsen. 1996. Ultraviolet radiation in North American lakes: Attenuation estimates from DOC measurements and implications for plankton communities. *Limnology and Oceanography* 41:1024–1034.

Willson, M.F., S.M. Gende, and B.H. Marston. 1998. Fishes and the forest. *BioScience* 48:455–462.

Wilson, G.W.T., W. Rice, M.C. Rillig, A. Springer, and D.C. Hartnett. 2009. Soil aggregation and carbon sequestration are tightly correlated with the abundance of arbuscular mycorrhizal fungi: Results from long-term field experiments. *Ecology Letters* 12:452–461.

Wilson, J.B. and D.Q. Agnew. 1992. Positive-feedback switches in plant communities. *Advances in Ecological Research* 23:263–336.

Wilson, K.B., D.D. Baldocchi, M. Aubinet, P. Berbigier, C. Bernhofer, et al. 2002. Energy partitioning between latent and sensible heat flux during the warm season at FLUXNET sites. *Water Resources Research* 38:1294, doi:1210.1029/2001WR000989.

Winner, W.E., H.A. Mooney, K. Williams, and S. von Caemmerer. 1985. Measuring and assessing SO_2 effects on photosynthesis and plant growth. Pages 118–132 *in* W.E. Winner and H.A. Mooney, editors. *Sulfur Dioxide and Vegetation*. Stanford University Press, Stanford, California.

Wolheim, W.M., C.J. Vörösmarty, B.J. Peterson, S.P. Seitzinger, and C.S. Hopkinson. 2006. Relationship between river size and nutrient removal. *Geophysical Research Letters* 33:L06410, doi:06410.01029/02006 GL025845.

Woodward, F.I. 1987. *Climate and Plant Distribution*. Cambridge University Press, Cambridge.

Woodward, S., P.M. Vitousek, K. Benvenuto, and P.A. Matson. 1990. Use of the exotic tree *Myrica faya* by native and exotic birds in Hawaii Volcanoes National Park. *Pacific Science* 44:88–93.

Woodwell, G.M. and R.H. Whittaker. 1968. Primary production in terrestrial communities. *American Zoologist* 8:19–30.

Wright, I.J., P.B. Reich, and M. Westoby. 2001. Strategy shifts in leaf physiology, structure and nutrient content between species of high- and low-rainfall and high- and low-nutrient habitats. *Functional Ecology* 15: 423–434.

Wright, I.J., P.B. Reich, M. Westoby, D.D. Ackerly, Z. Barusch, et al. 2004. The world-wide leaf economics spectrum. *Nature* 428:821–827.

Wright, M.S. and A.P. Covich. 2005. Relative importance of bacteria and fungi in a tropical headwater stream: Leaf decomposition and invertebrate feeding preference. *Microbial Ecology* 49:536–546.

Wu, J. and O.L. Loucks. 1995. From balance of nature to hierarchical patch dynamics: A paradigm shift in ecology. *Quarterly Review of Biology* 70:439–466.

Xiao, J., Q. Zhuang, D.D. Baldocchi, B.E. Law, A.D. Richardson, et al. 2008. Estimation of net ecosystem carbon exchange for the conterminous United States by combining MODIS and AmeriFlux data. *Agricultural and Forest Meteorology* 148:1827–1847.

Xiao, J., Q. Zhuang, B.E. Law, J. Chen, D.D. Baldocchi, et al. 2010. A continuous measure of gross primary production for the conterminous United States derived from MODIS and AmeriFlux data. *Remote Sensing of Environment* 114:576–591.

Yamada, A., T. Inoue, D. Wiwatwitaya, M. Ohkuma, T. Kudo, et al. 2006. Nitrogen fixation by termites in tropical forests, Thailand. *Ecosystems* 9:75–83.

Yoo, K., R. Amundson, A.M. Heimsath, and W.E. Dietrich. 2005. Process-based model linking pocket gopher (*Thomomys bottae*) activity to sediment transport and soil thickness. *Geology* 33:917–920.

Young, O.R. and W. Steffen. 2009. The Earth System: Sustaining planetary life-support systems. Pages 295–315 *in* F.S. Chapin, III, G.P. Kofinas, and C. Folke, editors. *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Springer, New York.

Young, T.P., D.A. Petersen, and J.J. Clary. 2005. The ecology of restoration: Historical links, emerging issues and unexplored realms. *Ecology Letters* 8:662–673.

Zak, M.R., M. Cabido, D. Cáceres, and S. Díaz. 2008. What drives accelerated land cover change in central Argentina? Synergistic consequences of climatic, socioeconomic and technological factors. *Environmental Management* 42:181–189.

Zangerl, A.R. and M.R. Berenbaum. 2006. Parsnip webworms and host plants at home and abroad: Trophic complexity in a geographic mosaic. *Ecology* 87:3070–3081.

Zech, W. and I. Kogel-Knabner. 1994. Patterns and regulation of organic matter transformation in soils: Litter decomposition and humification. Pages 303–335 *in* E.-D. Schulze, editor. *Flux Control in Biological Systems: From Enzymes to Populations and Ecosystems*. Academic Press, San Diego.

Zheng, D., S. Prince, and R. Wright. 2003. Terrestrial net primary production estimates for 0.5° grid cells from field observations: A contribution to global biogeochemical modeling. *Global Change Biology* 9:46–64.

Zimmermann, M.H. 1983. *Xylem Structure and the Ascent of Sap*. Springer, New York.

Zimov, S.A., V.I. Chuprynin, A.P. Oreshko, F.S. Chapin, III, J.F. Reynolds, et al. 1995. Steppe-tundra transition: An herbivore-driven biome shift at the end of the Pleistocene. *American Naturalist* 146:765–794.

Zimov, S.A., E.A.G. Schuur, and F.S. Chapin, III. 2006. Permafrost and the global carbon budget. *Science* 312:1612–1613.

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