A TREATISE ON ECOLOGICAL SCIENCE

Vikas Rai

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A Treatise on Ecological Science

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FOREWORD

When we started to plan our course "Dynamic Models in Biology", and the textbook of the same name to go with it (Princeton University Press, 2006), my co-author and co-instructor John Guckenheimer observed that "the best books are often the most personal books". That is: books aiming for even-handed, comprehensive coverage of a subject are useful as reference books -- I have a few such on my bookshelf, many with "encyclopedia" or "handbook" in their titles, and some of them really have been very useful. But books that very selectively highlight one person's idea of what is important in a subject area, one person's interpretation of current knowledge, and their projections about the future – those are the books that get read from cover to cover, which can divert a reader into a different line of inquiry, and even change the direction of an entire field.

Vikas Rai has written a very personal book about ecology. The viewpoint is modern. Classically an ecosystem was typically conceptualized as stocks and flows of various molecules (C, N, P, *etc*.). That view is not without value when our goal is to summarize global biogeochemistry. But we now know how crucial it is that those molecules are clustered into individual organisms, who attend to the world around them and make intelligent decisions, shaped by natural selection. The fundamental events in ecosystems are then births and deaths, that is: consuming, being consumed, and converting consumed resources into offspring. Accordingly, the book opens with the study of these interactions and the competition that results when there are multiple consumers for one food item. The subsequent chapters broaden from this fine scale to networks of interacting species, and then to the level of global biodiversity. Individual actions – in particular human individual actions – again take center stage in the next three chapters, exploring how human decisions now determine the state and fate of planet Earth. The last chapter concerns sustainable development goals; the agenda set by Comity of Nations; UNO.

So will this book teach you about all of ecological science? No, not even close. But it will tell you how one person views those topics after decades of thinking about them and contributing to them, and what he thinks is most important. And maybe it will help you choose how you want to make your own contributions.

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PREFACE

A textbook on ecology that covers all aspects of ecological sciences has been missing in the literature. It will be befitting to bring out such a text that prepares for an introductory class of undergraduate students. For this, the knowledge of matrix theory and differential equations (both ordinary and partial) is the prerequisite. The present book lacks a chapter on 'microbial ecology'. The author has no expertise in the subject. Details of microbes and their interactions with plants can be found in other texts. A concise book with essential details and lucid descriptions of the latest knowledge on key topics is bought out.

Ecological Imbalance is the principal cause of most of the problems on Earth. Ecosystem services are impeded in several known and unknown ways when such an imbalance occurs. In order to understand how this causative agent operates, key elements of 'ecological complexity' are required to be understood. The present book provides a framework to understand the 'balance of nature' with minimal use of mathematics in order to reach a broader readership.

Ecological systems are an example of 'complex systems'. The content of the chapter presents **ecosystems** as the 'network of networks'. The chapter on network ecology provides a brief description of how interaction types and the number of interactions among species determine its 'existential capacity' and 'functional efficiency'. The key elements of an ecosystem are food webs; a network of interconnected food chains. The present text classifies food chains into two types: ***linear and nonlinear.***

Climate change drives catastrophic changes in biodiversity. This is the reason why the book presents a brief chapter on biodiversity and its relationship with **climate change**in Chapter 2. The third chapter on human ecology provides a framework to integrate ***ecological sciences with neurosciences***. Modern civilization cannot exist without industry. Industries cause pollution which deteriorates the '**quality of life**' on Earth. The author emphasizes that it must be taught at the undergraduate level so that the basic philosophy of the subject is injected into the DNA of individuals of *homo - sapiens.* This is the fourth chapter.

The last chapter on Sustainable Development Goals (SDG) provides a historical perspective on the topic of 'sustainable development'. Under SDG 1 (**No poverty**), both the definitions of poverty; workable and broader, are provided. Ecological viewpoints of all SDGs are discussed. In sum, after reading all the chapters in the book, a student will have sufficient knowledge to analyze the phenomenal world around him/her.

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CHAPTER 1

Network Ecology

Abstract: Ecological systems (**populations and communities**) interact with each other. These entities can be viewed as networks and ecosystems as 'networks of networks'. Ecological networks share common properties with other networks; *e.g*., Wireless Sensor Networks (WSNs). WSNs consist of receivers and transmitters of information at locations called **nodes.** These nodes transmit and receive information with each other in 'packets'. In the context of ecology, these packets contain material and energy; *e.g*., the bird from the bird sanctuary (20 kms away from my residence) being caught by the cat for food. Elements of network theory which are essential for applications to ecological networks are introduced. Decisions of animal movements and observed patterns of movement can be better explored in this framework. Although these networks have complex architecture, their hierarchical nature admits well-defined patterns that illuminate mechanisms of functioning of **ecosystems**. Applications of network theory would advance the understanding of complex interactions between species; 'tangled banks' of nature.

Ecological networks are simulated. These simulation experiments illuminate observed patterns of movement. ***A network of social interactions*** and a ***network of movement patterns*** are explored to know how movement decisions are taken.

Keywords: Biodiversity, Energy, Layering, Food chains, Food webs, Host-Parasite interactions, Interaction Types, Link distribution, Loss of resilience, Levels of organization, Material, Monolayer network, Multilayer, Multilevel, Networks, Resilient, Resilience, Strong trophic interactions, Temporal food – webs, Weak – trophic interactions.

INTRODUCTION

Investigations in ecological theory and modeling have focused largely on simple food – webs; two or more food - chains linked with migration or with a few ***weak – trophic interactions***. Natural ecological systems are more complex than one can imagine. Ecological systems consist of several weak (predation/harvesting) and a few ***strong trophic interactions*** (McKann, 1998; O'Gorman & Emmerson, 2009). Network ecology presents a framework for conceptualization and analysis of ecosystem function and its response to external perturbations. The concept of ecosystem refers to both the flow of energy and to species interactions. Interaction

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strengths in complex food webs are discussed by Berlow *et al*. (2009). Before we begin to describe different types of networks, definitions of essential elements of network theory are described below.

Graph Pair-wise relations between two objects.

Degree Degree of the vertex of a **graph** is the number of edges incident on it.

Edge A link between two vertices in a network. When weighted denotes interaction strength.

Vertices A point where two or more lines, curves, or edges meet.

Flow dynamics The movement of resources (energy and information) on a network.

MONOLAYER NETWORK

Farage, *et al*. (2021) have presented a scheme to identify flow modules in ecological networks using ***infomap***; a software package for landscape analysis. Fortin *et al*. (2021) have discussed the dynamics of ecological networks in response to environmental changes. It focuses on how the interplay between species interaction networks and spatial structures of landscape patches explains the observed variability in space and time. Newman and Girvan (2004) proposed algorithms to divide network nodes into densely connected subgroups, which represent community structure. The authors presented a measure to determine the strength of identified community structures. Readers are referred to a book on the subject by Newman (Newman, 2010). Algorithms have been designed to remove edges from the network iteratively. These algorithms are based on graph partitioning ideas. It finds groups of nodes with dense connections with sparser intergroup connections. The network is broken into its communities by these clustering algorithms. Newman and Girvan also proposed a measure to determine the strength of communities thus identified. A typical monolayer network is shown in Fig. (**1**).

A food - web consists of food – chains linked with migration (Kitching, *et al*. 1987). Food chains are of two types: ***linear and non-linear***. Fig. (**2**) shows a representative terrestrial food - web which exemplifies a monolayer network given in Fig. (**1a**). It consists of three food chains (Murray & de Ruiter, 1991).

1. Grass - Grasshopper – Frog – Hawk
2. Grass – Mouse – Hawk
3. Grass – Rabbit - Hawk

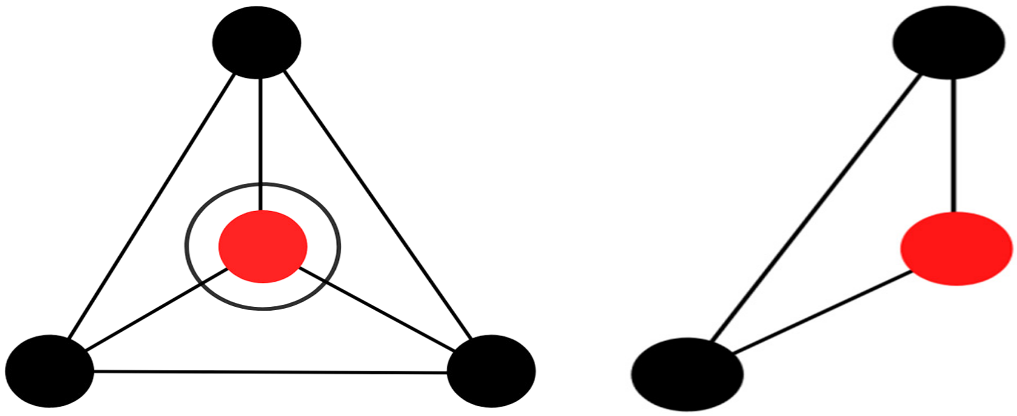

Fig. (1). (a) Connected nodes. Nodes represent patches. Species dispersal in a patchy environment is shown. (b) A Monolayer Network. The keystone species patch is shown in red. A keystone species is a critical source of food for predators; *e.g*., Antarctic krill, Canadian snowshoe hares, *etc*. Wolves and sea otters are predators that control populations and the range of their prey. Loss of a keystone species means loss of ecosystem services as it would no longer be functional. Three monolayer networks are linked together.

Hawk is a keystone species. Grass is the primary producer. Grasshoppers and frogs are herbivores. Hawk is a predator. Grass – Grasshopper system is the consumer resource system. Frog–Hawk is an example of a weak trophic interaction. Fig. (**2**) presents a food chain with these species. Fig. (**3**) presents an aquatic food chain.

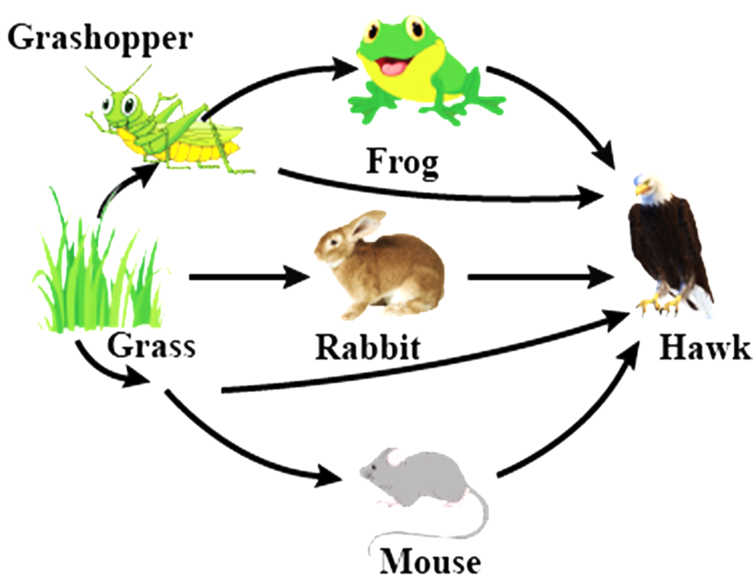

Fig. (2). A Terrestrial Food – web (part of an ecosystem). It consists of many food chains.

CHAPTER 2

Biodiversity and Climate Change: The Missing Link

Abstract: Changes in an organism's DNA can influence all aspects of its life. Mutations serve as raw material for genetic variability and its evolution. These are caused by high-energy radiation. Chemical substances present in the environment are other potential causative agents. They may also occur during DNA replication. Radiation damage has increased many folds after the advent of cellular telephony. Genes are DNA molecules. These molecules are distributed on the chromosomes of individuals or populations of a species. Some populations grow faster than others. Why? The chapter tries to find an answer to it.

Population increase has been observed in some countries and for others, a decrease has been detected. It has been predicted that the human population will increase to 8.5 billion in 2030 from 7. 8 billion in 2020. The exploitation of natural resources would increase accordingly. **World Economic Forum** reports that research conducted at the Swiss Re Institute has pointed out that an 18 percent reduction in GDP is achievable by 2050 if the **Global temperature rise** is restricted to 3.2^0 C. About 16 to 29% reduction in CO_2 emissions would lead to a less dangerous climate change provided population growth is slowed down. If factors contributing to Global warming are managed in such a way that the Global temperature rises by 1.5^0 C, **Sustainable Development Goals** are achievable. Net–zero emissions targeted to be achieved by 2050 are not feasible as international agreements are not honored.

Keywords: Biodiversity, Diversity, Extinction, Genetic variability, Meiosis, Niche differentiation, Niche dimensionality, Nonlinear oscillations, Passenger pigeon, Plant-pollinator systems, Representative concentration pathways.

INTRODUCTION

Populations of a species are distributed in space (geographical locations). Species migrate from one patch to another in a fragmented landscape. The genomic buildup of individuals varies both in space and time. This chapter discusses factors that cause loss of biodiversity at all three levels: *Genetic, Species, and Ecosystems*.

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GENETIC DIVERSITY

It has three components

1. Genetic make - up of a species,
2. Genetic variability,
3. Genetic diversity

The genetic makeup of a species is determined by how many genes are there on the chromosomes of an individual plant or animal species. The same applies to viruses that associate themselves with these species. Genetic diversity is the total number of genetic characteristics in the genetic makeup of a species. It is different from genetic variability in the sense that genetic variability describes the tendency of genetic characteristics to vary. Genetic diversity is a measure of the potential of a population to survive in fluctuating environments. The genetic variation can be caused by mutation, random mating, random fertilization, and recombination between homologous chromosomes during ***meiosis***. Meiosis reshuffles alleles within an organism's offspring. Random fertilization occurs in plant-pollinator systems. The Kimura - Crow theory (Kimura & Crow, 1970) suggests that evolution at the molecular level occurs by random drift of neutral mutations.

Passenger pigeons are blue, long-tailed, fast, and graceful. These migratory birds are endemic to North America. Flocks a mile wide flying overhead from 7. 3 a.m. in the morning and 4 p.m. in the afternoon are a few characteristics. Pigeons migrate in the early spring from the south to their breeding areas in New England, New York, Ohio, and the southern Great Lakes. The death of a passenger pigeon, Martha, at Cincinnati Zoo at the age of 29 prompted zoologists to take measures to conserve these species of pigeons, which were hunted to extinction. Species with low genetic variation are more prone to extinction long after their population size is recovered. Murray *et al*. (2017) discussed the rise and fall of genetic diversity in passenger pigeons. The authors studied the genomes of four passenger pigeon samples from different localities within its range. The interplay between passenger pigeon population size, genomic structure and recombination, and natural selection was explored. The genetic diversity provided limited avenues for the bird to respond to human pressures, which dumped it into oblivion (Hung *et al*., 2014).

Passenger pigeons could not switch over to living in smaller flocks. Lee *et al*. (2010) examined the rate of loss of genetic diversity of the bird to figure out why it could not survive in a few small populations. Investigators explored the demography and genetic structure of winter flocks in a small passerine, the vinous throated parrotbill, *paradoxornis webbianus*. The objective was to determine the match between observed demography and the genetic structure of winter flocks and the consequences of kin structure for the risk of inbreeding during the breeding season. With 600 to 120 individuals, there was no deviation from parity in the sex ratio. The survival of adults was moderately low (Berner & Grubb, 1985; Lee *et al*., 2010; Pulliman, 1973).

SPECIES DIVERSITY

There exist ~ 8.7 million total species on this earth. There are a total of 6.5 million species on land (forests, mangroves, marshes, wetlands, *etc*.) and 2.2 million in oceans. One square kilometer of a forest can have a hundred different tree species; broadleaf trees, mosses, ferns, and orchids all thrive in rainforests. Densely growing trees and their branches block the sun from penetrating the understory. A variety of birds, bats, and other animals live on them.

It is the number of species present in a given community. It represents 1) a number of species in a community, and 2) the evenness of species abundances; *i.e*., its richness and evenness. Species evenness is the variation in the abundance of individuals per species in a community. The relationship between species richness and evenness in plant communities was investigated by Zhang, *et al*. (Zhang, *et al*., 2012). A total number of 30 sampling quadrants of size 0.5m×0.5m were laid out along two transects at each meadow. The authors found a negative correlation between richness and evenness in these communities along the succession gradient at the sampling site. The authors explored the relationship by varying the scale in the range (0.5m×0.5m-10m×10m). They found that niche differentiation and spatial scale effects cooperate to maintain high species richness in sub-alpine meadows communities. Niche differentiation is the process by which competing species use the environment for coexistence.

Variation within species is measured using differences in the base sequence of DNA or amino acid sequence of proteins. This method is known as sequence-based identification of biodiversity. Biodiversity within a community can be measured using species richness and an index of diversity (Creer, *et al*., 2016).

ECOSYSTEM DIVERSITY

It has two aspects: 1) habitat, and 2) community. Ecosystems are both ***natural*** and ***artificial***. Natural ecosystems are of four types: 1) Forest, 2) Grassland, 3) Aquatic, and 4) Desert. Artificial ecosystems are of three types: terrestrial, microbial, and aquatic.

CHAPTER 3

Human Ecology: A New Perspective

Abstract: Complexity exists in systems with simple architecture. The unit of architecture, in this context, is a predator–prey community. In case another predator invades the patch in which this community inhabits, temporal dynamics would go chaotic. Chaotic dynamics is characterized by short–term predictability. This leads to **Predator-induced phenotypic plasticity.** It has been found in Daphnia's Neuro - physiological mechanisms of Ad hoc environmental phenotypic adaptation. **Induced defenses** in *Daphnia*; a prey for fish, phantom midge larvae, tadpoles, and several aquatic insects, engage in predation-specific chemical cues that signal increased predation risk. Identification of friends and foes is facilitated by Chemo-receptors in Daphnia. Olfactory receptor (OR) neurons belong to the G – protein-coupled – receptor super family. These neurons get activated when air-borne molecules bind to ORs expressed on their cilia. Transport of goods and services involves the movement of vehicles that release NO_2 into the environment.

M**olecular switches** on plant leaves help sense their environment. These switches are 10^{-15} m long molecules made of **femto particles**. Animals and 'social animals' (individual humans living in different societies) interact with each other through members of G – protein-coupled receptor superfamily. Animals consume plants that provide food, fodder, fuel, and fiber for the growing human population. **Social Capital**, a network of relationships among people in an efficient society, creates **Human capital**; good health, and knowledge of things, which are useful for the execution of duties of an employee in a company. The chapter provides a crisp description of all that goes into different aspects of human ecology. This discipline puts humans on the center stage. An integration of this discipline with neurosciences would broaden the scope of both disciplines.

Keywords: Anthropocentric, Complex systems, Cultural dimensions, Dynamical complexity, G-protein, Human capital, Hierarchical structures, Neuroscience, Predator-prey community, Predator-induced phenotypic plasticity, Receptor superfamily, Social environments, Social capital, Sustainable development.

INTRODUCTION

Human Ecology is the study of the relationship between humans and their natural, social, and built environments. The human dimension of Ecology is the main focus of this discipline. Herbert Spencer's view of Ecology reminds us of a discipline that enquires into the ***patterns*** *and* ***processes*** of interaction of humans

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with their environments. The evolution of structures; both social and natural, is the focalpoint. It recommends the study of humans as living systems in complex environments; social, natural, and built. One of the main objectives of this discipline is ***sustainable development***.

Natural environments embrace all living and non-living things; vegetation, micro-organisms, soil, rocks, atmosphere, and natural events (Clayton, 2003). Forest fires, floods, and cyclones are a few examples of natural environments. The effect of natural events on living things causes drastic changes and sometimes irreversible changes in the dynamics of ecological entities; *e.g*., forests and lakes. The potential of ecological processes; regeneration and succession of vegetation, decides how fast a forest returns to its original state (Allen and Starr 1982). Forests and Lakes are ***complex systems***. Ant-hills and ants themselves, human beings and their economies, nervous systems, and nerve cell themselves, are a few examples of complex systems with hierarchical structures (Fig. **1**). The economy is yet another example (Anderson, *et al*. 1988; Glass, 2001; Kaufman, 1993; Nicolis and Nicolis, 2007) with hierarchical structures (Lutz, 2000; Li – he & Dong – Sheng, 2004, Sales – Pardo, *et al*. 2007). There could be systems without hierarchical structures. Those without hierarchical structures are difficult to observe and understand (Simon, 1962). The former class of complex systems have multi-level organization and are decomposable.

Fig. (1). Ant hill on a meadow in wisconsin state park.

Components (individual units) of complex systems interact nonlinearly; *i.e*., for such a system rule "*two plus two equal to four*" does not hold. The outcome of the mathematical operation of adding two to two lies between zero to four.

Sometimes, the operation may yield '4'. One should note that adding and multiplying two to two is the same. It implies that there cannot be a way to get the 'whole' by assembling the parts. Complex systems with hierarchical structures exist. A building with several floors; with individual rooms on each floor connected by pathways, is a classic example. A complex system can be decomposed into subsystems (components) with different scales. Thus, **multi–level organization** is its intrinsic property. The mathematical operation of adding 'two' to 'two' would mean that these individual components (or units) have two interacting species; *e.g*., a predator–prey community distributed in two nearby patches (Fig. **2**). The predator is a specialist; *i.e*., it has limited food options. Individuals of both species are allowed to cross over and move to the other patch. Predator-prey interaction is nonlinear (Rai, 2013). This is an example of a complex system without a hierarchical structure. The dynamics of this simple system can be complex depending on the value of the parameter, which measures the intensity of migration.

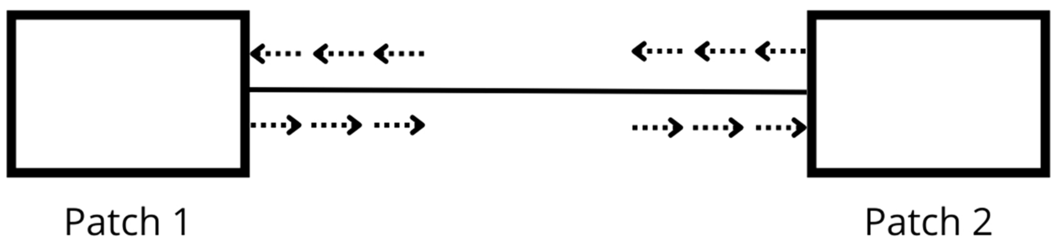

Fig. (2). The emergence of dynamical complexity in a two-patch system linked by migration in a fragmented landscape.

Social Environments refer to the immediate physical and social setting in which people live. It includes a culture that the individual was educated or lives in, people and institutions; marriage and family, beliefs and practices, *etc*. A new model has been developed to explore how changing an individual's certainty in the belief on the truth of one statement leads to changes in their beliefs on the truth of others. This tool has the potential to help estimate likelihood of being persuaded into a new belief. Opinions are rarely formed by accepting or rejecting the social consensus of others.

Social capital refers to the network of groups of individuals having a common goal. Thus, unity of purpose is the connecting thread. The concept of social capital as a resource for action provides an instrument to introduce social structure into the rational action paradigm. Social capital expresses itself in the following forms:

CHAPTER 4

Elements of Industrial Ecology

Abstract: The central theme of industrial ecology is the idea that the waste material from one industry can serve as raw material for the other. It is **industrial symbiosis**. This eases tension created by the pressure of ever-accumulating industrial waste. Another aspect of an industry is the input of energy. It must be clean; emissions to the environment are minimal, and green, *i.e*., we must utilize the least amount of resources. The search for clean energy sources has converged to **Hydrogen Energy**. The production efficiency of the electrolysis process is enhanced by the application of an external magnetic field. Solar to hydrogen conversion efficiency attains the levels of economic feasibility with the use of semiconductor sheets made of Rh – co-doped $SrTiO_3$ powders embedded into a gold layer. Solar to hydrogen conversion efficiency (1.1% and 30% quantum yield at 419 nm) was achieved by splitting pure water (pH 6.88). Effects of electric power, external magnetic field, and temperature on conversion efficiency have been investigated and found to be appreciable.

Bio–diesel is another potential source of energy. The energy of sunlight is converted into chemical energy through a biochemical process. A positive aspect of algal cultivation is that it can be grown either in freshwater or brackish water. In this way, it does not compete for fresh water. Microalgae respond by producing more carbohydrates or lipids in conditions of environmental stress; *e.g*., when a particular nutrient is lacking. Biodiesel derived from algal lipids is ***non-toxic*** and **biodegradable**. Microalgae produce oils 15 – 300 times more than traditional crops per unit cultivated area. The ability of an endolithic cyanobacterial strain, *Leptolyngbya* sp. ISTCY101 to produce biomass from which biodiesel can be produced, has been assessed in experiments conducted exploiting principles of carbon assimilation in the natural ecological niche of the cyanobacterium. Measurements of relevant variables and parameters showed that this strain is capable of returning a reasonably high yield of biomass productivity.

Integration of industrial ecology and ecological economics would expand the scope of the **circular economy**. New information generated in the process of integration would be used to develop new tools for decision-makers. **Self-guidance,** a special attribute, would be available to industry leaders if a course based on this chapter is introduced in the curriculum of engineering undergraduates.

Keywords: Ammonium-oxidizing bacteria, Biochemical process, Cyanobacterial, Endolithic strain, Electrolysis, Hydrogen production, Hydrogen energy, Lipid, Nitrite oxidizing bacteria, Nitrogen fixation, Particulate semiconductor sheets, Sustainable agriculture, Symbiosis.

INTRODUCTION

In the formative stage of **Industrial Ecology (IE)** as a discipline in the 1990s, when it embraced **Social Ecology, IE** was defined by, 1) industrial metabolism, 2) socio-economic metabolism, and 3) urban metabolism. The latter concerns with urban infrastructure frameworks, transportation, waste, energy, greenhouse gas emissions, and food in cities (Kennedy, 2016). Robert Ayres coined the term '***industrial 'metabolism'*** in analogy with **biological metabolism**. It refers to the integrated collection of physical processes that convert raw material into energy (Ayres, 1994). It also includes labor input, finished products, and wastes as output. A few of these aspects are discussed in this chapter. A dynamic industrial development with structural changes, permitting investments in modern technology and emission control with waste minimization, environmental auditing, political and industrial decision–making, human behavior, and attitudes, creates a livable society (Anderberg, 1998).

Industrial Ecology is a sub-discipline of ecological science that is concerned with the optimum utilization of natural resources and minimization of damage to the environment caused by human activities (*e.g*., setting up industries and developing the real estate, *etc*.). Frosch (1992) put the subject of "industrial ecosystems" in the mainstream. What emerged in the nineteenth century is now known as ***Industrial Symbiosis***. It is an association between two or more industrial facilities or companies in which the wastes or byproducts of one is used as raw material by the other. Thus, the cost of waste disposal is reduced. Residues and byproducts provide new avenues. Wastes do not go to the landfill, carbon emissions are contained and new business opportunities are generated in the process. The natural world favors ***industrial synergy*** as it is advantageous for both the parties involved and leads to both commercial and environmental advantages. A sequence of independent economically driven actions led to the establishment of an industrial district at Kalundborg, Denmark. The functioning of other industrial districts was analyzed in the light of the Kalundborg Industrial Ecosystem, which is essentially an eco-industrial park. Two closely located industrial units in symbiosis (Ehrenfeld & Gertler, 1997) are shown (Fig. **1**). Flow of both energy and matter is shown.

It is an industrial network with partnerships between private and public companies located in the area. Kalundborg eco-industrial park, a classic example of industrial symbiosis, saves 24 million Great Britain Pounds annually. It reduces CO_2 emission to the atmosphere by 635,000 tons, 3.6 million cubic meters of water, and 100 GHz of energy. In addition to these savings, it contributes 87000 tons of solid materials. This sets a benchmark for the evaluation and analysis of other similar projects.

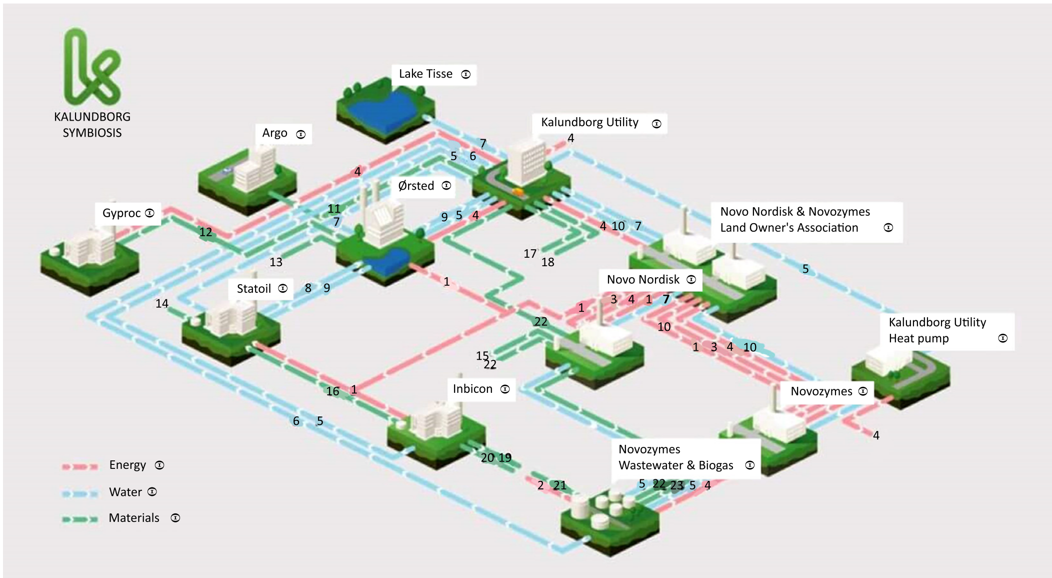

Fig. (1). The Kalundborg Industrial Ecosystem; an Eco-industrial park based on a circulation model of production. The basic principle behind its operation is: that matter is convertible into energy. The figure shows the flow of materials and energy. Source: University of Southern California, School of Engineering's blog.

Industrial Ecology is a study of the interaction between industry and the environment. It is based on the circular model of production; the waste of an industry serves as a raw material for the other industry (Graedel & Allenby, 1998). The theoretical and practical framework of the circular economy needs to be expanded to help sustainability. Analysis of the flow of matter and energy was carried out using concepts and tools borrowed from other fields. Bruel *et al*. (2018) recommend the reconciliation of IE and EE in order to develop better tools that help in decision-making. A study of socio-economic consequences of these flows would generate new information. This new information along with consideration of Earth's carrying capacity, and behavioral and social aspects of the natural system, would lead to a model of socioeconomic system. Analysis of this model system would guide us to sustainability (Bruel *et al*. 2018).

Damage to the environment is minimized if clean fuel is used in motor vehicles. Human society has been looking for clean energy sources; sources not polluting the environment. Biodiesel is a clean fuel. In the next section, we present different aspects of biodiesel production.

CHAPTER 5

Sustainable Development Goals: Good and Bad

Abstract: The central theme of human ecology is sustainable development. United Nations Organization (UNO) in 2015 identified 17 goals; known as ***sustainable development*** **goals (SDGs)**, to be achieved by 2030. SDG1 (No poverty) and SDG2 (Zero hunger) are difficult to achieve. For the former, a workable measure of poverty is to be evolved. The poverty line defined by the United Nations Department of Economic and Social Affairs (UNDESA) is linked with the Gross Domestic Product (GDP), which varies significantly for countries rich and poor. There is no relationship between poverty in the USA and India. It is ***relative poverty***. A universal absolute poverty, which is not linked with Gross Domestic Product, needs to be considered. The prospect of whether the goal of zero hunger would be achieved, depends on the state of **sustainable agriculture** in a country at any given time. SDG2 may be achieved by 2030 with cooperation among rich and poor countries. If developing countries are provided soft credit by developed countries from time to time, a few targets could be achieved.

Agricultural productivity depends on capital. The interaction of disease and human capital leads to dynamics in the state space of the system represented by multiple equilibria (two stable equilibria and an intervening unstable equilibrium). If compared with the famous Lorenz attractor, which presents trajectories of two convective cells; one lying over the other, in the state space of the system (the bottom convective cell is heated up from below, with two unstable foci and an intervening saddle point), it is clear that the interaction of disease and human capital would generate oscillations in system's state space. This explains why agricultural productivity varies; and oscillates between two states of low and high productivity. The incidence of unpredictable epidemics in this system would lead to chaos; which allows only short-term predictability. Therefore, SDG 3 (Good Health and Well–Being) appears to be wishful thinking. This knowledge adds value to SDG 12 (**responsible consumption and production**). Production refers to both agricultural and industrial.

Occupational Choice (SDG 3, SDG 8) is a critical factor. It depends on the beliefs and practices of the people of a nation. Banerjee & Newman (1993) developed a model of economic development. Economic development is considered as a process of **institutional transformation.** Capital market imperfections drive the dynamics of the system considered. Depending on the initial distribution of wealth, the economy generates two scenarios:1) either widespread cottage industry or factory production, 2) prosperity or stagnation. An individual's decision of occupation depends on whether he/she is wealthy or poor. The poor go for employment contracts (factory production) and the wealthy go for entrepreneurship (widespread cottage industry). A society needs both kinds of people. An economy that is poised between two scenarios is desirable.

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SDGs 13, 14, 15, and 17 are linked with each other in the sense that rain depends on tree cover present on the land surface. Water bodies receive water through precipitation which depends on the interaction between the sun and ocean; the reservoir of resources. Forest cover and land use patterns also affect climate. If rich countries help poor countries under the aegis of UNO through its different developmental programs, a few of the SDGs can be partially achieved. If developed nations continue to exploit situations in poor (developing) countries, then, there is no hope.

Keywords: Climate change, Distributive justice, Freedom, Family planning, Gross national product, Gross national income, Homeostasis, Industry, Institutional transformation, Occupational choice, Occupational safety, Poverty, Population growth, Sustainable agriculture, Sustainable human settlements.

INTRODUCTION

A gap between two perspectives (*i.e.*, between an exclusive concentration on economic wealth and a broader focus on the lives we can lead) has been identified as a central theme (Sen, 1997) of human life. In his opinion, democracy and human rights hold the key to **sustainable development** with good development goals. Human life faces many challenges in its journey; *e.g.*, epidemic outbreaks (DON, 2023), pandemic waves (Madhav, *et al*. 2017, Rai & Sarita, 2023), and Droughts and famines (Sen, 1997). Droughts and famines are not unfamiliar events. The welfare economist argues that the famine presents a situation in which people do not have sufficient buying power. It is not the shortage of food grains.

The reader's attention is drawn to a few examples of both.

Droughts and Famines

It is an extended period of extremely dry weather when there is not enough rain to support agricultural activities; *e.g.*, sowing paddy crops for food grain production and consumption. It could also cause a shortage of drinking water when the period of dry weather gets elongated. A linked event is famine. A few examples are given below.

Africa

1983 - 1985 Ethiopia famine

2011 East Africa Drought

India

The Great Bengal famine of 1770 struck during the period (1769 – 1770). It affected 30 million people. Bihar famine (1966 – 1967), 2353 deaths were reported by the state. It was happily tackled by the state.

Bangladesh

After independence in 1971, Bangladesh confronted a famine in 1974.

Developing Countries are located in the **Global South**; a geopolitical group of poor or middle–income states. It is located in a broad strip ranging from South-East Asia, Africa, and Pacific islands, all the way to the Caribbean to Latin America. The history of Europe suggests that two countries, France and Britain, were imperialists; *i.e*., expansion of territory by way of invasion was their agenda. Common Wealth Nations are a group of countries ruled by Britain; North American countries, Canada, and Australia, are examples. These are in different subcontinents. In Canada, Wars were fought and peace was brokered between two Britain and France by a peaceful settlement.

Two major reasons for World War II were: 1) the worldwide **economic depression** and 2) the failure of the **League of Nations.** In order to have an idea of the magnitude of the Holocaust, World War II (1941 – 1945), it is suffice to note that Nazi Germany and its allies murdered nearly six million Jews across Europe-occupied Germany. The world economy was devastated by WWII as the war was long drawn. In an attempt to establish international peace and ensure global security, the United Nations Organization was established. It began its operations on October 24, 1945.

Poverty and other deprivations go hand-in-hand with health and educational concerns, and to reduce inequality, economic growth needs to be enhanced to ensure the preservation of nature. United Nations Conference on 'Sustainable Development' **took the initiative to start deliberations among member states to evolve goals that guarantee** sustainable development. A chronology of events is given below.

Chronology of Events

1992 In Earth Summit, Rio de Janeiro Brazil, more than 178 countries adopted Agenda 21, Global Partnership to improve quality of life, which is dependent on how little damage we inflict on the environment

2000 Millennium Summit emphasized Sustainable patterns of consumption, production, economic and social development

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VIKAS RAI

Vikas Rai did masters in physics from Banaras Hindu University in 1985. In the same year, he joined a group of researchers in the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India, who focused on causes and consequences of current environmental problems. His thesis entitled: "Order and Chaos in Ecological Systems" earned him a Ph.D. degree in 1993. Since then he has been working on applications of nonlinear dynamics to ecological systems, brain dynamics, and neuro – degenerative diseases. The book advocates for the integration of concepts from ecological science and neuroscience.