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# Resilience and Sustainability of the Ecosystem: An Environmental Health Perspective

*Sokan – Adeaga Adewale Allen, Ana Godson R.E.E, Sokan-Adeaga Micheal Ayodeji & Sokan-Adeaga Eniola Deborah*

*University of Ibadan*

## ABSTRACT

Since the industrial revolution, humanity had witnessed rapid economic development and technological advancement; but the gains have come at a price. This rising concern gave birth to the Convention on Biological Diversity (CBD) in order to address pertinent issue centres on sustainable development. This review begins by giving an in-depth overview of the ecosystem, as a working structural and functional unit. It presents its discussion within the resilience concept, sustainable development, ecological sustainability and adaptive development. It describes the profound imprint we humans have had on nature and ideas on how to deal with the resulting challenges from a socio-ecological perspective. It conclude that managing complex, coevolving social-ecological systems for sustainability requires the ability to cope with, adapt to and shape change without losing options for future development. It suggested that the two useful tools for resilience-building in complex, unpredictable systems are structured scenarios and active adaptive management.

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# Resilience and Sustainability of the Ecosystem: An Environmental Health Perspective

Sokan – Adeaga Adewale Allen[α], Ana Godson R.E.E [σ], Sokan-Adeaga Micheal Ayodeji [ρ] & Sokan-Adeaga Eniola Deborah [¥]

## I. Abstract

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*Author α σ:* Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria.

*ρ:* Department of Microbiology, Faculty of Sciences, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

*¥:* Department of Physiology, Faculty of Basic Medical Sciences, College of Medicine, Ladoke Akintola University (LAUTECH), Ogbomosho, Oyo State, Nigeria.

## II. INTRODUCTION

During the last 20 decades, and particularly after World War II, economic development, international collaboration, technical and social innovation, improved health and wealth have all contributed to improve the standard of living of most people. Despite this development, globally there are still one billion absolute poor and three billion people living on less than 2.5 USD a day (UNEP, 2011). It cannot be argued that humans have been successful in modifying the planet to meet the demands of a rapidly growing population. But the gains achieved by this spectacular re-engineering have come at a cost. It is now widely acknowledged that humanity's use of the biosphere, that sphere that supports life on the planet, is not sustainable. For mankind to live and thrive successfully in this planet, it has to stay away from critical 'hard-wired' thresholds in the Earth's environment and respect the planet's biogeochemical processes.

The United Nations Millennium Ecosystem Assessment (MA) in 2005 published the first 'global health control' of the world's ecosystems. The observation was lucid; the rapid technological advancement of mankind in the past 50 years has degraded the Earth's ecosystems faster than ever before. The assessment showed that some 60 percent of the ecosystem services that support human well-being are being degraded or used unsustainably. This eco-deterioration could grow



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significantly worse during the first half of this century and is an impediment to combating global poverty and achieving the Millennium Development Goals (Millennium Ecosystem Assessment (MA), 2005). It is obvious that human wellbeing and economic progression depends not only on the interrelationship within and between different regions of the globe but also on ecological sustainability (Arrow *et al.,* 1995; Folke *et al.,* 1998). Therefore, a major challenge is to develop adaptive forms of governance systems that make it possible to develop environmental assets in a fashion that strength their capacity to support societal development for a long duration into the future (Costanza *et al.,* 2000; Lambin, 2005).

Resilience thinking is about advancing knowledge on how to strengthen institutional capacity to cope with stresses arising from climate change and other emerging environmental issues. It is also involves designing means to deal with unforeseen contingencies and identifying sustainable ways for humans to live within the ecosphere. Several authors who work on resilience only focused on the capacity to absorb shocks and still maintain function. But, there is also another aspect of resilience that concerns the capacity for renewal, re-organization and development, which has been less in focus but is essential for the sustainability discourse (Gunderson and Holling, 2002; Berkes *et al.,* 2003). In a resilient social–ecological system, disturbance has the potential to create opportunity for exploit, innovation and advancement. In weak system even small disturbances may cause great disaster (Adger, 2006). Old dominant perspectives have implicitly assumed a stable and infinitely resilient environment where resource flows could be managed and nature could bounce back into equilibrium when human stressors were removed. Such static equilibrium center views provide narrow insight into the transient behavior of systems that are far from equilibrium (Holling, 1973). The resilience perspective drifts from archaic policies that assume stable equilibrium to those that build social-ecological adaptation and resilience (Berkes *et al.,* 2003, Smit and Wandel, 2006). It is argued that managing for resilience enhances the likelihood of sustainable development in changing environments where the future is unpredictable and surprise is likely (Walker *et al.,* 2004; Adger *et al.,* 2005).

This review enunciates on ecosystem as a structural and functional unit of the large complex biosphere, with a succinct description of the various human activities that threaten its sustainability. It further presents its discussion within the resilience concept, sustainable development, ecological sustainability and adaptive development. It describes the profound imprint we humans have had on nature and ideas on how to deal with the resulting challenges from a socio-ecological perspective. This review concludes by illustrating how we can use the growing insights into the many challenges we are facing by starting to work with the processes of the biosphere instead of against them.

## III. OVERVIEW OF THE ECOSYSTEM

### *3.1 Introduction - What is an Ecosystem?*

There are many definitions for ecosystem. The definition of Christopherson (1997) seems quite workable, but so are quite a few others. Ecosystem definition: An ecosystem is a natural system consisting of all living things interacting with all the non-living factors of the environment (Christopherson 1997). The term ecosystem was coined in 1930 by Roy Clapham, to denote the physical and biological components of an environment considered in relation to each other as a unit. British ecologist Arthur Tansley later refined the term, describing it as the interactive system established between biocoenosis (a group of living creatures) and their biotope (the environment in which they live) (Tansley, 1935). Central to the ecosystem concept is the idea that living organisms are continually interacting with both the biotic and abiotic components of their environment (Golley, 1993).

The term ecosystem is generally referred as to the entire assemblage of living organisms that make


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up the biotic community or biocoenosis interacting with their environment (or biotope), in a defined space, functioning as a loose unit. Together, these components and their interactions with and relationships to each other form a dynamic and complex new whole, functioning as an "ecological unit", with additional characteristics that can't be found in the individual components. Nor could any organism live completely on its own without involving any other species of organism (Odum, 1971). Politically, the concept has become important, since the Convention on Biological Diversity, (CBD), signed by almost 200 nations. The CBD formulates the concept in the following definition: "Ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (Convention on the Biological Diversity, 1992).

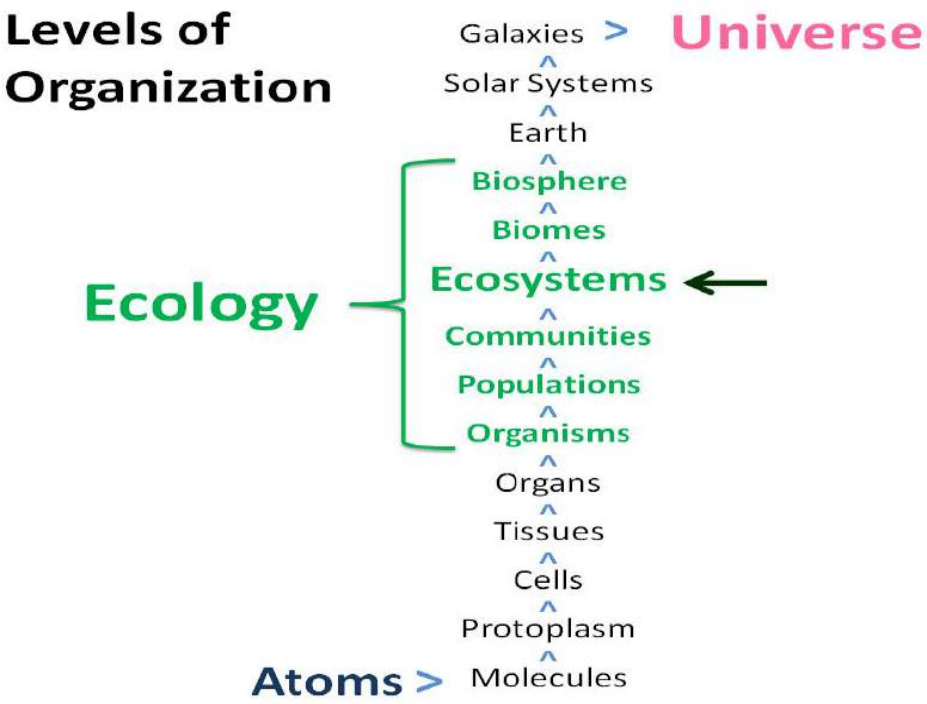


*Fig. 1:* Levels of Organization of Ecology, highlighting ecosystems (Credit: Erle Ellis, 2014).

The ecosystem is a core concept in Biology and Ecology, serving as the level of biological organization in which organisms interact simultaneously with each other and with their environment. As such, ecosystems are a level above that of the ecological community (organisms of different species interacting with each other) but are at a level below, or equal to, biomes and the biosphere. Essentially, biomes are regional ecosystems, and the biosphere is the largest of all possible ecosystems as depicted in **Fig 1**.

### *3.2 Components of an Ecosystem*

Ecosystems consist of living things existing in a symbiotic relationship with their environment. Living things within the ecosystem are continuously competing with one another to thrive reproductively and survive in their niche, or environment. Two main components exist in an ecosystem: abiotic and biotic. The abiotic components of the ecosystem refer to the non-living matter of the environment while the biotic components are the living properties of a given ecosystem.





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*Abiotic Components*

Abiotic components of an ecosystem consist of the nonorganic aspects of the environment that determine what life forms can thrive. Examples of abiotic components are precipitation, humidity, pressure, turbidity, salinity, temperature, light, topography, edaphic factors (soil factors), and natural disturbances such as earthquake, landslide, typhoon, hurricanes, lighting storms, tsunamis, forest fires etc.

*Biotic Components*

The biotic components of an ecosystem are the life forms that inhabit it. The living component of an ecosystem plays a vital role in the biogeochemical and energy cycle. They are grouped in terms of the means they use to get energy. Producers such as plants produce their own energy by utilising energy from sunlight via photosynthesis. On the next level of the energy pyramid are the consumers. These consumers exist in three forms namely: herbivores, carnivores and omnivores. Herbivores feed on plants, carnivores get their food by eating other carnivores or herbivores, and omnivores can digest both plant and animal tissue.

*Interaction*

The living and non-living components of ecosystem interacts together to bring about a functioning system. For example, whenever there is a decrease in the temperature of an area, organisms living in such area changes behaviourally, physiologically and structurally to adapt to the new condition. An increase in the global average temperature of the earth's surface (Global warming), arising from greenhouse effect, will speed up the metabolism rates of most organisms. Metabolic rate increases with temperature because the nutrient molecules in the body are more likely to contact and react with one another when excited by heat. According to "Science News," tropical ectothermic -- cold-blooded organisms could experience increased metabolic rates from an increase of as little as 5°C because their internal temperature is largely dependent on the temperature of their environment. To adapt to these circumstances, poikiothermic life forms could hibernate in shade and not actively search for food during daylight hours when the sun is most intense.

## 3.3 Ecosystem Structure and Function

### 3.3.1 Ecosystem components (structure)

An ecosystem could be view in different ways; hence there is single set of components that make up the ecosystem. However, all ecosystems must include both living and non-living factors, their interrelationship, and some source of a single living plant (biotic component) within a small energy. The simplest and least representative of an ecosystem might therefore contain just terrarium exposed to light to which a water solution containing essential nutrients for plant growth has been added (abiotic environment). An extreme view would be the biosphere, which comprises the totality of Earth's organisms and their interactions with each other and the earth systems (abiotic environment). And of course, most ecosystems fall somewhere in between these extremes of complexity (Odum, 1971).

At a basic functional level, ecosystems generally contain the primary producers which are capable of harnessing solar energy from sunlight during photosynthesis and converting carbon dioxide, water and other inorganic chemicals into the organic building blocks of life. Consumers feed on this captured energy which is chemical form, and decomposers not only feed on this energy, but also break the organic matter back into its inorganic constituents, which can be used again by producers. These interactions among producers, consumers and decomposers constitute the trophic interactions, and are composed of trophic levels in an energy pyramid, with the highest energy and biomass concentrated in the primary producers which are found at the base of the pyramid. The energy decreases up the pyramid to the top, starting with primary consumers feeding on primary producers, secondary consumers feeding on these, and so on (Odum, 1971). Trophic


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interactions are also described in more detailed form as a food chain, which depicts a linear feeding relation in an ecosystem, and by food webs, which detail the complex feeding interactions among all organisms in an ecosystem. Together, these processes of energy transfer and matter cycling are essential in determining ecosystem structure and function and in defining the types of interactions between organisms and their environment. It must also be noted that most ecosystems contain a wide diversity of species, and that this diversity should be considered part of ecosystem structure (Golley, 1993).

### 3.3.2 Ecosystem processes (function)

By definition, ecosystems function by the use energy and nutrients cycle. Energetic processes in ecosystems are usually described in terms of trophic levels, which define the role of organisms based on their level of feeding relative to the original energy captured by primary producers. As always, energy cannot be recycle, so ecosystems require a continuous flow of high-quality energy to maintain their structure and function. For this reason, all ecosystems are described as an "open systems" requiring a continuous net flow of energy. Hence without the continuous supply of radiant energy from the sun, the biosphere would soon run short of energy and consequently life will cease on the earth.

Energy input to ecosystems drives the biogeochemical processes by ensuring continuous flow of matter between organisms and the environment. The biosphere provides a good example of this, as it interacts with and exchanges matter with the lithosphere, hydrosphere and atmosphere, driving the global biogeochemical cycles of carbon, nitrogen, phosphorus, sulfur and other elements. Ecosystem processes are dynamic, responding to seasonal changes arising from variation in the solar output, this affect the net photosynthesis of primary producers over the year, driving remarkable annual variability in the carbon cycle—the largest of the global biogeochemical cycles (Odum, 1971). This fixed organic carbon in plants are utlised as food for consumers and decomposers, who breaks the carbon to forms with lower energy, and ultimately releasing the carbon fixed by photosynthesis back into carbon dioxide in the atmosphere, producing the global carbon cycle. The biogeochemical cycling of nitrogen also uses energy, as nitrogen fixing bacteria uses energy obtained from organic materials and sun, to converts atmospheric nitrogen into nitrates and then protein a form that can be utlised by living organisms. Ecosystems also cycle phosphorus, sulfur and other elements. As biogeochemical cycles are defined by the exchange of matter between organisms and their environment, they are classic examples of ecosystem-level processes (Golley, 1993).

## 3.4 Human Activities that Affect the Ecosystem

*Overhunting*

Overhunting by humans for animals in the wild, leads to an imbalance in the ecosystem, as they eliminate vital tertiary consumers such as lions, tigers and bears etc that help to checkmate plant consumers in balance and prevent overgrazing. A healthy ecosystem must have a well balance of predators and prey that naturally cycle through life and death sequences. Over-hunting often results in ecosystem species imbalance and environmental stress. Humans also practice commercial overfishing, where massive fishing nets result in “bycatch,” in which unwanted fish are caught in nets and then thrown away. Bycatch results in the loss and death of one million vital aquatic organisms annually that helps to maintain ecobalance. Heavy fishing machines also kills large fragile coral reefs found at the bottom of the ocean.

*Deforestation*

Cutting of trees and forest for commercialization, settlements and industrialization by humans over the years has led to the loss of many viable species putting some of these species on the verge of extinction. The world’s rainforests are being





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destroyed at a rate of 78 million acres per year, resulting in vegetation degradation, nutrient imbalance, flooding and animal displacement. Trees also act as a natural air filter in the carbon cycle by removing carbon dioxide in the atmosphere during photosynthesis and releasing oxygen. Hence deforestation makes a lot of carbon dioxide in the atmosphere from being removed, thus contributing to global warming. Some estimates indicate that canopy forest species will be reduced by 35 percent by 2040 if deforestation continues at the same rate.

*Pollution*

Industrialization and technological advancement has led to increase in waste generation over the decades. Most of these pollutants contaminate the air, soil and water affecting human health and the environment adversely. Modern transportation systems utlising fossil fuels emit toxic gases that include carcinogenic particles and irritants, creating air pollution. Humans use of pesticides such as organochlorides, organophosphates etc for farming has led to the pollution of underground water and other water bodies leading to the destruction of the natural biodiversity. Advancement in military weapons and nuclear programs has severally affects the life-sustaining ecosystem making it losing its totipotency.

*Land Conversion*

Rapid urbanisation and construction of road systems and buildings has greatly affect the Earth's natural surface, through loss of soil nutrients, removal surface vegetation and trees that filter the air and balance the carbon cycle. Urbanization also displaces animals from their natural habitat and increases environmental pollution from vehicles and factories. A system of highways also causes serious migratory obstacles for animals and replaces native plants with impermeable concrete, resulting in habitat destruction. Since the concrete is impermeable, it doesn't allow water to seep through, resulting in increased vulnerability to flooding. This practice of human construction continues at a rapid pace, leading to urban sprawl, where cities are essentially forever expanding outside the traditional inner-city limits.

## IV. RESILIENCY

### *4.1 Overview of Resiliency*

Resiliency in ecology is defined as the capacity of an ecosystem to cope with disturbance and still retain its basic structure and function. Resilience-thinking emerged from the need to manage interactions between human-constructed systems and natural ecosystems in a sustainable way despite the fact that to policymakers a definition remains elusive. Resilience-thinking deals with how much the planet earth can cope with anthropogenic disturbances and still remain viable for present and future generations. It is also concerned with commitment from geopolitical policymakers to protect and manage earth essential resources through resilience and harness these resources to ensure their benefit and sustainability for future generation (Brian and Salt, 2012). The resiliency of an ecosystem, and thereby, its sustainability, can be reasonably measured at junctures or events where the combination of naturally occurring regenerative forces (solar energy, water, soil, atmosphere, vegetation, and biomass) interact with the energy released into the ecosystem from disturbances (Ben, 2013).

A more detailed practical view of sustainability can be view as closed systems that maintain processes of productivity indefinitely by substituting resources used by actions of people with resources of equal or greater value by those same people without causing the degradation of the natural biotic systems (Melvin 2014). In this way, sustainability can be quantitatively measured in human projects provided there is transparent accountability between the resources depleted from the ecosystem and those use to replace them. In nature, the accountability occurs naturally through a process of adaptation as an ecosystem returns to viability from an external disturbance


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such as earthquake, volcanic eruption, hurricane, tornado, flood, or thunderstorm etc. The adaptation involves a multi-stage process that begins with the disturbance event followed by absorption, utilization, or deflection of the energy or energies that the external forces created (Brian and Salt, 2006).

### *4.2 The resilience concept*

Understanding the dynamic and intertwining relationship between sudden change and resilience sources makes it lucid that resilience of complex adaptive systems is not simply about resistance to change and preservation of existing systems. In literature, resilience is conventionally defined as the ability of a system to adapt to disturbance and re-organize while undergoing transformation so as to still retain its initial paramount forms, roles, identity, and feedbacks (Walker *et al.,* 2004). Many studies on ecosystem resilience have stressed the first part of this definition, i.e. capacity to accommodate disturbance, or the buffer capacity that allows persistence. It has also been linked to social change where, for example, social resilience was defined by Adger (2000) as the ability of human communities to cope with extrinsic stressors to their social infrastructure, which may include political turbulence, socio-economic reforms, and environmental variability. Anderies *et al.,* (2004) used the concept robustness to mean the preservations of some congenital systemic features despite alterations in the behavior of its component parts or its environment (see Table 1).

Resilience also deals with utilization of opportunities arising from changes in terms of reformation of existing systems, structures and processes, and emergence of great developments; and not only coping with disturbances. According to Smit and Wandel (2006), resilience provides adaptive capacity that allow for progressive development, like a dynamic adaptive interplay between sustainability and development with change. Disequilibrium between the two will ultimately lead to collapse of the system. This implies that resilience does not always result into pleasant to outcomes. At times it may be extremely difficult, if not impossible to transform a resilient system from its current state to a more congenial one (Scheffer *et al.,* 2001; Gunderson and Holling, 2002; Walker *et al.,* 2004).

Adaptive processes that involve the ability to cope and adapt with change emerge out of the system's self-organization. Furthermore, the changes after a disturbance or even a regime shift is essentially dependent on the self-organizing capacity of the complex adaptive system (Norberg and Cumming, 2006) and the self-organizing process draws on temporal and spatial scales above and below the system in focus (Nyström and Folke, 2001; Gunderson and Holling, 2002). This is why the idea of self-organization, adaptation and learning in addition to the overall ability to persist in disturbance is integrates in the concept of resilience in relation to social–ecological systems. Carpenter *et al.* (2001) interpreted social–ecological resilience as follows:

(1) the quantitative measures of disturbance a system can cope with and still maintains its inertia or domain of attraction,
(2) the degree to which the system is capable of self-organization (versus absence of organization, or organization dictate by external factors), and
(3) the extent to which the system can progress and expand the capacity for learning and adaptation.

Based on the above proposition, resilience is a systematic approach, a way of cogitating, that presents a platform for cumulating and organizing ideas and it is in this broader sense that it provides a valuable context for the critiquing of social–ecological systems, an area of explorative research under rapid development with policy implications for sustainable development (Folke *et al.,* 2002). The resilience approach provides one among several arenas (e.g. vulnerability research, ecological economics, sustainability science) for generating integrative science and interdisciplinary collaboration on issues of fundamental importance for governance and





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managing a transition toward more sustainable development channels, which is one of the one of the dreadest challenge facing mankind (Lambin, 2005).

*Table 1:* A sequence of resilience concepts, from the more narrow interpretation to the broader social–ecological context

| Resilience concepts | Characteristics | Focus on | Context |
|---|---|---|---|
| Engineering resilience | Return time, efficiency | Recovery, constancy | Vicinity of a stable equilibrium |
| Ecological/ecosystem resilience social resilience | Buffer capacity, withstand shock, maintain function | Persistence, robustness | Multiple equilibria, stability landscapes |
| Social–ecological resilience | Interplay disturbance and reorganization, sustaining and developing | Adaptive capacity transformability, learning, innovation | Integrated system feedback, cross-scale dynamic interactions |

## V. SUSTAINABLE DEVELOPMENT

### *5.1 Definition and Background*

There are diverse definitions and origins of the term sustainable development; but the "Brundtland Report" published in 1987 by the World Commission on Environment and Development is by far the best and widely accepted definitions:

"Sustainable development is development that satisfies the needs of the present without undermining the capability of future generations to meet their own needs. It embedded two key concepts:

- The concept of 'needs', in particular the essential needs of the indigents people across the world, to which overriding priority should be given; and
- The idea of limitations dictated by the state of technology and social organization on the environment's ability to meet present and future needs."

This report, published in 1987 by the United Nations World Commission on Environment and Development, emphasize on the need to protect biodiversity of species. This is of paramount importance with respect to measures to protect the quality of the environment, and by the restoration, development, and preservation of habitats that are consequential to the survival of species. This implies the sustainable management of the use of the animal and plant populations being exploited. In other words, it is the rational management of human, natural, and economic resources with the objectives to satisfy the essential needs of humanity for a longer duration. Sustainable development implies the fulfillment of several conditions: preserving the overall balance, conservation of the environment, and preventing the degradation of natural resources. Waste management and rationalization of energy production and consumption by mankind is also of paramount importance to sustainable development. Sustainable development offers more or less distinguished panacea from other modes of development, which have led and are still leading to worrying social and ecological damage on both a global and a local scale. In order to be sustainable, development must conglomerate three main elements: fairness, protection of the environment, and economic efficiency. A sustainable development project must integrate a better-developed mode of


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consultation between the community and the members it comprises. The success of such a policy also depends largely on consumers accepting certain constraints and citizens observing certain requirements with regard to transparency and participation.

### *5.2 Three pillars of sustainability*

In 2005 the World Summit on Social Development identified sustainable development goals, such as environment protection, economic reformation and social development (UN General Assembly, 2005). This view has been expressed as an illustration using three overlapping ellipses indicating that the three pillars of sustainability are not mutually exclusive and can be mutually reinforcing as shown in **Fig 2**. These trio pillars have served as a common base for several sustainability standards and certification systems in recent years, in particular in the food industry (Manning *et al.,* 2011; Reinecke *et al.,* 2012). In modern time standards which explicitly refer to the triple bottom line are Rainforest Alliance, Fairtrade and UTZ Certified (SAI, 2010; Alvarez, 2011). Some luminaries and practitioners of sustainability have illustrated four pillars of sustainability, or a quadruple bottom line. One such pillar is future generations, which stress the long-term thinking associated with sustainability (SURF, 2013).

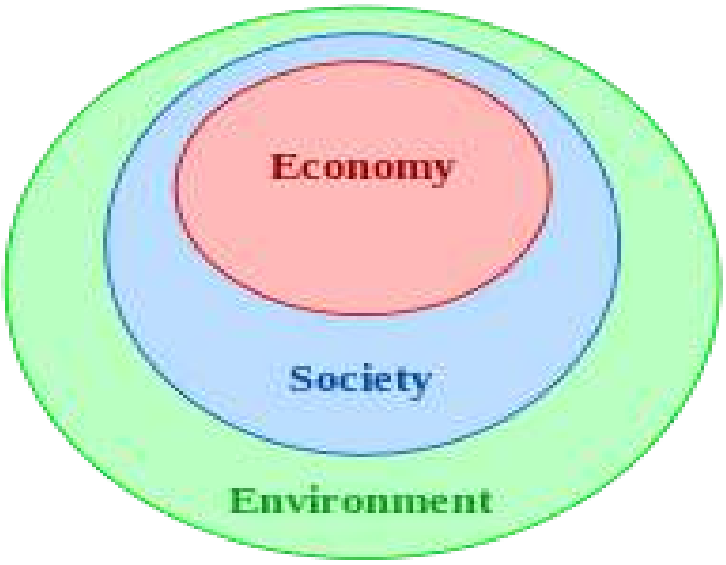


*Fig. 2:* Relationship between the "trio pillars of sustainability", in which both society and economic are circumscribed by environmental limits (Scott, 2009).

Sustainable development involves striking balance between local and global efforts to meet core human needs without distorting the ecosystem (Kates *et al.,* 2005; IISD, 2009; EurActiv, 2004). The pertinent question is how to represent the relationship between those needs and the environment. A study conducted by Micheal (2005) pointed out that environmental justice is a vital tool just as sustainable development (Michael, 2005). From this perspective, the economy is a subsystem of human society, which is itself a subsystem of the biosphere and a gain in one sector is a loss from another (Porritt, 2006). This perspective led to the nested circles figure of 'economics' inside 'society' inside the 'environment'.

A more elementary definition is that sustainability is something that enhances "the quality of human life while living within the carrying capacity of supporting eco-systems" (IUCN/UNEP/WWF, 1991), though nebulous, it conveys the idea of sustainability having quantifiable limits. But sustainability is also a clarion call, a task in progress or "journey" and therefore a political process, so some definitions set out common goals and values (Milne *et al.,* 2006). The Earth Charter (2000) speaks of "a sustainable global society





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founded on respect for nature, universal human rights, economic justice, and a culture of peace." This suggested a more complex figure of sustainability, which included the importance of the domain of 'politics'. (**see Figure 3).**

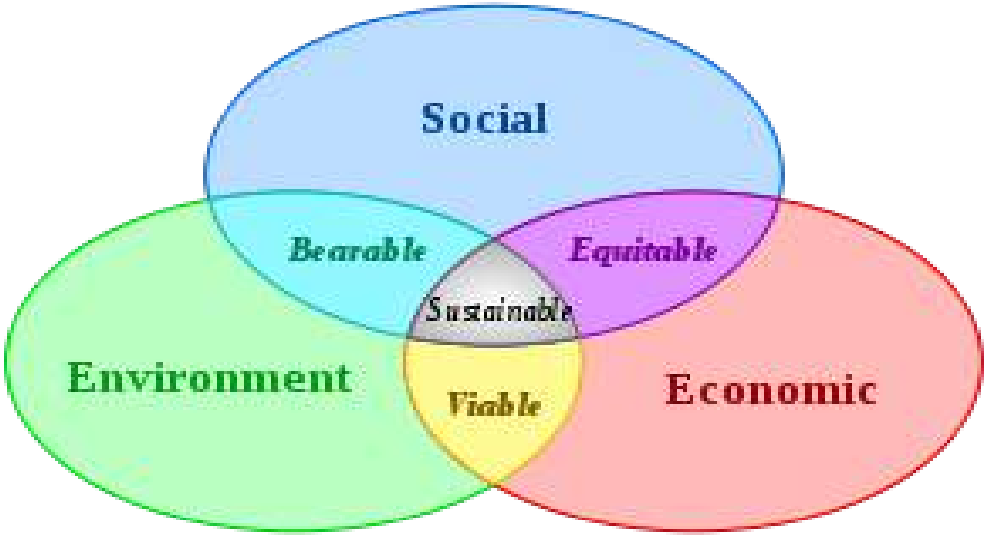


*Fig. 3:* Venn diagram of sustainable development: at the confluence of three constituent parts (Adam, 2006).

In addition, sustainability implies responsible and proactive decision-making and innovation that ameliorates negative effects and maintains equilibrium between ecological resilience, political justice, economic prosperity, and cultural vibrancy to ensure a desirable planet for all species now and on long term (Liam *et al.,* 2013). There are specific types of sustainability, these include, sustainable architecture or ecological economics, sustainable technology, and agriculture (Costanza and Patten, 1995).

*Some of the pertinent issue centres around sustainable development are:*

*Addressing Biodiversity Loss*

The UN Conference on Environment and Development (the Earth Summit) in 1992 adopted the Convention on Biological Diversity (CBD), with about 192 countries, plus the EU, signatories to the convention. In April 2002, the Parties to the Convention pledged to significantly reduce the biodiversity loss by 2010, eventually that dream do not materialize. Despite the numerous successful conservations measures supporting biodiversity, the 2010 biodiversity target has not been met at the global level.

*Poverty and the Environment*

The causes of poverty and of environmental degradation are multifactorial implying that tackling sustainable development requires comprehending the issues surrounding it from many perspectives, not just a one-way approach say an environmentalist or economics perspective alone.

*Non-governmental Organizations on Development Issues*

Non-Governmental Organisations (NGOs) are non-profit enterprises serving as middlemen between governments and the society; and also filling the gap where governments will not, or cannot perform. In the past however, some NGOs from the developed nations have earned bad reputation in some third world countries because


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of things like imperialism, being a foreign policy arm or agent of the original country and so on. In recent years some of these criticisms were still valid. However, recently some new and old NGOs alike have started to become more participatory and grassroots-oriented by engaging community-based empowerment programmes which are regenerative and transferable. This is in general a positive development. Yet, the fact that there are numerous NGOs popping up everywhere perhaps points to institutional failure, poor governance, economic recession, lack of political will on the part of government, dereliction of basic human right and poor foreign policy.

*Foreign Aid for Development Assistance*

In 1970, the rich nations of the world, agreed to give 0.7% of their gross national income as official international development aid, annually. Since that time, billions have certainly been given annually, but rarely have the developed nations actually met their promised target.

Furthermore, aid has often come with a price of its own for the developing nations. Some of the common criticisms, associated with foreign aid, for many years, include the followings:

- Aid is often use as a strategy to exploit the recipient by bargaining on conditions of compulsory use of exorbitant goods and services by recipient from donor countries.
- Most aid does not actually met the need of the target population (poorest) who really need it.
- Aid amounts are dwarfed by rich country protectionism that denies market access for poor country products while wealthy nations use aid as a lever to enlarge market for their products in indigent countries.
- Elephant projects or massive grand strategies often fail to help the vulnerable; as most of the fund are loss to corruption and misappropriation.

*Water and Development*

Water privatization are paramount issues in developing countries as it negates the fundamental right of the people to water, by exploit them and capitalizing on their vulnerability.

*Corporate Social Responsibility*

Corporate Social Responsibility is a bit of a buzz word and many feels it has drain from its original objectives, while others are trying to find innovative ways to engage with businesses to be more responsible in their practices by integrating social responsibilities to the communities where their goods and services are being used.

*Energy Security*

Energy security and demand is an emerging issue for both developed and developing nations alike. This unquantified quest for fossil fuel energy has led to social disorders and commotions such wars, civil unrest, overthrow of democratically elected leaders, and emergence of puppet governments and dictatorships. World leaders had admitted that there is a dwindling in the underground carbon source, and hence there is dire need for an alternative renewable energy source such as biomass derived energy. However, investment into the alternatives has been lacking, or little in comparison to fossil fuel investments. As the menace of continuous global fall in oil prices and its resultant environmental degradation continue to escalate coupled with the increasing awareness of climate change, more nations and companies are trying to invest in alternative renewable energy.

*Brain Drain of Workers from Poor to Rich Countries*

Brain drain has being a nagging problem for many poor countries losing most of their professionals and highly talented human resources to the developed nations. This effect is greatly felt in the healthcare, for example, in many rich countries; up to one third of doctors may be from abroad, many of which are from Sub-Sahara Africa Ironically, many African countries have as little as 500 doctors serving their entire population. Reasons for this brain drain vary, ranging from





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unhealthy working conditions and poor emoluments domestically; to attractive opportunities and active incentive from abroad.

*Environmental Issues*

Environmental problems are vital issues of major global concern. Humans' survival depends on a healthy and sustainable environment, and yet we have deteriorated the environment in numerous ways. This issue includes global climate change, deforestation, loss of biodiversity, ozone depletion, eutrophication, wildlife conservation, urbanisation, genetically engineering, sustainable development, and more.

*Aid*

There are several forms of aid, ranging from humanitarian emergency assistance, to longer term development aid. Some provide relief aids during natural and anthropogenic disaster occurrence such as food, shelter aid, medical supplies or military assistance, but all these forms of aid seem to be accompanied with severe criticism, either around ineptness of delivery, or of political motives or more.

### *5.3 Ecological Sustainability*

In ecology, **sustainability** is the capacity to endure; it is defined by the capacity of a biological system to remain diverse and indefinitely vigour. Examples of sustainable biological systems are long-lived and healthy wetlands and forests. From a wider perspective, sustainability can be seen as the capacity of systems and processes to endure disturbances. The core value for sustainability is sustainable development, which comprises of four interconnected domains viz ecology, culture, politics, and economics (James *et al.,* 2015). Sustainability can also be defined as the capacity of a system or process to be preserved, enhanced, upheld, or maintained. Sustainability science is the systematic study of the combination of environmental science and sustainable development (Lynn *et al.,* 2014).

The survival of humankind and other organisms are dependent on sustainable environments and healthy ecosystems. There are various ways of minimizing the adverse human impacts on the ecosystem, which include green technology, environmental protection and environmental resources management. Information is gained from earth science, green chemistry, conservation biology and environmental science. Ecological economics studies integrate the fields of academic research with the aims to address biosphere protection and human economies. Transcending into sustainability is also a social challenge that circumscribes the judicious implementation of urbanisation and transportation, foreign and national laws, local and individual lifestyles and ethical consumerism. There are several ways of living a more sustainable lifestyles ranging from reorganizing living conditions (e.g., ecovillages, eco-municipalities and sustainable cities), reappraising economic sectors (permaculture, green building, sustainable agriculture), or work practices (sustainable architecture), using science to develop new technologies (green technologies, renewable energy and sustainable fission and fusion power), or designing systems in a flexible and reversible manner (Zhang and Babovic, 2012), and promoting positive lifestyles to conserve ecological resources.

In spite of the widespread usage and knowledge of the term "sustainability", the possibility that mankind will achieve environmental sustainability has been doubtful, and continues to be, questioned—in light of environmental degradation, global climate change, alarming population growth rate, overconsumption and societies' pursuit of infinite economic growth in a closed system.

## VI. RESILIENCE AND SUSTAINABLE DEVELOPMENT

*Resilience* is the capacity of an ecosystem or social system to continue functioning despite natural and anthropogenic disturbances. The cores of a sustainable environmental support system are the resilient ecosystems. A key to resilience is


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anticipating disturbances and preparing ahead for them. There are numerous ways to achieving resilience, these include:

- *Redundancy:* Duplication and diversification of function provide backups for when systems goes out of control. This principle is most conspicuous in the design of modern spacecraft, which have extensive backup systems to replace parts of the spacecraft that fail to function properly. Redundancy is a pivotal key in natural ecosystems. The presence of species with overlapping ecological roles and niches contributes to the resilience of ecosystems.

- *Low dependence on human inputs:* Sustainable human - ecosystem interaction is associated with ecosystems that have small human inputs. The bulk of the work in an ecosystem is performed by nature. Anthropogenic interferences reduce resilience because sooner or later event erupts that interferes with a society's ability to provide the inputs. An example of such scenario is the collapse of Middle Eastern civilizations when irrigation ditches were clogged with sediment is a typical example.

Resilience is desirable, but it can interfere with other social objectives that are equally beneficial. Efficiency, for example, has become a vital component for modern industries because low costs of operation are consequential for survival. Economic efficiency and resilience are often in conflict because the redundancy that reinforces resilience requires extra cost and effort. Economic pressures to reduce resilience are increasing as competition heightens in the global economy.

### *Trade Off between stability and resilience*

*Stability* means constancy - things remaining in equilibrium. Stability is desirable if it minimizes unwanted fluctuations. Ecosystems and social systems that rarely change are more easily drifted to a different stability domain when extrinsic disturbances force them to accommodate change beyond their carrying capacity. A common source of conflict between stability and resilience is the loss of resilience when a system is so stable that it does not demonstrate its ability to adapt to stress. An illustrious example is the disaster that followed a sudden drop in fuel oil supply in north-eastern United States some years ago. Many Americans who usually enjoy copious of energy to comfortably heat their homes were caught unaware when the supply of fuel oil fall at a time of uncommon severe winter weather. The outcome was accompanied by an unprecedented number of deaths from exposure to severe cold when their chimneys ran out of fuel. Many of the aged people who seldom went outside during severe weather lack access to appropriate clothing for protection against cold while some people lacked a social support system to combat this sudden development.

Another typical example of the loss of resilience when resilience is not demonstrated is floodplains. A large proportion of the world's human population inhabits floodplains because of its fertile soil, abundant precipitation and high agro-capacity. River water spreads over a floodplain for a short period annually, depositing a thin layer of mud that keeps the soil deep, fertile and viable for agriculture. However, floodplains also demonstrate setback such as floods destroying crops, houses and other property. During most years, floods are mild and do not result in environmental damage, but sometimes flooding can be severe.

Modern medicine is also faced with similar challenges on the use of drugs to control public health diseases such as malaria and tuberculosis. While drugs provide obvious benefits, their large-scale use can lead to emergence of drug-resistant strains of pathogens just in the same fashion large-scale use of insecticides leads to resistance in insects. The stability (low level of disease) achieved by orthodox medicine is accompanied by a loss of resilience due to dependence on drugs. The risk of epidemics with drug-resistant strains can be particularly severe when:





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- The human population lost its innate immunity to a disease;
- Social institutions saddled with the responsibilities of providing alternative means of diseases prevention have been abandoned because their roles seem to be obsolete.

The most important of the conflict between stability and resilience is the one that involves food security. Although advanced nations of the world have an abundant and stable food supply, food storage has declined drastically during the past decade. The abundant food supply lulls wealthy societies into an unrealistic sense of security. At the same time that modern science, technological advancement and economic development are increasing global food production, environmental deterioration and dwindling water supplies are reducing the potential. There are also possibilities of sudden and unexpected agricultural failure arising from climate shifts induced by global warming. Nations such as Japan, which imports 60 per cent of its food, are particularly vulnerable.

The relevance of stability and resilience for sustainable development can be expressed in terms of complex systems cycles. Congeniality with nature by doing things 'nature's way' and preventing degradation of the Earth's ecosphere is paramount for sustainable development; but sustainable development is not merely static equilibrium with the environment. Sustainable development is not just only about making the earth's ecosystem functioning without any disturbance as natural disturbances are inevitable part of life. Design for resilience is an essential part of sustainable development. The key to resilience is the ability to reorganize a system/ process when disturb, by making dissolution as brief and benign as possible. The question is what should be done about the conflict between stability and resilience? Both stability and resilience are desirable. It is best to have a balance. The social system should structure its interaction with ecosystems, so neither stability nor resilience is at disequilibrium. This involves using resilient strategies to achieve an acceptable level of stability.

## VII. ADAPTIVE DEVELOPMENT

Adaptive development is the institutional capacity to cope with change. It can make a significance contribution to ecologically sustainable development by altering some parts of the social system so that social system and ecosystem interplay in a healthier fashion. Adaptive development involves two core element namely survival and quality of life. Adaptive development integrates resilience into human - ecosystem interaction. It does not simply respond to problems; it anticipates problems or detects them in early stages, taking measures to combat them before it escalate. Adaptive development provides a framework for sustainable development while simultaneously strengthening the capacity to adapt to problems that may inevitably arise if sustainable development is not achieved.

The two basic elements of adaptive development are: 1) regular assessment of on-going events in the ecosystem; and 2) taking corrective action. The key to ecological assessment is the ability to detect the actual events taking place within ecosystems. The key to corrective action is a truly functional community. Adaptive development requires the organization, commitment, effort and courage at all facets of society to identify the necessary corrective actions and make them happen. A society must examine its norms, values, perceptions, social institutions and technologies and modifies them promptly.

Adaptive development for a sustainable society involves caring for individuals, society, posterity and other biotic component of the environment. In order to achieve this feat, social justice and real democracy must be employed because decisions and actions that the interest future generations require full community mobilization and participation. When a small number few privileges people and decision makers control ecosystem or other natural resources, they do so for their own short-term economic gain. Societies


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are limited in their capacity to achieve adaptive development, when a few privileged people wield power and arrogate the control of resources to themselves. These people obstruct any economic change that threatens their privilege.

Challenges involving definite and compelling local issues can propel communities into action that eventually gives them the authority to control their destiny and resources on a broader front. While explanations for these may vary enormously from one setting to another, the following themes are illustrative of long-range action:

- Reversing undesirable trends/events: local communities take periodic assessment of their present socio-economic and environmental status, as well as changes that takes place in recent times. They strengthen support systems for the vulnerable ones in their society such as the elderly, children, women, handicaps etc through provision of neighbourhood safety, social welfare for the needy, constructive recreational activities for children, or whatever is most significant in their particular situation. They examine the balance of natural, agriculture and urban ecosystems within their city and in the surrounding regional landscape. If the landscape mosaic is in disequilibrium, they undertake initiatives to restore the balance.
- Anticipating disaster/disturbance: communities should prepare for unforeseen natural and anthropogenic contingencies such as war, landslide, volcanic eruption, famine, earthquakes, floods, drought, food security etc. Part of the preparation is emergency response and disaster preparedness to mitigate the severity of a disaster or the likelihood that it will even occur. For example, health workers can develop vaccines in regions where a disease epidemic is expected due to public health breakdown. Decision makers can strengthen public health surveillance and disease notification; and also expand health centres and increase medical supplies.

Community organization must not only focus on the environment in order to attain ecologically sustainable development rather this action (community organization) would by itself for any purpose create the enabling avenue to identify environmental needs and acts expediently to solve it. The foremost step is creating a vision of a suitable life presently desire by the community and in the future - a vision that encompass socio-ecological development. This kind of community vision is sensitive to the basic needs of the people such as food, housing, water supply, healthcare etc and also to the protection and judicious use of the environment. The vision addresses issues of dependence versus autonomy vis-à-vis the surrounding world. In what ways would greater or less self-sufficiency benefit the community? What are the significant needs that of paramount importance to the local community?

What roles can governments play in adaptive development? Of course they should address emerging environmental issues such as global warming, climate change, ozone depletion and show political will to implement national and global environmental policies. Equally important, governments should sensitize and educate the populace on environmental issues and provide educational and material assistance to strengthen the capacity of local communities to follow a path of adaptive development. Governments should create environmental districts that will assist local people to handle environmental issues similar in organization to the local school districts in many countries.

NGOs can serve as catalysts for adaptive development. While recognizing the fact that non-governmental organizations vary immensely in their organization and objectives, one concise example will illustrate the possibilities. Nature conservation organizations have realized that their efforts to preserve and protect the ecological system are frequently thwarted by anthropogenic activities in the surrounding area - including those that are consequential to people's survival. In order to adapt to this development, some conservation organizations are setting up business





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ventures in training and demonstration to the people, how to pursue economic development and still achieve ecosystems protection. For example, they have embarked on joint collaboration with timber companies to manage forests in ways that are not only sustainable for wood production but also preserve the natural forest ecosystems as part of the landscape mosaic. They have developed cooperatives with coral reef fishermen to ensure a sustainable supply of fish without altering the unique biological diversity of the reefs. Some of them partners with local farmers to make agricultural practice compatible with natural ecosystems in watershed. Where silt from soil erosion threatens estuaries or other natural ecosystems, conservationist farmer joint venture companies are providing the necessary technical support and marketing to enable farmers earn satisfactory income with low-erosion crops and cultivation practices.

## VIII. CONCLUSION

At least three general policy recommendations can be drawn from the synthesis of resilience in the relation to sustainable development. The first level stressed on the importance of policy that highlights interrelationships between the biosphere and societal economic prosperity. The second emphasises the necessity of policy to create room for flexibility and innovative collaboration towards sustainability, and the third suggests a few policy directions for how to operationalize sustainability in the context of social-ecological resilience.

1. Policy should strengthen the perception of humanity and nature as interdependent and interacting and stimulate development that enhances resilience in social-ecological systems, recognizing the existence of ecological threshold, uncertainty and surprise.
2. Policy should stimulate the creation of arenas for flexible collaboration and management of social-ecological systems, with open institutions that allow for learning and build adaptive capacity. Policy frameworks with clear directions for action towards building adaptive capacity and thus social-ecological sustainability are required in this context.
3. Policy should stimulate the development of indicators of gradual change and early warning signals of loss of resilience and possible threshold effects. Policy should encourage monitoring of key ecosystem variables and aim to manage diversity for insurance to cope with uncertainty.

This review concludes that the ecosystem is currently threatened by anthropogenic activities such as industrialization, urbanization etc and is on the verge of collapse, if prompt action is not taken to avert this premonition. It emphasize that the two useful tools for resilience-building in complex, unpredictable systems are **structured scenarios** and **active adaptive management**. Structured scenarios attempt to envision alternative futures in ways that expose fundamental variables and branch points that may be collectively manipulated to evoke change. Active adaptive management seeks a set of structured management experiments designed to reveal fundamental variables and system potential. These techniques should be encouraged and expanded to help increase capacity to build ecological resilience.

*Conflict of Interest*

The authors declare that there is no conflict of interests regarding the publication of this review article.

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