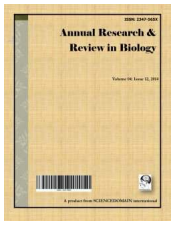

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# Sustainability: The Over-Arching Concept in Environmental Science and Development

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***Authors' contributions***

*This product was as a result of collaboration between both authors. Author MAEN managed the literature searches and produced the initial draft. Author SNO wrote the final manuscript. Both authors read and approved the final manuscript.*

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## ABSTRACT

The introduction focuses on the history of the three key terms in this review: environmental science, development and sustainability. The other two sections are devoted to sustainability in environmental science and sustainability in development. The problem-solving interdisciplinary nature and ethical considerations in environmental science are highlighted. The right to development and the unattended negatives of development are discussed. The three components of sustainability (economic, social, environmental) and their relationships are explained. The pervasive nature of sustainability in environmental science: renewable (e.g.: forests, fisheries, wildlife) and non-renewable (e.g.: minerals) natural resources, water management, agriculture, etc. are emphasized. The historical odyssey of the term, sustainable development, from its first mention nearly 50 years ago to Brundtland's Our Common Future that generated almost worldwide political consensus and the adoption of the Sustainable Development Goals (SDGs) by the United Nations General Assembly at its seventieth session is outlined. The conclusion stresses that in addition to the adoption of the sustainability concept in management of resources and development, international efforts on the reduction of human population growth rates, emission of greenhouse gases and pollution should be intensified for a sustainable future.

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## 1. INTRODUCTION

The three key terms in this review: environmental science, development and sustainability are discussed. The other two sections are devoted to sustainability in environmental science and sustainability in development.

Prior to 1980s, there were concerns on resource consumption and the focus on economic growth in discussions on development. Hardin's [1] groundbreaking treatise, The Tragedy of the Commons argued that increases in resource consumption gave a new urgency to the problem of the commons. If each individual with the right of access to a common resource whether it be a forest, a fishery or a grazing land, continues to increase the yield he receives from it in pursuit of his own interest and to the exclusion of all considerations of mutual interdependence, eventually the stock will be depleted and all those who depended on the common resource will be impoverished. The British Magazine, The Ecologist [2], published, The blueprint for survival, emphasizing that in addition to economic growth, a stable society required a minimum disruption of ecological processes, maximum conservation of materials and energy, a population in which recruitment equals loss and a social system in which people enjoy rather than endure. Schumacher's [3] illuminating text, Small is Beautiful, emphasized that development must be people-centered and not exclusively based on production. It should address the primary cause of poverty and provide more that the wherewith for basic subsistence. In 1975, Dag Hammerskjold Institute produced the report titled, What Now, another development which proposed a form of development that respected people and the distinctiveness of their traditions and culture [4].

How humankind can best live within Earth's environment is the subject of what is loosely called Environmental Science, the interdisciplinary study of how humanity affects other living organisms and the non-living physical environment. Environmental Science encompasses many complex and interconnected problems: involving human numbers, earth's natural resources and environmental pollution. It is interdisciplinary because it uses and combines information from many disciplines: Biology (primarily Ecology), Chemistry, Geology, physics, Economics, Sociology (particularly demographics, the study of human population dynamics), natural resources management and pollution [5]. Unlike biology, geology, chemistry and physics, sciences that seek to establish general principles about how the natural world functions, environmental science is by its very nature an applied science, a form of problem-solving; it is the search for constructive alternatives to environmental damage. The science of ecology, a discipline of biology that studies the interrelationships between living resources and their environment is the basic tool of environmental science [5].

Environmental values can be based on four categories of justification: utilitarian, ecological, aesthetic and moral. A utilitarian justification sees some aspect of the environment as valuable because it provides individuals with economic benefit or is directly necessary to their survival (e.g. fisheries) [6]. An ecological justification is based on the values of some factor that is essential to larger life-support functions, even though it may not benefit an individual directly (mangrove trees provide habitats for marine fish, burning coal and oil leads to greenhouse gas emissions that may change climate) [7]. Aesthetic justification has to do with our appreciation of the beauty of nature (many find wilderness scenery beautiful). Moral justification has to do with the belief that various aspects of the environment have a right to exist and that it is our moral obligation to allow them to continue or help them to persist. Moral arguments have been extended to many non-human organisms or to inanimate objects. The formulation of a practical and morally just global environmental ethic relates to issues of cultural relativism and moral pluralism, and it implies that these can be reconciled with some form of cross-cultural unity [8]. Among environmental ethicists, Callioot [9] has argued that a global ethos might be justified if it is based on an array of diverse cultural interpretations rooted in local ecosystems. The secular, scientific framework of such an ethic was evident at the 1993 World Parliament on Religions, where the Declaration toward a Global Ethic by the World Wildlife Fund initiated Assist Declarations.

As Wilson [10] noted, the hesitancy of the majority to protect and preserve nature for future generation is understandable. The sacred Abrahamic texts contain few instructions about the rest of the living world. The Iron Age Scribes

who wrote them knew war, they knew love and compassion. They knew purity of spirit, but they did not know ecology [10]. The issue is moral; science and technology are what we can do, morality is what we agree to do or not do. The ethic from which moral decisions spring is a norm or standard of behavior in support of a value, and value in turn depends on purpose, whether personal or global, whether urged by conscience or engraved in a sacred text, expresses the image we hold of ourselves and our society. In short, ethics evolved through discrete steps, from self-image to purpose to value to ethical precepts to moral reasoning. A conservation ethics is that which aims to pass onto future generations, the best part of the non-human world [10].

The principle of the right to development is enshrined in international law in the two main human rights treaties, the International Convenants on Civil and Political Rights, and on Economic, Social and Cultural Rights. Article 1(2) of both documents call for the recognition of development rights for all peoples. The right to development for traditional communities includes (a) the right of access to resources in their territories (b) the right to seek development on their own terms. The goals of development are: increased standard of living, modern facilities, etc. Consequently, in developed countries, the observable indices are: Industrialization, low fertility rates, low infant mortality rates and high per capita income. There are cynics to the concept of development. Bergh and Straaten [11] described development as the spreading conditions of homelessness. The creation of homelessness takes place both through the ecological destruction of the “home” and the cultural and spiritual uprooting of peoples from their homes. Goulet [8] suggests that development requires cultural diversity, biological diversity, plural modes of rationality, plural models of development and non-reductionist approach to economics.

Sustainability refers to resources and their environment. Botkin and Keller [6] describe two scientific meanings: (1) Sustainable resource harvest, such as a sustainable supply of timber, means that the same quantity of resource can be harvested annually (or other harvest interval) for unlimited or specified amount of time without decreasing the ability of resources to produce the same harvest level, (2) A sustainable ecosystem is an ecosystem from which we are harvesting a resource that is still able to maintain its essential functions and properties. Hillborn et al. [12] stressed that the sustainable exploitation of renewable resources depends on the existence of a reproductive surplus, which is determined by the balance between births, deaths and somatic growth. The reproductive surplus differs spatially and temporally as environmental conditions vary, and even in the absence of exploitation, change is the rule and constancy is the exception. Goodland [13] described three types of sustainability: Environmental, Social and Economic Sustainability. Overlap exists, but economic and Environmental have strong linkages. Historically, economic theory focused on efficiency in the use of goods and to a much lesser degree on equity of distribution. Economic sustainability focuses on that portion of the natural resource base that provides physical inputs both renewable (eg: forests) and exhaustible (e.g. minerals) into the production process. Environmental sustainability or maintenance of life-support systems is a prerequisite for social sustainability. Redclift [14] claims that poverty reduction is the primary goal of social sustainability, even before environmental quality can be addressed. Daly [15-16] insists that the two environmental services (the source and sink functions) must be maintained unimpaired during the period over which sustainability is required. Environmental Sustainability (ES) is a set of constraints on the four major activities, regulating the scale of the human economic subsystem: the use of renewable and non-renewable resources on the source side, and pollution and waste assimilation on the sink side. This short definition of ES is the most useful [16].

For sustainability, the optimal rate of depletion of resources, “natural capital”, is not that of conventional economics [17], but is determined by three factors: (1) Estimates of the amount of resources required to build replacement. Human-capital we feel entitled to consume (2) The speed at which such replacement can be carried out and (3) Assessments of how much other natural capital we feel entitled to consume. A sustainable policy on non-renewables does not require a complete ban on their consumption, but involves wise, economic use so we leave as large stocks as possible for future generations [18].

Another approach to the question of the sustainable use of non-renewable resources is via the notion of sustainability between natural resources and the goods and services we create from them, in other words between natural and human-made capital. Mainstream economists

assume that human-made capital which fully compensates for the decline in natural capital may be equated to using natural resources sustainably. Pearce et al. [19] describes this approach as "broad sustainability" or constant wealth, as opposed to "narrow sustainability' where the approach is to focus on natural capital assets and suggest that they should not decline through time. Daly [20] makes a similar distinction but uses different terms. Maintaining total (natural and human-made) capital intact might be referred to as "weak sustainability" in that it is based on generous assumptions about the sustainability of capital for natural resources in production. By contrast, "strong sustainability" would require containing both human-made and natural capital intact separately, on the assumption that they are really not substitutes but complements in most productive functions.

## 2. SUSTAINABILITY IN ENVIRONMENTAL SCIENCE

Sustainability is pervasive in environmental science- in renewable (e.g. fisheries, wildlife, forestry, etc.) and non-renewable (e.g. minerals) natural resources, water management, agriculture, etc.

### 2.1 Sustainability in Fisheries and Wildlife Management

At the beginning of the 20$^{th}$ century, each species was viewed as a single population in isolation. The goal for species to be harvested was maximum sustainable growth. Species were to be conserved when they reached their carrying capacity. This approach was unsuccessful. There is now a broader view that a population exists in a changing environment; populations interact in an ecosystem and landscape context. The goal for a species to be harvested is an optimum sustainable population. The concept of maximum sustainable population was based on the logistic population growth curve. A logistic population is stable within its carrying capacity, to which it will rebound following a disturbance. The concept of carrying capacity is important in wildlife management. It may be defined in 3 ways: by the logistic growth curve known as logistic carrying capacity, an abundance a population can sustain without any detrimental effects that would decrease the ability of that species to maintain the abundance. The more recent definition is the optimum sustainable population which is the maximum population that can be sustained indefinitely without decreasing the ability of that species or its habitat or ecosystem to sustain that population level in future. Another key concept from the logistic growth curve is the population size that provides the maximum sustainable yield (MSY). In the logistic curve, the greatest production occurs exactly when the population is one-half of the carrying capacity [6].

### 2.2 Sustainability in Forestry

A major modern goal is to have sustainable forests. Stated in the most general theoretical terms, a sustainable forest is one from which a resource can be harvested at a rate that does not decrease the ability of the forest ecosystem to continue to provide that same rate of harvest in the future, although the situation is more complicated. Botkin and Keller [6] identified two kinds of sustainability in forestry: Sustainability of the harvest of trees (logging) and sustainability of the forest ecosystem. These two kinds apply to other biological resources.

### 2.3 Sustainability in Water Supply and Use

More than 97% of the earth's water is in the oceans, 2% are in the ice caps and glaciers. Both constitute more than 99% of the human use. Only about 0.001% of the total water on earth is in the atmosphere at any one time. Thus the relatively small amount of water in the global water cycle produces all our freshwater through the process of precipitation in the global hydrologic cycle [6]. Water is essential to sustain life and maintain ecological systems necessary for the survival of humans. As a result, water plays important roles in ecosystem support, economic development, cultural values and community well-being [21]. Managing water use for sustainability is thus important in many ways. From a water supply use and management perspective, sustainable water use can be defined as use of water resources by people in a way that allows society to develop and flourish into an indefinite future without damaging the various components of hydrological cycle or the ecological systems that depend on it. Van de Leeden [22] has outlined some criteria for water use sustainability:

- Develop water resources in sufficient volume to maintain human health and well being

- Provide sufficient water resources to guarantee the health and maintenance of ecosystems
- Ensure minimum standards of water quality for the various users of water resources
- Ensure that a cross-section of humans do not damage or reduce long-term renewability of water resources
- Promote the use of water efficient technology and practice
- Gradually eliminate water pricing policies that subsidize the inefficient use of water.

## 2.4 Ground Water Sustainability

The concept of water sustainability, by its very nature involves a long-term perspective. With groundwater resources, the length of time for effective management for sustainability is even longer than for other renewable resources. Surface water for example may be replaced over a relatively short time. In contrast, groundwater development may take place over many years at relatively slow rates [22]. The long-term approach to sustainability with respect to these resources is with recharge of these resources which is an important component of water management [23]. Management of water resources for water supply is a complex issue that will become difficult in the coming years. A method of water management utilized by a number of municipalities is known as the variable water-source approach – importing water, developing new sources, using reclaimed water and conservation [23].

## 2.5 Integrated Sustainable Energy Management

The concept of integrated sustainable energy management recognizes that no single energy source can provide all the energy required by the various countries of the world. A basic goal of integrated energy management is more towards sustainable energy development that is implemented at the local level. Van Koevering and Sell [24] listed the characteristics of sustainable development:

- Promote reliable sources of energy.
- Prevent destruction or serious harm to our global, regional or local environment.
- Help ensure that future generations inherit a quality environment with a fair share of the earth's resources.

A good energy plan is part of an aggressive environmental policy with the goal of producing a quality environment for future generations. A good plan should:

- Provide sustainable energy development
- Provide for aggressive energy efficiency and conservation
- Provide for the diversity and integration of energy sources
- Provide for a balance between economic health and environmental quality
- Use second law efficiencies as an energy policy tool that strive to produce a good balance between quality of energy source and end uses for that energy [25].

## 2.6 Sustainable Agriculture

Hansen [26] proposes two broad interpretations on sustainability in agriculture. Firstly, sustainability interpreted as an approach to agriculture, developed in response to concerns about the impact of agriculture with motivating adherence to sustainable ideologies and practices, as a goal. Secondly, sustainability interpreted as property of agriculture, developed in response to concerns about threats to agriculture, with the goal of using it as a criterion for guiding agriculture as it responds to change. Interpreting sustainability as an approach has been useful for motivating change; although interpreting sustainability as a property of agriculture is more logically consistent, it has been of limited value in stimulating change. FAO [27] defines sustainable agriculture as an integrated system of plant and animal production practices, with site-specific applications that will over the long term

- ✓ Satisfy human food and fibre needs
- ✓ Enhance environmental quality and the natural resource base upon which the agricultural economy depends.
- ✓ Make the most efficient use of non-renewable resources and integrate with appropriate natural, biological cycles and controls
- ✓ Sustain the economic variability of farm operations
- ✓ Enhance the quality of life for farmers and society as a whole

These goals may be achieved by the following alternatives to energy-based inputs

- ➢ Legume rotation

- Use of waste organic matter as well as from animals
- Integrated pest management
- Pests and diseases forecasting
- Mulching and mechanical weed control
- Conservation tillage
- Specialized innovative cultural techniques

  i. Intercropping
  ii. Strip cropping
  iii. Under sowing
  iv. Trap cropping
  v. Double row cropping
  vi. Use of resistant plant and animal varieties

In response to the tenets of sustainable agriculture, new trends emerged in crop production and pest control. Studies in the 1960s and 1970s demonstrated the feasibility of crop production without plowing or tillage, which was termed NO-tillage agriculture, with important implications in soil conservation [28]**.** It protects soil from water and wind erosion. Motivated by support from conservation agencies and savings as a result of fuel and labour costs, farmers began to adopt reduced or no-tillage agriculture worldwide, together referred to as conservation tillage [28]. Tillage or lack of it influences insects and other invertebrates in three major ways: mechanical disturbance, residue replacement and effects on weeds control. The widespread adoption of conservation tillage in the 1980s was accompanied by an increased interest in pest biology and management in these systems [29]. Trap crops are plant stands that are grown to attract insects or other organisms like nematodes to protect target crops from attack [29]. To enhance the attractiveness of trap crops, specific chemical compounds such as insect pheromones, plant kairomones or insect food supplements may be used [30]. Behavioural manipulation and habitat management have been extensively discussed by Foster and Harris [31] and Landis et al. [32] respectively. Other gains of sustainable agriculture have been documented [33].

## 3. SUSTAINABILITY IN DEVELOPMENT

The term sustainable development was first used by Ward and Dubos [34] to stress the point that environment, protection and development are linked. Ward founded the International Institute for Environment and Development. The International Union for the Conservation of Nature (IUCN) first used the term Sustainable Development in the World Conservation Strategy (WCS) in 1980, but it was Gro Brundtland and her UN Commission, who in a brilliant feat generated almost worldwide political consensus on the urgent need for sustainability with her report, OUR CCOMMON FUTURE [35]. Brundtland's [35], Our Common future, was followed by spirited discussions of the concept in the late 1980s [14,36-38]. Terms which have already been defined, such as Economic Sustainability, Social sustainability emerged. It is development that meets the needs of the present without compromising the ability of future generations to meet their needs. There are diverse views on the approaches and goals of sustainable development. Redclift [14] claims that poverty reduction is the primary goal of sustainable development even before environmental quality can be fully addressed. Poverty reduction comes from qualitative development, from redistribution and sharing, from population solidarity, rather than from emphasis on economic indices. Goodland [13] insists that sustainable development should integrate social, environmental and economic sustainability and use these three to start to make development sustainable. Daly [20,39] describes sustainable development as development that is without throughput growth beyond environmental carrying capacity and which is sustainable. Robin and Trisoglio [40] described the paradoxical role of industry. It is the major productive and wealth-creating sector of society but it is also a major pollute, both directly through its production process and indirectly through the products it sells. Maurice Strong, Secretary General of UNCED proposed eco-industrial revolution with two major priorities:

- Redirect corporate energies to satisfy the broader human aspects of development
- Maximize long-term efficiency in the use of environmental resources in the production and consumption of useful goods and services

North-South nations accepted that development based on economic growth had failed and no concept of development can be accepted which continues to condemn hundreds of millions of people to starvation and despair. Development which showed too little concern for the quality of growth and too little respect for different cultures and traditions should be jettisoned [41,42]. Sachs [43] considers sustainable development the central concept of our age- a way of understanding the world and a method of solving

global problems. It makes sense of the interactions of 3 complex systems: the world economy, the global society, and the earth's physical environment. It recommends a holistic frame work, in which society aims for socially inclusive development, underpinned by good governance. Sachs concludes by describing sustainable development as the greatest most complicated challenge humanity has ever faced.
Some of the major events in the Sustainable Development Timeline include:

1962 - Rachel Carson's Silent Spring
1968 – Paul Ehrlich's Population Bomb
1970 – First Earth day
1971 – Establishment of IIED
1972 – UN conference on Human Environment
1980 – Word Conservation Strategy
1984 – International Conference on Environment and Economics
1987 – Brundtland's Our Common future
1990 – International Institute for Sustainable Development, established in Canada
1992 – Establishment of Business Council for Sustainable Development
1992 – United Nations Conference on Environment and Development
1993 – UN Commission on Sustainable Development (First Meeting)
1995 – World summit for Social Development at Copenhagen (first time the International Community commits to eradicating poverty)
2000 – UN Millennium Development Goals
2002 – World Summit on Sustainable Development Johannesburg promotes partnerships. (www.iisd.org , iisd2010 20th, https://www.iisd.org/sd )

Sachs [44] described the 2000 Millennium Development Goals (MDGs) as marking a historic and effective method of global mobilization to achieve a set of important social priorities worldwide. They expressed widespread public concern about poverty, hunger, inequality, disease, unmet schooling gender, and environmental degradation. By packaging these priorities into an easily understandable set of goals and by establishing measurable and time-bound objectives, the MDGs helped to promote global awareness, political accountability, improved metrics, social feedback and public pressures [44]. Following the success of the MDGs, the over-arching concept of Sustainability has again been highlighted in the International Community's goal for the period, 2015-2030. The idea of the Sustainable Development Goals (SDGs) gained ground because of the growing urgency of Sustainable Development for the entire world. Although specific definitions vary, sustainable development embraces the so-called triple bottom line approach to human well-being. Almost all the world's societies acknowledge that they aim for a combination of economic development, environmental sustainability and social inclusion but the specific objectives differ globally, between and within societies.

The United Nations General Assembly adopted the SDGs at its seventieth session on 25 September, 2015, in the document, titled, "Transforming Our World: the 2030 Agenda for Sustainable Development". In spite of the gains of the Millennium Development Goals (MDGs), billions of citizens globally still live in poverty and are denied a life of dignity, rising inequalities within and among countries, enormous disparities of opportunity, wealth and power, gender inequality remains a challenge, unemployment, global health threats, natural resource depletion, adverse impacts of environmental degradation and climate change. It is envisaged that the supremely ambitious and transformational vision set out in Goals and Targets, would usher in a world free of poverty, hunger, disease and want, where all life can thrive, free of fear and violence, universal access to quality education, access to safe drinking water and sanitation, human habitats are safe and universal access to affordable, reliable and sustainable energy [45].

The 17 Sustainable Development Goals (SDGs) with 169 associated targets are integrated and indivisible [45]. The SDGs are:

Goal 1 End poverty in all its forms everywhere

Goal 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3 Ensure healthy lives and promote well-being for all at all ages

Goal 4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Goal 5 Achieve gender equality and empower all women and girls

Goal 6 Ensure availability and sustainable management of water and sanitation for all

Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Goal 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Goal 10 Reduce inequality within and among countries

Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12 Ensure sustainable consumption and production patterns

Goal 13 Take urgent action to combat climate change and its impacts*

Goal 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Goal 17 Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

## 4. CONCLUSION

Sustainability is one of the themes in Environmental Sciences. Two of the other themes receiving increasing traction in discussions on the environment are the Human Population Problem and Global Warming. The impact of human population's alarming increase on the environment has been extensively discussed [46-49]. The potential adverse effects of global warming have received international attention [5,6,50]. The International Panel on Climate Change (IPCC) including about 1000 scientists stated in 1995 that:

> "The balance of evidence suggests a discernible human influence on global climate".

The response from the International Committee was the 1997 Kyoto Protocol on the reduction of greenhouse emissions. Major polluters, USA and Australia were not signatories, Russia ratified in 2004 [51]. In 2001, IPCC was more assertive when it stated:

> "There is new and stronger evidence that most of the warming observed over the last 20years is attributable to human activities"

It is estimated that 26 billion metric tons of $CO_2$ are added annually into the atmosphere [51]. The agreement of the 2015 COP21 in Paris on 1.5℃ maximum rise in global temperature was a step in the right direction [50]. It is therefore important that in addition to adopting the concept of sustainability in managing resources and development, there must be a concerted international effort at reducing human population growth, greenhouse emissions and environmental pollution to achieve a sustainable future.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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