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Sustainable Economy of Ecological Footprint in Africa: An Economic Analysis and Impacts

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Abstract Ecological footprint is an important measure in calculating the human demands and impacts on our global environment. In this respect the ecological footprint is a function of all the parameters that interact between the power of ecosystem productivity and human interactions and activities on a particular ecosystem or the demand from that ecosystem. The present paper will cover and analyze the ecosystems productivity and the human demand from the ecosystems of African continent. It will produce comprehensive analyses in measuring the possibility of capabilities of the ecosystems in Africa to provide goods and services to the human beings who are living on African continent. Further, the paper will discuss the models that can be used in measuring the sustainability of ecosystem and what we should be doing to maintain the African healthy ecosystems. In this respect, the paper will assess and introduce a comprehensive model that can describe the status of African ecosystems productivities and the impacts of human population on the African continent. Furthermore, the paper will provide some answers to the human issues in Africa, further warning to the current trend in use and abuse of our natural ecosystems in Africa and what will be expecting from these ecosystems to provide the human needs in response to the current use of our global ecosystems. Finally, it will conclude and setup several recommendations to save the African Continent ecosystems from the irreversible impacts of human beings on these ecosystems and also for global environment.

Keywords Economic Analysis, Ecological Footprint (EF), Impacts, African Global Biological Capacity (AGBC), African Global Biological Demand (AGBD), African Global Deficit Capacity (AGDC), African Global Ecological Capacity (AGEC), African Sustainability Index or African Maintenance Index (AMI)

1. Introduction

African Continent is the world's second-largest and second most-populous continent. At about 30.2 million km² (11.7 million sq mi) including adjacent islands, it covers 6% of the Earth's total surface area and 20.4% of the total land area. The area of Africa is equal to 30,221,532 km² (11,668,598.7 sq mi) and its population reached one billion people in an average of 80 individual per square mile. The continent is surrounded by the Mediterranean Sea to the north, both the Suez Canal and the Red Sea along the Sinai Peninsula to the northeast, the Indian Ocean to the southeast, and the Atlantic Ocean to the west[Wikipedia Web Site][1]

Ecological Footprint has been introduced by Wackernagel and Rees[2]; Wackernagel *et al*.[3]. However, the Authors of this paper are defining Ecological Footprint (EF) as a measure of the status of the global ecosystems ability to provide service and goods to all human beings that are living on the Earth. Further, the global ecosystems provide for the needs of all other organisms that exist on the planet and in consequence enable to provide the goods and services to human beings. Therefore, the global ecosystems provide for the needs of all living beings on the Earth including the human beings. This definition will be implied on African Continent in our analysis.

In light of the above definition, we need to discuss in a broader sense what is actually happening on the planet Earth now and on African continent. In previous ages we the human population, we were not faced with several aspects of shortage in resources such as water, productive soil to produce food, energy, raw materials, clean air, and so on that is now raising a question of great importance to human beings: Can the Earth continue to cover the needs of its growing human population? We must ask ourselves where we are going and how to maintain our global environment to maintain and sustain our existence. Can we maintain our existence? How can we maintain the productivity of our global ecosystems at a level to sustain our existence and standard of living in the light of growing our demands? Further these questions can be applied to African Continent to provide information on how this continent can provide services and goods to its people and to be balanced with its biological capacities. In addition the question that can be raised is that African Continent can produce surplus of goods and services that can be exported to other continents in the

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world. The other question is that the African continent is in balance with its human population needs.

Warnings have been seen about the growth of human populations and their needs (Wackernagel, M.,[4], Rees[5], Lenzen *et al*[6] and Grazi *et al*[7]. These warnings have indicated that the growing population has affected the global ecosystems. In recent conference of Food Security in Rome, Italy on November 16-18, 2009, the delegates of the countries attending the conference have indicted that the world is facing a shortage of food as an important one item of the global ecosystem service to human beings. Zhao *et al*[8] have indicated that humans have had a considerable impact on the Earth that is associated with population increase and economic development. They indicated also that humans are faced with a series of disturbing contradictions and trends among the natural resources, the environment, and the economy, such as rising population growth, resources depletion and environmental deterioration. These trends are pointing to adverse impacts and the need for considering the importance of sustainability in maintaining globe natural resources. Otherwise, the human race will face shortage of these natural resources with serious consequence for the global economy.

Moderate United Nation Environmental Program (UNEP)[9] scenarios suggest that if current population and consumption trends continue, by the middle of the next decade, we will need the equivalent of two Earths to support us, and of course, we only have one. Turning resources into waste faster than waste can be turned back into resources puts us in global ecological overshoot, depleting the very resources on which human life and biodiversity depend.

The challenge of maintaining the Earth's ecology and sustaining the regeneration of its resources is an enormous effort that requires collaborative work between government agencies, localities and the human beings themselves on global scale. Without these efforts, the global ecosystems could be facing a collapse leading to global chaos. In this respect, sustainability whether nationally, regionally, or globally is requires that natural resources not be exploited beyond the renewable limits.

The ecological footprint is a broad measure of resource use that highlights where consumption is exceeding environmental limits. The Best Foot Forward Company in United Kingdom[10] uses the ecological footprint methodology to help businesses and other organizations measure, monitor and reduce their impacts.

The present paper will assess the status conditions of the African Continent, predicts the African Global Biological Capacity (AGBC) of the African Continent, African Global Biological Demand (AGBD) and to introduce a comprehensive model that can describe the status of the ecosystems of the African Continent in term of productivity and the impacts of human population of the African Continent. Furthermore, the paper will provide some answers to the human issues, warning on the current trend in overuse and abuse of our natural ecosystems and what should be expected in terms of ability of the ecosystems of the African Continent to provide for human needs in response to the current use of its ecosystems. The paper concludes with recommendations for avoiding irreversible impacts of human beings on the African ecosystems and in consequence on our global environment.

2. Material and Methods

Data used in this paper were collected from different data set of series available on the web sites of World Research Institute (WRI)-Earth-Trends[11], World Bank[12], Food and Agricultural Organization (FAO)[13][14], United Nation Development Program, World Wildlife Fund (WWF)[15][16][17] and Global Footprint Network[18][19]. The data were analyzed using the regression, correlation, and statistical methodologies using Sigma Plot Software[20].

African Maintenance Index (AMI) or (Sustainability index) is a percentage of the total African Global Biological Capacity (AGBC) (i.e. total availability or supply) in global hectares to the total African Global Biological Demand (AGBD) (i.e. consumption or demand) in global hectares from the Earth of the African Continent. This index explains the ability of the African Earth to regenerate its natural resources. In other words, it explains the status of African Earth in providing goods and services to the human population needs. The (AGBC) is defined as the ability of the African Earth to produce renewable natural resources in term of global hectare / capita. AGBD is defined as the resources consumptions by human beings in term of global hectare / capita. It is important to indicate the calculations of Total (AGBC) and Total (AGBD) are the most important factors in the calculations of indices that have been discussed in this paper. Other terms used in calculations are African Cropland Footprint (ACF) in billion global hectares, African Grazing Land Footprint (AGLF) in billion global hectares, African Forest Ground Footprint (AFGF) excluding fuel wood in billion global hectares, African Fish Ground Footprint (AFF) in billion global hectares, African Total Energy Footprint (ATEF) in billion global hectares, African Built-up Land (ABL) in billion global hectares and African Global Deficit Capacity (AGDC) in billion hectares. The formulas for calculating the following indices are as follow:

$$\text{AMI Index} = \text{AGBC} / \text{AGBD} * 100 \quad (1)$$

$$\text{AGBC} = \text{ACF} + \text{AGLF} + \text{AFGF} + \text{AFF} + \text{ATEF} + \text{ABL produced} \quad (2)$$

$$\text{AGBD} = \text{ACF} + \text{AGLF} + \text{AFGF} + \text{AFF} + \text{ATEF} + \text{ABL consumed} \quad (3)$$

$$\text{AGDC} = \text{AGBC} - \text{AGBD} \quad (4)$$

These estimates are calculated according to several authors of ECOTEC-U.K group[21] and Wackernagel *et al*[22] using the following: 1) Net primary Productivity (NPP); 2) Growing crops for food, animal feed; 3) Fibber and oil; 4) Grazing animals; 5) Wood from forest; 6) Fishing from marine and freshwater; 7) Infrastructure for housing and building transportation and electrical power; 8) Burning for fuel in CO_2 emissions. These calculations depended on

the governmental, UN data series from the World Bank. These calculations were converted in billion hectares from the global sized hectares.

Predictions of Total (AGBC) and Total (AGBD) for the African Continent Earth in the next decades were calculated to show the impact of growth of the African population on the basis of annual data from series of years 1960 to 2008 for almost 48 years of published data. The predications for the years 2009 to 2050 were analyzed using correlation and regression lines (Table1&2).

3. Importance of Understanding Ecological Footprint in Africa

Ecological footprint as described above is the measure to analyze the human needs from the Earth in the form of resources that provide services and goods for consumption by human beings. Currently, human population carrying capacity is exceeding the resources of the Earth[9]21]. It is important to calculate the human population carrying capacities from each nation on this Earth against its resources and to create an Ecological Accounting System (EAS) that gives each country an ecological measure indicating how each country stands against its resources. This accounting system can be of a control of a nation and its impact on whole global environment (i.e. the maintenance indicator or parameter for the nation in global ecosystems). This is a scenario to explain how to close the gap between the Earth resources and the human basic needs from this Earth. In general in our life we are at the level of individuals calculating our earning and expenses (i.e. income against our spending). If we have positive balance that means we are not in debts to the others. The same will be the scenario against the Earth resources. What are the credits that each country has against its boundaries resources exploitations? We have to think ecologically about the natural resources that we have to provide us with services, products, and the natural resources that we consume. We have to consider how are we able to save or conserve these resources for the next generations. Then we have to think about how we can trade our surplus from the resources to the others. It is imperative in this thinking process to consider the welfare of human being over the generation of rapid wealth against the humanity. At the same time, we have to regulate the human behaviour in exploiting the natural resources in order to save the Earth for the next generations. The Next section presents the most important factors that determine the African human populations' needs and their impacts on global ecosystems of our planet Earth.

4. Impacts of Human Population on Food Security and Natural Resources of the African Continent

Human population has increased to the point that the African continent cannot support the human population with the food that is needed to survive. This conclusion can be explained in (Tables 1&2). In tables, the need for each human being living on African Continent is estimated by about 2000 Calories per day as an estimation of US (US Department of Health and Human Services and US Department of Agriculture, 2005)[23]. The total number of human beings who are living on African continent is 0.942 billion people (Table 1) in year 2008. Therefore, the daily need for the African populations is about 1.89 trillion calories per day and their annual need is about 689.85 trillion calories per year. Accordingly, what are the sources of all these calories? These calories would come from crops, meat, vegetables and other sources on African surface area or below the sea water. The question is whether, the African's resources can support the populations who are living on this Continent. The most useful resources from Africa to produce the needed calories are, the arable-cropped lands, forest ecosystems, water resources, grazed lands, converted as carbon footprint, fishing ground footprint, and built-up lands. It is estimated that the African land in 2008 that can produce the food that are required to keep every human being in a status of normal health is requiring 2.02 global hectare / capita (i.e. the demand 1.90/0.942). However, 2008, it is estimated 2.25 hectare / capita (i.e. 2.12/0.942) is the biological capacity of the African Continent to provide African people with the calories as calculated from Table 1. This means that Africa is in marginal sufficient for producing enough calories to cover all human beings on African Continent. The current support for African people from the continent in African hectare per / capita is equal to surplus of 11 % in 2008. However in 2009, the shortage will reach 33% of African hectares to support the human population. In this respect, the maintenance index of the African Continent as I suggested is the total AGBC of the Africa / total AGBD or the African Ecological Footprint Consumption of the Earth as % as a measure of how the African land needed to be protected and to look in the further conservation of the natural resources to meet human beings needs (Fig.1) and Tables 1-2). From the regression line, it is expected that the when the population reach to about 2.685 billion, the maintenance index of sustainability will reach 0.61 (0.77 hectare deficit per capita).

It is apparent from the regression model of the African human population and African global biological capacity resources (Fig. 2 & 3) we can come to conclude that the future of African global biological capacity on the current trend of use is about to 1.13 hectare /capita when the population density of Africa reaches 2.685 billion in year 2050 as the projected estimates indicates in (Table 2). This means that a declining in the resources to support the African Global Biological Capacity Resource.

Existing human beings and future generation: On the other hand, the demands from the Earth will increase to reach 5.12 global billion hectares in year 2050. This means the demands will increase to reach 1.91 global hectare / capita in African Continent. Respectively the human population will run deficit against the African Earth resources in about 0.77

hectare / capita. Also, the AGDC against the surface area will reach 169.4% (Fig. 4, 5 & 6). We believe it is an alarming that human should control the abuse of the current Earth natural resources.

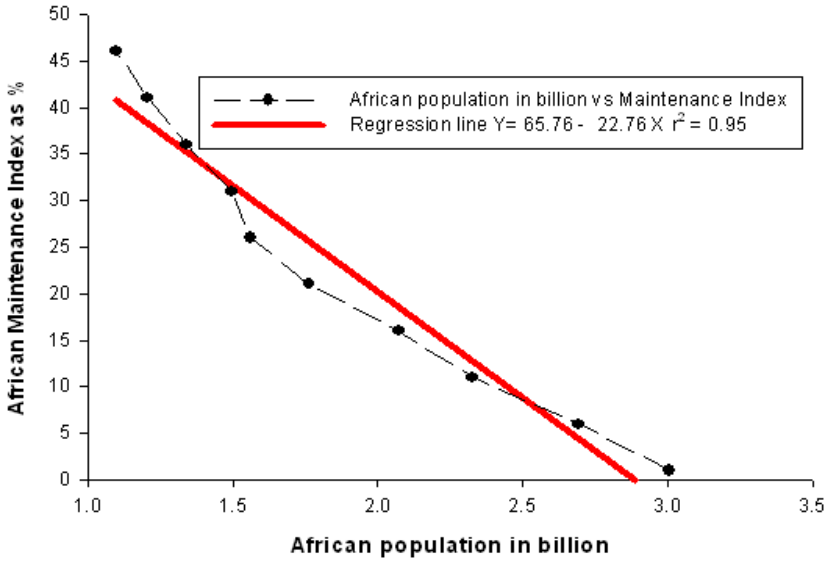

Figure 1. Relationship between African human population and African maintenance index(AGBC in billion hc/AGBD Billion Global ha)

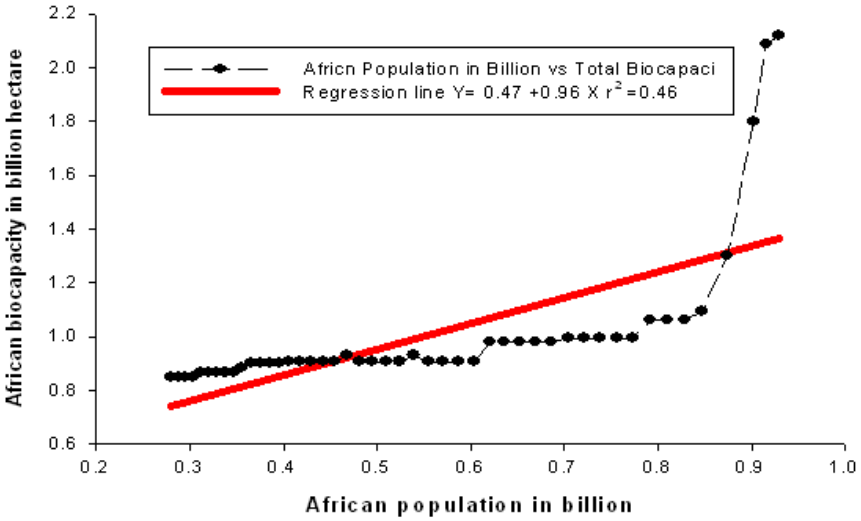

Figure 2. Relationship between African population in billion and African biological capacity in billion hectare

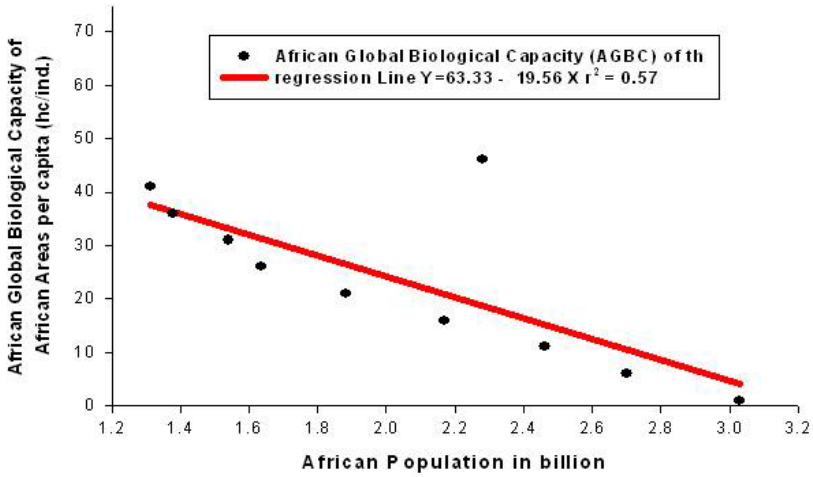

Figure 3. Relationship between African population in billion and global biological capacity of the earth per capota (ha/ind.)

Table 1. African Global Population, African Global Biological Capacity (AGBC), African Global Biological Demand (AGBD) and Maintenance Index of the African Continent up to Year 2008 - Data are in 10 years intervals *

Year	African Population in billion	Surface Area in billion ha	Total African Global Biological Demand (AGBD) (billion global ha)	African Global Biological Demand in Global Hectare/Surface Areas global hectare as %	Total African Global Biological Capacity (AGBC) (billion global ha)	Deficit in African l billion hectare =AGBC-AGBD	Maintenance Index =AGBC/ AGBD
1961	0.280	3.022	0.28	9.33	0.85	+0.57	3.01
1970	0.356	3.022	0.39	12.80	0.89	+0.50	2.29
1980	0.468	3.022	0.51	17.00	0.93	+0.39	1.80
1990	0.620	3.022	0.66	21.67	0.98	+0.32	1.49
2000	0.792	3.022	0.82	27.03	1.06	+0.25	1.30
2008	0.942	3.022	1.90	65.71	2.12	+0.22	1.06

* Data Sources are World Bank- FAO – WWF – Ecological Footprint Network – WRI-Earth Trends - US estimates

Table 2. Predicted Values Calculated for African Global Population, African Global Biological Capacity (AGBC), African Global Biological Demand (AGBD) and Maintenance Index of the African Continent from Year 2009-2050. The Presented Data are in 10 Years intervals

Year	African Population in billion	Surface Area in billion ha	Total African Global Biological Demand (AGBD) (billion global ha)	African Global Biological Demand in Global Hectare/Surface Areas global hectare as %	Total African Global Biological Capacity (AGBC) (billion global ha	Deficit in African global billion hectare =AGBC-AGBD	African Maintenance Index =AGBC/AGBD
2009	0.952	3.022	2.03	67.33	1.38	-0.65	0.68
2010	0.977	3.022	2.08	68.76	1.41	-0.67	0.68
2020	1.258	3.022	2.58	85.31	1.68	-0.90	0.65
2030	1.619	3.022	3.22	106.07	2.02	-1.21	0.63
2040	2.085	3.022	4.05	134.74	2.47	-1.58	0.61
2050	2.685	3.022	5.12	169.40	3.05	-2.07	0.60

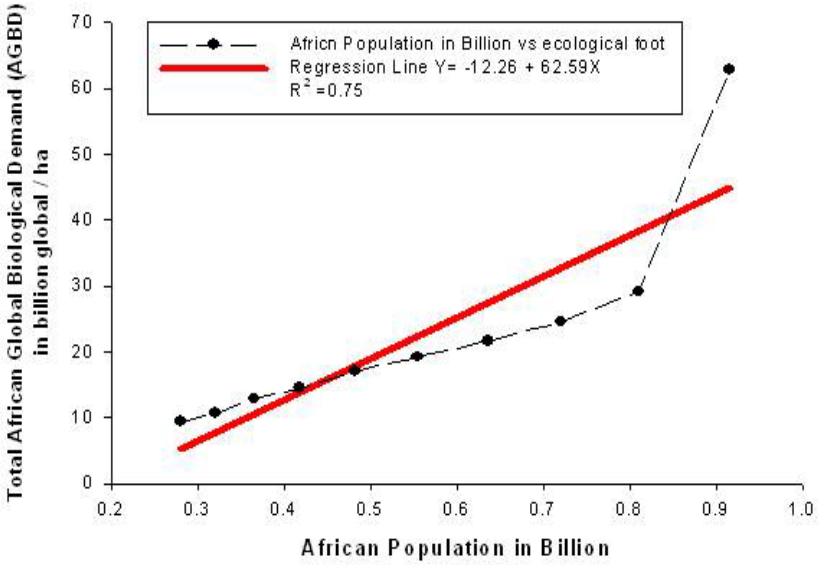

Figure 4. Relationship between African population in billion and Global African Biological Demand (AGBD) in billion hectare

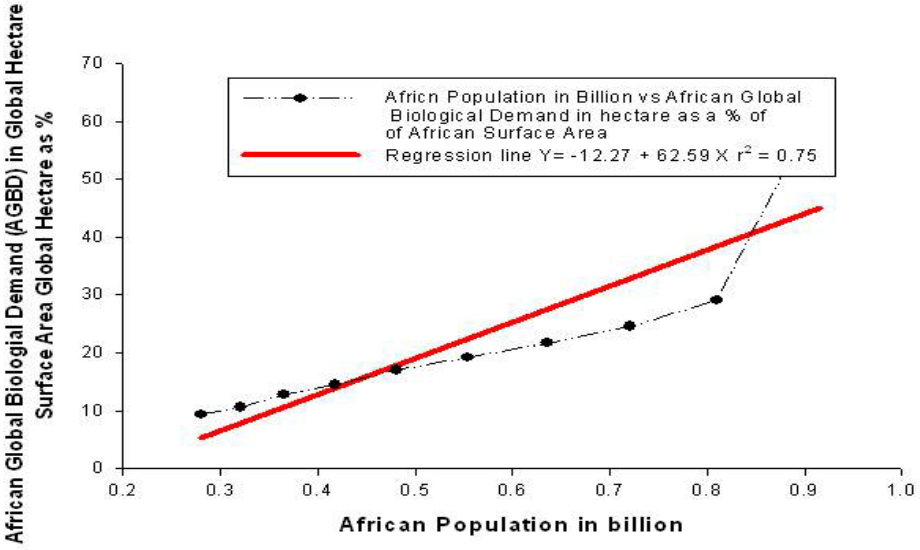

Figure 5. Relationship between African population in billion and African global biological demand in hectare/surface area gobal hectare as %

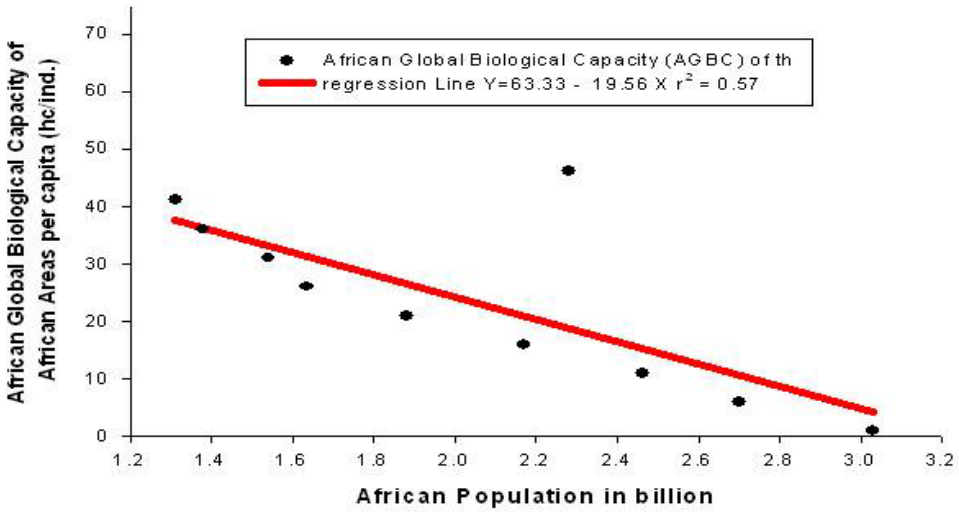

Figure 6. Relationship between African population in billion and African global biological capacity of the earth per capota (ha/ind.)

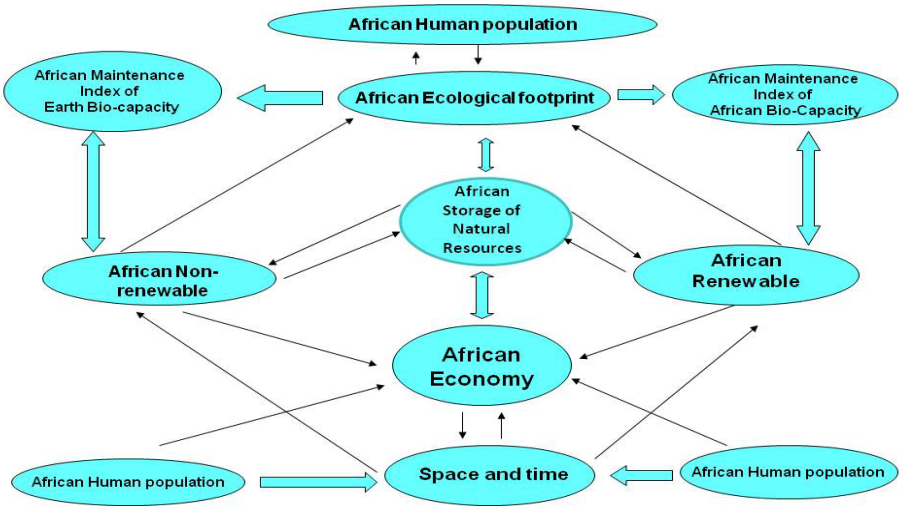

Figure 7. Diagram Shows the inter-relationships between African Natural Resources, African Ecological Footprint and African Economy

5. Economy and Concept of Emerging of Ecological Footprint

Emerging concept of ecological footprint issue has been developed over the past twenty five years since 1988 Odum[24][25]. This emerging concept as indicated from its name is the works of nature and the activities nature of human beings in producing products and services. On the other hand, humans are demanding from the nature the raw materials, crops, energy, services and consumption to survive. This concept can be developed in a model in economic analysis using the money factors and values of the natural resources and the service of these resources. Accordingly, to the model in the diagram (Fig. 7) below explains the flow of natural resources in the ecosystems and its relationship to the global economy. Also, this figure shows the interrelationships between human activities, their ecological footprint, maintenance of natural resources (i.e. renewable and non-renewable resources) and their impact on global economy.

The model below (Fig. 7) indicates the relationships between aspects of natural resources (renewable and non-renewable), ecological footprint, human population, space and time and economy. It is important to take into consideration the factor of space and time as a value in the evaluating the economy of natural resources that we are exploiting including the rate of speed of the use of these natural resources.

According to economic analysis taking into consideration the economy model that predict the value and prospective of natural resources including the in the calculation the human impacts, it is, important to realize the relationship between the speed of increase in population worldwide and the speed of the renewability of the resources. In other words, what is the speed of growth of renewability resources against the growth of human beings? The renewability of the natural resources will become steady or experience a little growth in the next decades and in the opposite the human population will increase in alarming annual rate at 1.1 %.

The ecological footprint "accounts for the flows of energy and matter to and from any defined economy and converts these into the corresponding land / water area required from nature to support these flows" Wackernagel, M. & Rees, W.,[1].

6. The Challenges Facing African Global Ecosystem

In the light of the above analysis, the human beings are faced with a lot of challenges not only from economic point of view (i.e. unemployment, funding of projects, funding of disastrous that are happenings in the world, financial recovery …etc) but also from ecological issues. These ecological issues are:

- Lack of arable lands that are used for production of food, forestry woods, pastures and animal breading for producing milk and other meet products for human nutrition
- Conserve the wild-land habitats and to be set aside to preserve large and small preserves for the use of the next generation and to maintain the biological species diversity. In this respect, the plant species, animal species and natural ecosystems cannot utilize the Earth lands extensively as human beings doing for exploitation the Earth natural resources in an alarming rate. Preserving the current African biological species diversity of plants and animals will require leaving sizable landscape areas with light utilization from African human beings or non-utilization in order to support the life cycle of the African Earth.
- It is important to use the efficient technology to save African's Earth Lands and continue reuse the materials that African population exploit from the natural resources several times to ensure the sustainability of the African's Earth Lands.
- The success of African economy should be based on the ecological sustainability of African's Earth Lands. In other words, the African global economy should adhere to sustainability of African Global Ecological Capacity (AGEC) of global Earth as a measure of equalization between the total African Global Biological Demand (AGBD) from the Earth in global hectare/capita and total African Global Biological Capacity (AGBC) of the Earth in global hectare/capita. This means that African human beings will sustain the Earth ecological budget. The data in the Table 2 showed that year 2008 is year that had AGBC equal to AGBD.
- The most important challenge of all the above is human beings controlling themselves in sustain population numbers within the acceptable limits that the Earth can support (i.e. maintaining the ecological budget of the African's Earth Lands without overloading or stressing these natural resources). This will take more efforts from the African governments, African non-government organizations (ANGO) and individuals to sustain the African's Earth bio-capacity. Otherwise, the African's Earth returns its action (i.e. exposure to lack of food, famines, diseases, global climatic disasters on the human race...etc).
- The education is the most crucial element in the above challenges to educate the public of the issue of maintaining the Earth ecological capacity.

7. Discussion

African Ecological footprint is an accountant and economical measure that can describe the balance, surplus and deficit between the African global productivity (i.e. renewability of African natural resources global biological capacity in global million hectare) and the African human demands from the Earth resources (i.e. African global biological demands or consumption in global billion hectares). Considerable attention recently to the methodologies in calculating ecological footprint and importance of this issue is discussed Zhao *et al* ([8], ECOTEC-U.K.[21]) and Wackernagel *et al*[22]. There are several scientists and researchers have considerable

oppositions or weaknesses to the ecological footprint accounting ECOTEC-U.K[21]. These oppositions and concerns are 1) Measure of sustainability; 2) Only CO_2 emission calculation included in the ecological footprint rather than the other greenhouse gases; 3) Human welfare is a multi-dimensional issue and a single index over-simplifies; 4) Ecological footprint index is including quantitative rather qualitative issues; and 5) the sequestration of CO_2 in the ocean. However, in spite of these weaknesses, the authors are considering the African ecological footprint as a sensitive measure that can be important to allow the decision makers to take care about the African natural resources and to start thinking in matter of conserving these natural resources in spite of the human pressure. From the above analysis, we found that African's Earth Lands will only support in approximately 55-60 % of the total population of the globe in year 2050 and it will run a deficit of the total global biological capacity about 40% of the African's Earth Lands in a conservative assumption. This conclusion will indicate an alarming to the leaders of the African Countries, African Non Governmental Organization and Government Agencies, United Nation with all its agencies to take appropriate actions to conserve African and world resources for the future generations. Otherwise the African population and the world are facing severe competition on these natural resources (i.e. renewable and non-renewable), and none can predict the consequences of this situation. It is important that leaders of the African countries and the world to concentrate on education of the population about the disastrous consequence of human population growth against the regenerative speed process of the biological capacity of the ecosystems to sustain the demand with production of these resources.

Generally, it is important to discuss the issue of energy conversion of global hectare to quantitative measure (i.e. Energy Conversion Factor per global hectare in energy units). This will be my next analysis of conversion of hectare land to energy use and then modelling for the global bio-capacity against global demands for energy from the Earth.

8. Conclusions

This paper indicates an alarming warning about the trends in African Global Biological Capacity (AGBC)[i.e. regenerative capacity of African's Earth Lands] and African Global Biological Demand (AGBD)[i.e. African global consumption from the African Earth Lands]. In addition, this paper shows the trends in the deficit regenerative capacity of the African's Earth Lands. The current deficit regenerative capacity of the African's Earth Lands is about 40% and continues to be 50%. From this study, it is found that 2008 is the year that African Continent has a breakeven point between the AGBC to be equivalent to AGBD. In this respect, we have to monitor the African status and condition of the balance between the AGDB and AGBC. This will not be accomplished without the collaborative efforts of the all individuals, governmental and non governmental agencies, and global world organizations as United Nations.

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