

Ecosystem Management



Jonah Martinez

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Ecosystem Management

This book elucidates new techniques and applications of ecosystem in a multidisciplinary approach. Ecosystem Management is a study of the interactions of living organisms with the natural resources like water, air and mineral soil. Ecosystem processes include energy flow, primary production, decomposition, nutrient cycling, biodiversity, ecosystem management, ecosystem ecology, etc. This book is a valuable compilation of topics, ranging from the basic to the most complex theories and principles in the field of ecosystem study. The topics included in it are of utmost significance and are bound to provide incredible insights to students. The textbook aims to serve as a resource guide for students and experts alike and contribute to the growth of the discipline.

Jonah Martinez pursued his Master of Science in Biodiversity Conservation and Ecosystem Management from Newcastle University, United Kingdom. He is actively engaged in the researches focused on natural resources restoration and ecosystem sustainability. Martinez has authored and edited several texts, which include articles, technical papers and book chapters, in the field of ecosystem conservation and management. His works have also been helpful to many fellow researchers in their respective fields.

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Edited by
Jonah Martinez

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Preface

This book elucidates new techniques and applications of ecosystem in a multidisciplinary approach. Ecosystem Management is a study of the interactions of living organisms with the natural resources like water, air and mineral soil. Ecosystem processes include energy flow, primary production, decomposition, nutrient cycling, biodiversity, ecosystem management, ecosystem ecology, etc. This book is a valuable compilation of topics, ranging from the basic to the most complex theories and principles in the field of ecosystem study. The topics included in it are of utmost significance and are bound to provide incredible insights to students. The textbook aims to serve as a resource guide for students and experts alike and contribute to the growth of the discipline.

A detailed account of the significant topics covered in this book is provided below:

Chapter 1- The interaction of the community of living animals with the non-living components is referred to as ecosystem. The biotic and the non-biotic components of our planet are all interlinked and while the biotic can be of any size, the essential abiotic components are water, nitrogen, energy and soil minerals. The existence of life is completely dependent on our ecosystem.

Chapter 2- The ecosystem found in water bodies is an aquatic ecosystem and the two sub classifications of the aquatic ecosystem are marine ecosystem and freshwater ecosystem. Another type of ecosystem is the terrestrial ecosystem, which is concerned with the ecosystem found only on landforms. The primary terrestrial ecosystems are forests, littoral zones, and the urban ecosystem.

Chapter 3- The chapter on ecosystem management offers an insightful focus, keeping in mind the complex subject matter. The conservation of our ecosystem and the ethical use of our resources is ecosystem management; there are several approaches towards effective ecosystem management, which involve adaptive management, natural resource management and ecosystem-based management.

Chapter 4- Ecosystem health is used to describe the condition of our ecosystem. The condition of an ecosystem can vary from place to place. Recent damage caused by flooding, drought, mining, chemical accident etc. can damage the health of the area affected. There is no benchmark that can be accepted for a healthy ecosystem. This chapter discusses the methods of ecosystem management in a critical manner providing key analysis to the subject matter.

Chapter 5- The damage done to our ecosystem has caused issues like global warming. Due to climate change there is a rise in sea levels, which will result in powerful and frequent hurricanes making floods a common phenomenon. Scientists suggest that within 100 years, because of climate change, the world's glaciers will disappear, and the polar ice caps will deplete entirely.

Chapter 6- The essential aspects of ecosystem explained in this chapter are nutrient cycle, regeneration, and ecological land classification. These are the fundamental components that regulate and revive the ecosystem and hence are important topics of study. The topics discussed in the chapter are of great importance to broaden the existing knowledge on ecosystem.

I would like to make a special mention of my publisher who considered me worthy of this opportunity and also supported me throughout the process. I would also like to thank the editing team at the back-end who extended their help whenever required.

Editor

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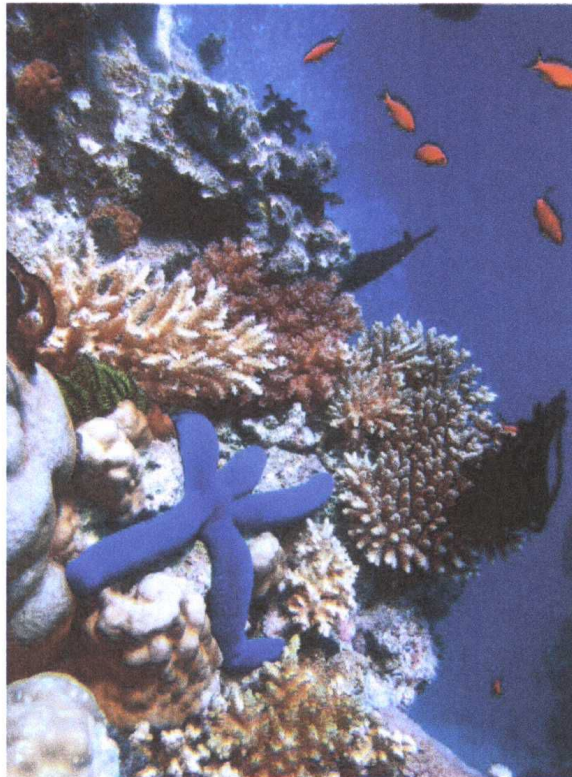
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Introduction to Ecosystem

The interaction of the community of living animals with the non-living components is referred to as ecosystem. The biotic and the non-biotic components of our planet are all interlinked and while the biotic can be of any size, the essential abiotic components are water, nitrogen, energy and soil minerals. The existence of life is completely dependent on our ecosystem.

Ecosystem

An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system. These biotic and abiotic components are regarded as linked together through nutrient cycles and energy flows. As ecosystems are defined by the network of interactions among organisms, and between organisms and their environment, they can be of any size but usually encompass specific, limited spaces (although some scientists say that the entire planet is an ecosystem).



Coral reefs are a highly productive marine ecosystem.

Energy, water, nitrogen and soil minerals are other essential abiotic components of an ecosystem. The energy that flows through ecosystems is obtained primarily from the sun. It generally enters the system through photosynthesis, a process that also captures carbon from the atmosphere. By

feeding on plants and on one another, animals play an important role in the movement of matter and energy through the system. They also influence the quantity of plant and microbial biomass present. By breaking down dead organic matter, decomposers release carbon back to the atmosphere and facilitate nutrient cycling by converting nutrients stored in dead biomass back to a form that can be readily used by plants and other microbes.



Rainforest ecosystems are rich in biodiversity. This is the Gambia River in Senegal's Niokolo-Koba National Park.

Ecosystems are controlled both by external and internal factors. External factors such as climate, the parent material that forms the soil, and topography control the overall structure of an ecosystem and the way things work within it, but are not themselves influenced by the ecosystem. Other external factors include time and potential biota. Ecosystems are dynamic entities—invariably, they are subject to periodic disturbances and are in the process of recovering from some past disturbance. Ecosystems in similar environments that are located in different parts of the world can have very different characteristics simply because they contain different species. The introduction of non-native species can cause substantial shifts in ecosystem function. Internal factors not only control ecosystem processes but are also controlled by them and are often subject to feedback loops. While the resource inputs are generally controlled by external processes like climate and parent material, the availability of these resources within the ecosystem is controlled by internal factors like decomposition, root competition or shading. Other internal factors include disturbance, succession and the types of species present. Although humans exist and operate within ecosystems, their cumulative effects are large enough to influence external factors like climate.

Biodiversity affects ecosystem function, as do the processes of disturbance and succession. Ecosystems provide a variety of goods and services upon which people depend; the principles of ecosystem management suggest that rather than managing individual species, natural resources should be managed at the level of the ecosystem itself. Classifying ecosystems into ecologically homogeneous units is an important step towards effective ecosystem management, but there is no single, agreed-upon way to do this.

History and Development

The term “ecosystem” was first used in a publication by British ecologist Arthur Tansley.^[fn 1] Tansley devised the concept to draw attention to the importance of transfers of materials between organisms and their environment. He later refined the term, describing it as “The whole system, ... including not only the organism-complex, but also the whole complex of physical factors forming

what we call the environment". Tansley regarded ecosystems not simply as natural units, but as mental isolates. Tansley later defined the spatial extent of ecosystems using the term ecotope.

G. Evelyn Hutchinson, a pioneering limnologist who was a contemporary of Tansley's, combined Charles Elton's ideas about trophic ecology with those of Russian geochemist Vladimir Vernadsky to suggest that mineral nutrient availability in a lake limited algal production which would, in turn, limit the abundance of animals that feed on algae. Raymond Lindeman took these ideas one step further to suggest that the flow of energy through a lake was the primary driver of the ecosystem. Hutchinson's students, brothers Howard T. Odum and Eugene P. Odum, further developed a "systems approach" to the study of ecosystems, allowing them to study the flow of energy and material through ecological systems.

Ecosystem Processes

Energy and carbon enter ecosystems through photosynthesis, are incorporated into living tissue, transferred to other organisms that feed on the living and dead plant matter, and eventually released through respiration. Most mineral nutrients, on the other hand, are recycled within ecosystems.

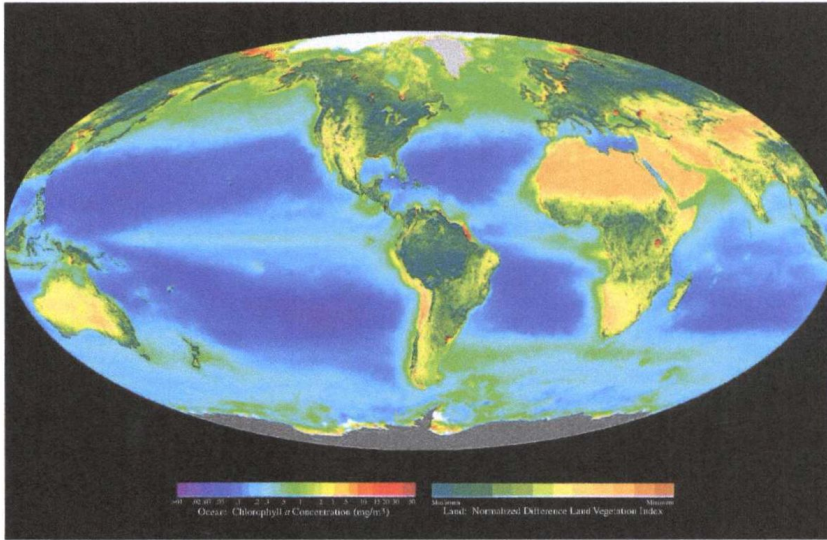
Ecosystems are controlled both by external and internal factors. External factors, also called state factors, control the overall structure of an ecosystem and the way things work within it, but are not themselves influenced by the ecosystem. The most important of these is climate. Climate determines the biome in which the ecosystem is embedded. Rainfall patterns and temperature seasonality determine the amount of water available to the ecosystem and the supply of energy available (by influencing photosynthesis). Parent material, the underlying geological material that gives rise to soils, determines the nature of the soils present, and influences the supply of mineral nutrients. Topography also controls ecosystem processes by affecting things like microclimate, soil development and the movement of water through a system. This may be the difference between the ecosystem present in wetland situated in a small depression on the landscape, and one present on an adjacent steep hillside.

Other external factors that play an important role in ecosystem functioning include time and potential biota. Ecosystems are dynamic entities—invariably, they are subject to periodic disturbances and are in the process of recovering from some past disturbance. Time plays a role in the development of soil from bare rock and the recovery of a community from disturbance. Similarly, the set of organisms that can potentially be present in an area can also have a major impact on ecosystems. Ecosystems in similar environments that are located in different parts of the world can end up doing things very differently simply because they have different pools of species present. The introduction of non-native species can cause substantial shifts in ecosystem function.

Unlike external factors, internal factors in ecosystems not only control ecosystem processes, but are also controlled by them. Consequently, they are often subject to feedback loops. While the resource inputs are generally controlled by external processes like climate and parent material, the availability of these resources within the ecosystem is controlled by internal factors like decomposition, root competition or shading. Other factors like disturbance, succession or the types of species present are also internal factors. Human activities are important in almost all ecosystems. Although humans exist and operate within ecosystems, their cumulative effects are large enough to influence external factors like climate.

Primary Production

Primary production is the production of organic matter from inorganic carbon sources. Overwhelmingly, this occurs through photosynthesis. The energy incorporated through this process supports life on earth, while the carbon makes up much of the organic matter in living and dead biomass, soil carbon and fossil fuels. It also drives the carbon cycle, which influences global climate via the greenhouse effect.



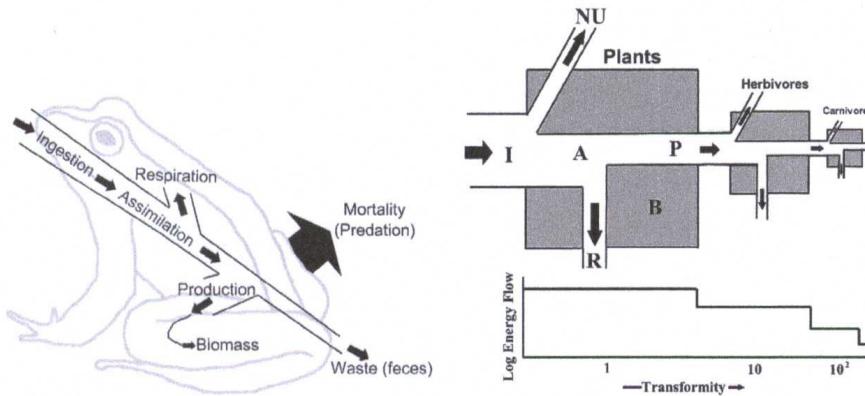
Global oceanic and terrestrial phototroph abundance, from September 1997 to August 2000. As an estimate of autotroph biomass, it is only a rough indicator of primary production potential, and not an actual estimate of it. Provided by the SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE.

Through the process of photosynthesis, plants capture energy from light and use it to combine carbon dioxide and water to produce carbohydrates and oxygen. The photosynthesis carried out by all the plants in an ecosystem is called the gross primary production (GPP). About 48–60% of the GPP is consumed in plant respiration. The remainder, that portion of GPP that is not used up by respiration, is known as the net primary production (NPP). Total photosynthesis is limited by a range of environmental factors. These include the amount of light available, the amount of leaf area a plant has to capture light (shading by other plants is a major limitation of photosynthesis), rate at which carbon dioxide can be supplied to the chloroplasts to support photosynthesis, the availability of water, and the availability of suitable temperatures for carrying out photosynthesis.

Energy Flow

The carbon and energy incorporated into plant tissues (net primary production) is either consumed by animals while the plant is alive, or it remains uneaten when the plant tissue dies and becomes detritus. In terrestrial ecosystems, roughly 90% of the NPP ends up being broken down by decomposers. The remainder is either consumed by animals while still alive and enters the plant-based trophic system, or it is consumed after it has died, and enters the detritus-based trophic system. In aquatic systems, the proportion of plant biomass that gets consumed by herbivores is much higher. In trophic systems photosynthetic organisms are the primary producers. The organisms that consume their tissues are called primary consumers or secondary producers—herbivores. Organisms which feed on microbes (bacteria and fungi) are termed microbiivores. Animals that feed on primary consumers—carnivores—are secondary consumers. Each

of these constitutes a trophic level. The sequence of consumption—from plant to herbivore, to carnivore—forms a food chain. Real systems are much more complex than this—organisms will generally feed on more than one form of food, and may feed at more than one trophic level. Carnivores may capture some prey which are part of a plant-based trophic system and others that are part of a detritus-based trophic system (a bird that feeds both on herbivorous grasshoppers and earthworms, which consume detritus). Real systems, with all these complexities, form food webs rather than food chains.



Left: Energy flow diagram of a frog. The frog represents a node in an extended food web. The energy ingested is utilized for metabolic processes and transformed into biomass. The energy flow continues on its path if the frog is ingested by predators, parasites, or as a decaying carcass in soil. This energy flow diagram illustrates how energy is lost as it fuels the metabolic process that transforms the energy and nutrients into biomass.

Right: An expanded three link energy food chain (1. plants, 2. herbivores, 3. carnivores) illustrating the relationship between food flow diagrams and energy transformity. The transformity of energy becomes degraded, dispersed, and diminished from higher quality to lesser quantity as the energy within a food chain flows from one trophic species into another. Abbreviations: I=input, A=assimilation, R=respiration, NU=not utilized, P=production, B=biomass.

Decomposition

The carbon and nutrients in dead organic matter are broken down by a group of processes known as decomposition. This releases nutrients that can then be re-used for plant and microbial production, and returns carbon dioxide to the atmosphere (or water) where it can be used for photosynthesis. In the absence of decomposition, dead organic matter would accumulate in an ecosystem and nutrients and atmospheric carbon dioxide would be depleted. Approximately 90% of terrestrial NPP goes directly from plant to decomposer.

Decomposition processes can be separated into three categories—leaching, fragmentation and chemical alteration of dead material. As water moves through dead organic matter, it dissolves and carries with it the water-soluble components. These are then taken up by organisms in the soil, react with mineral soil, or are transported beyond the confines of the ecosystem (and are considered “lost” to it). Newly shed leaves and newly dead animals have high concentrations of water-soluble components, and include sugars, amino acids and mineral nutrients. Leaching is more important in wet environments, and much less important in dry ones.

Fragmentation processes break organic material into smaller pieces, exposing new surfaces for colonization by microbes. Freshly shed leaf litter may be inaccessible due to an outer layer of cuticle or bark, and cell contents are protected by a cell wall. Newly dead animals may be covered by an exoskeleton. Fragmentation processes, which break through these protective layers, accelerate the

rate of microbial decomposition. Animals fragment detritus as they hunt for food, as does passage through the gut. Freeze-thaw cycles and cycles of wetting and drying also fragment dead material.

The chemical alteration of dead organic matter is primarily achieved through bacterial and fungal action. Fungal hyphae produce enzymes which can break through the tough outer structures surrounding dead plant material. They also produce enzymes which break down lignin, which allows to them access to both cell contents and to the nitrogen in the lignin. Fungi can transfer carbon and nitrogen through their hyphal networks and thus, unlike bacteria, are not dependent solely on locally available resources.

Decomposition rates vary among ecosystems. The rate of decomposition is governed by three sets of factors—the physical environment (temperature, moisture and soil properties), the quantity and quality of the dead material available to decomposers, and the nature of the microbial community itself. Temperature controls the rate of microbial respiration; the higher the temperature, the faster microbial decomposition occurs. It also affects soil moisture, which slows microbial growth and reduces leaching. Freeze-thaw cycles also affect decomposition—freezing temperatures kill soil microorganisms, which allows leaching to play a more important role in moving nutrients around. This can be especially important as the soil thaws in the Spring, creating a pulse of nutrients which become available.

Decomposition rates are low under very wet or very dry conditions. Decomposition rates are highest in wet, moist conditions with adequate levels of oxygen. Wet soils tend to become deficient in oxygen (this is especially true in wetlands), which slows microbial growth. In dry soils, decomposition slows as well, but bacteria continue to grow (albeit at a slower rate) even after soils become too dry to support plant growth. When the rains return and soils become wet, the osmotic gradient between the bacterial cells and the soil water causes the cells to gain water quickly. Under these conditions, many bacterial cells burst, releasing a pulse of nutrients. Decomposition rates also tend to be slower in acidic soils. Soils which are rich in clay minerals tend to have lower decomposition rates, and thus, higher levels of organic matter. The smaller particles of clay result in a larger surface area that can hold water. The higher the water content of a soil, the lower the oxygen content and consequently, the lower the rate of decomposition. Clay minerals also bind particles of organic material to their surface, making them less accessible to microbes. Soil disturbance like tilling increase decomposition by increasing the amount of oxygen in the soil and by exposing new organic matter to soil microbes.

The quality and quantity of the material available to decomposers is another major factor that influences the rate of decomposition. Substances like sugars and amino acids decompose readily and are considered “labile”. Cellulose and hemicellulose, which are broken down more slowly, are “moderately labile”. Compounds which are more resistant to decay, like lignin or cutin, are considered “recalcitrant”. Litter with a higher proportion of labile compounds decomposes much more rapidly than does litter with a higher proportion of recalcitrant material. Consequently, dead animals decompose more rapidly than dead leaves, which themselves decompose more rapidly than fallen branches. As organic material in the soil ages, its quality decreases. The more labile compounds decompose quickly, leaving an increasing proportion of recalcitrant material. Microbial cell walls also contain recalcitrant materials like chitin, and these also accumulate as the microbes die, further reducing the quality of older soil organic matter.