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Ecological Agro-ecosystem Sustainable Development in Relationship to Other Sectors in the Economic System, and Human Ecological Footprint and Imprint

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Abstract

Sustainable agriculture is the major economic sector (i.e. about 30% of Global economy) with the industrial and trading system in the world's economy. It is important to understand why the sustainable development is very important to the point of view of improving of human life and reducing the poverty. Additionally, we need to sustain our natural resources to be replenished and continue support our human population growth that is continued to increase in alarming rate rather than development, which is in a slow rate that does not meet the demands.
This paper is to discuss the importance of global agro-ecosystems, to support humans' needs for feeding and continue their lives in a healthy and sustainable life and to function within the society. In addition, the paper will show the availability of the agriculture natural resources in terms of global ecological biological capacities in hectares and the trends in using these resources in terms of an ecological footprint in hectares. Additionally, we study the term of ecological human imprint in relation to the agro-ecosystem as suggested by Shakir Hanna et al; 2014. Further the paper will address the impacts of agro-ecosystem on global economy and, further discuss the impacts of human technological advances on agro-ecosystems ecologically, economically, and social importance.
Our results show that the global population will be 10.50 billion people in 2050 (i.e. 1.1% the current population growth). The available global cropped land is 2.36 billion global hectares in 2008.The question is the Earth able to provide food and other

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agricultural products to support the healthy living of all human beings in year 2050 at the current growth rate? The paper is discussing these concerns.

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Keywords: Ecological Footprint, Global Crop Model (GCM), Human Population Growth, Value Added of Global Agriculture Systems, Maintenance Index of Cropping System.

1. Introduction

Agro-ecosystem is the system that is formed from the biological components (i.e. living organisms including plants, animals and microorganisms) and natural resources such as the water, rains, soils, climates) that are managed by humans. The purpose of agro-ecosystem is to provide all humans and other living organisms with food and other social valuables. In this respect the first author has defined the agro-ecosystem in the early 1980 by "varied degrees of interference of human activities in the natural ecosystems on which he ultimately relies". These interferences are the cultivation of the grasslands, cutting the trees and clearing the soils from its vegetation cover to convert it to areas for planting more crops, more vegetables and orchards to obtain food with or without livestock production. These interferences in the long term, without a sufficient knowledge of total ecological effects involved, have led to soil erosion, leaching of soil nutrients, appearing of new pests, and over exploitation of plant nutrient from the soil. It is also, the system that production of food, feed and fibers, including the balancing environmental soundness, causing social equality, and economic viability among all sectors public and private sector including global population and humanity. Therefore agro-ecosystem has the inclusion of 1) maintaining the natural resource base; 2) rely on minimum artificial inputs from outside the farm system; 3) manage pests and diseases through internal regulating mechanisms; and 4) recover from the disturbances caused by cultivation and harvest.

The idea of sustainable agriculture system will include use renewable sources of energy instead of non-renewable sources, use biological nitrogen fixation, use naturally-occurring materials instead of synthetic, manufactured inputs, use on-farm resources as much as possible, and recycle on-farm nutrients. Further; reduce or eliminate the use of materials that have the potential harm to the environment or the health of farmers, farm workers, or consumers and use farming practices that reduce or eliminate environmental pollution with nitrates, toxic gases, or other materials generated by burning or overloading agro-ecosystems with nutrients. It is intended that the agro-ecosystems patterns of practices could reduce the use of water and make efficient systems for irrigation and watering systems that conserve waters. In addition, the agro-ecosystems can conserve soil properties and qualities and maintain it is quality for more production of food. Furthermore; it is important to preserve the quality of seeding systems that maintain the genetic pool of high yield seeds for efficient production of quality and quantity of production in order to support the growing human population that are need for good production of food and other feeding sources and sustained. This will lead to better farming systems and better rural communities including the better landscaping which is making recreational option for the lot of people which can impact on local, national and global economy.

Agro-ecosystems provide food and it is valued at around $1.3 trillion per year (1997) and provides 94 percent of the protein and 99 percent of the calories consumed by humans. The production process directly employs some 1.3 billion people (WRI, 2000). In this respect, in the year 2014 it is estimated that the agro-ecosystems can provide values at around 2.8-3.0 trillion per year as 3.08 % of global GDP.

This paper provides an assessment of the agro-ecosystems to support all human beings with the needed food to support their lives. Additionally, it will show the availability of the agriculture natural resources in terms of global ecological biological capacities in hectares and the trends in using these resources in terms of an ecological footprint in hectares. Additionally, we study the term of ecological human imprint in relation to the agro-ecosystem as suggested by Shakir Hanna et al; 2014. Further, the paper will address the impacts of agro-ecosystem on global economy and, to discuss the impacts of human technological advances on agro-ecosystems ecologically, economically, and social importance.

2. Materials and Methods

2.1 Scientific Approach and Methodologies

Agro-ecosystem data that are used in this paper were collected from different data set of series available on the web sites of World Research Institute (WRI)-Earth Trends , World Bank (1960-2008), FAO (1960-2008, 2008), UN Development Program, World Wildlife Fund (WWF, 2002, 2004, 2006, 2008)) and Global Footprint Network (2008). The data were analyzed using the regression, correlation, and statistical methodology using Sigma Plot software.

Maintenance Index of agro-ecosystem (Sustainability index for Agronomy System) is a percentage of the total Global Biological Capacity for Crops (GBCC) / total Global Biological Demand of Crops (GBDC) from the earth). This index explains the ability of the earth to regenerate natural resources for crops. In other words, it explains the status of earth in providing food and crops goods and services to the human population needs. The (GBCC) is defined as the ability of the earth to produce crops and feeds from natural resources in term of global hectare / capita. GBDC is defined as the resources consumptions by human beings in term of global hectare / capita of copping and feeds. It is important to indicate the calculations of Total (GBCC) and Total (GBDC) are the most important factors in the calculations of indices that have been discussed in this paper as follow: 1) Total GBC (Total Availability or Supply in Global hectare) = Cropland Footprint (billion global hectares) + Grazing Land Footprint in (billion global hectares) + Forest Ground Footprint Excluding fuel wood (billion global hectares) + Fish Ground Footprint (billion global hectares); 2) Total GBDC (Total Consumption or Demand in Global hectare) = Cropland Footprint (billion global hectares) + Grazing Land Footprint in (billion global hectares) + Forest Ground Footprint Excluding fuel wood (billion global hectares) + Fish Ground Footprint (billion global hectares); and 3) Global Deficit Cropping Capacity (GDCC) in billion hectares is the difference between GBCC and GBDC in hectares. These estimates are calculated according to several authors of ECOTEC-U.K group and Wackernagel *et al* 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; 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 (GBCC) and Total (GBDC) for the earth in the next decades were calculated to show the impact of growth of the world population on the basis of annual data from series of years 1960 to 2014 for almost 54 years of published data. The predications for the years 2015 to 2050 were analyzed using correlation and regression lines (Table 1 and 2).

2.2 Modeling Agro-ecosystems and Assessment Methodologies

2.2.1 Description of the Model

The Global Crop Model (GCM) has been design to predict and assess the availability and valuable of agro-ecosystems in producing crops and other services for feeding globally. This model was written using STELLA modeling software package version 10.0. GCM predicts the status condition of the cropping systems globally and predicts the needs for supporting cropping systems from year 2010 to year 2050 for almost 40 years to come at the middle of the Twenty First Century.

The model used annually time step with the fourth Runge–Kutta integration method. The simulation period could be from one year to several years and could be used for a short time period of simulation. Background data and literature parameters were used to initialize the model and a short-term data collected from different sources and data sets of series available on the web sites of World Research Institute (WRI)-Earth-Trends, World Bank, Food and Agricultural Organization (FAO), United States Department of Agriculture (USDA), United Nation Development Program, World Wildlife Fund (WWF) and Global Footprint Network. Table (1) shows the list of variables and parameters in the Model and its interpretation.

2.2.2 Model Formulas Input in The Model

1. Relationship between global population and agriculture land in hectare per capita Y= 2.13 - .213 X and r^2= 0.976.
2. Relationship between global population and the arable agricultural lands per capita is Y= 0.46 -0.04 X and r^2=0.91.
3. Relationship between global population and ecological footprint consumption in billion global hectare Y=-0.28 + 2.65 X and r^2= 0.94.
4. Relationship between global population and crop production in pounds per square hectare of lands Y= 57177.67 -5733.15 X and r^2=0.97.
5. Relationship between global population and global biological capacity of Earth per capita Y=4.65 -0.45 X and r^2=0.94.
6. Relationship between global population and deficit of Erath global capacity is Y=10.06-2.42 X and r^2=0.96.
7. Relationship between global population and required planet Earth size is Y=0.13 +0.19 X and r^2=0.96.
8. Relationship between global population and global biological capacity of crops is Y= 4.95 – 0.39 X and r^2=0.84.
9. Relationship between global population and global biological capacity of crops per capita is Y= 1.83 -0.24 X r^2= 0.88.
10. Relationship between global population and maintenance index of global cropping system is Y= 1.87 -0.18 X r^2=0.93.
11. Y= relationship between global population and global agricultural value added as a % of total world GDP.

3. Results

3.1 Analysis of Global Cropping System

Analysis of agriculture and world agro-ecosystems lands (Figures 1-10), showed that the agricultural lands for each individual human is about 0.6-1.8 hectare. Additionally, the share of each human-being of the arable lands is between 0.20 hectare in the year 2010 and 0.36 hectare in the year 1961. However, the production of each hectare of crops is calculated to be between 15,000 lb. / year in the year 2008 and 45,000 lb. /year in the year 1961 of crops as calculated of 0.25 pound per square foot of lands per year. Global Biological Capacity for Crops (GBCC) as calculated from ecological footprint global bio-capacity per hectare is 0.2 when the population is 7.0 billion people in the year 2008, and 1.4 hectare per capita when the population is 3.08 billion people in the year 1961.On the other hand, the ecological footprint copping (i.e. consumption) for world population is equal to 0.94 hectare per capita when world population is 3.08 billion people in 1961 and 0.55 hectare when the world population of the world is 7.0 billion people in the year 2008. This is indicated that the Earth cannot maintain its capacity for producing crops to the Earth to the global population of the Earth (i.e. less than 60% to cover the needs of people from agricultural resources in 2008). However, the model of the GCM will predict the availability of foods and crops to sustain the human well-beings existence. In this respect, the world population will reach 10.9 billion people in the year 2050, and the world cropping system is producing.

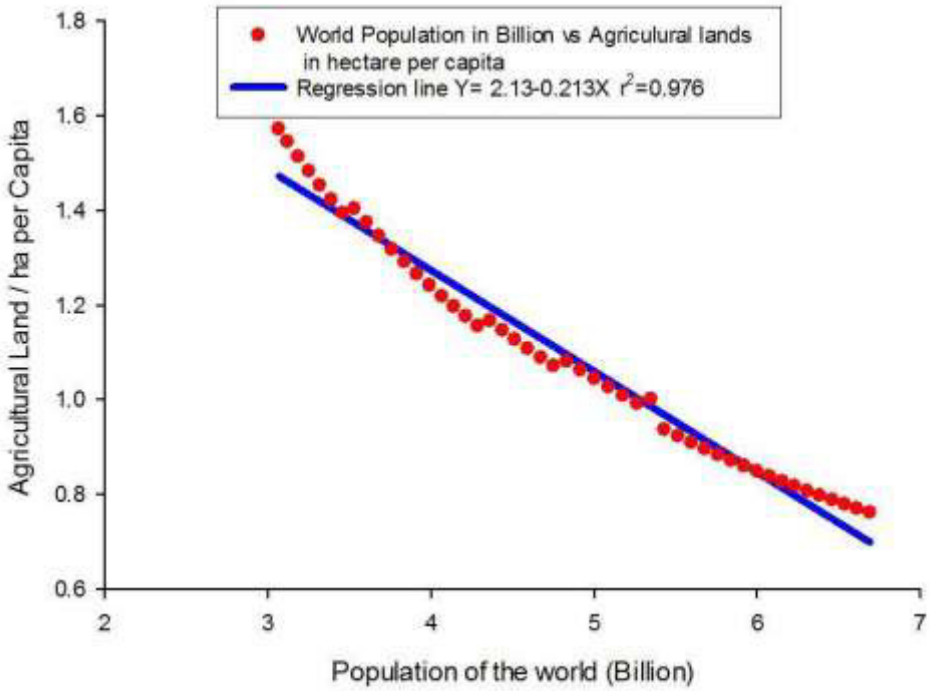

Fig. 1 - Relationship between world human population in Billion & Agricultural lands per capita

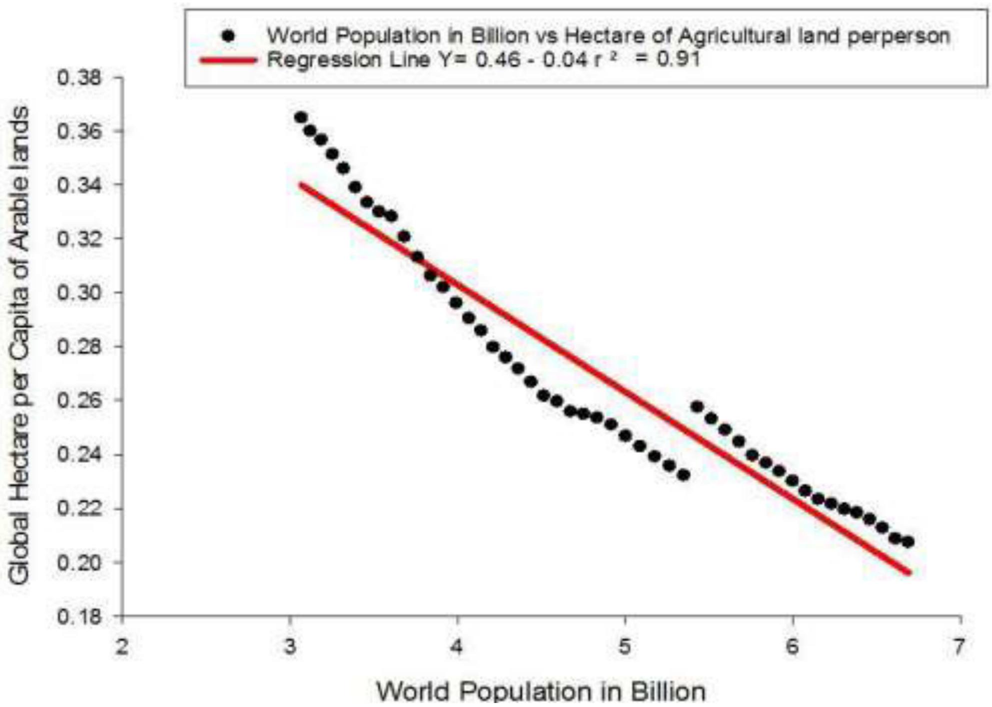

Fig. 2 – Relationship between world human population in billion and arable land in hectare/Capita

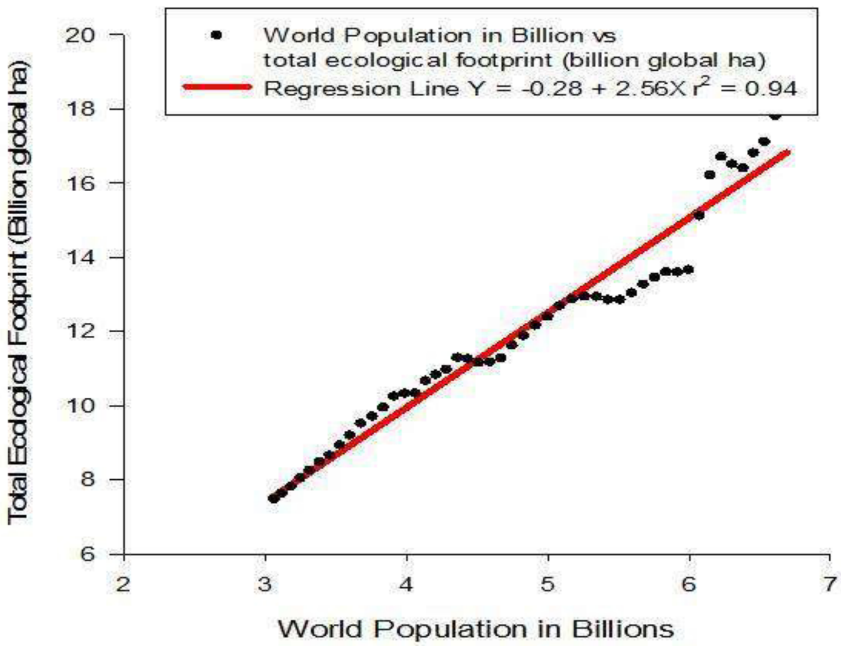

Fig. 3 – Relationship between world population in billion and ecological footprint consumption (Billion global ha)

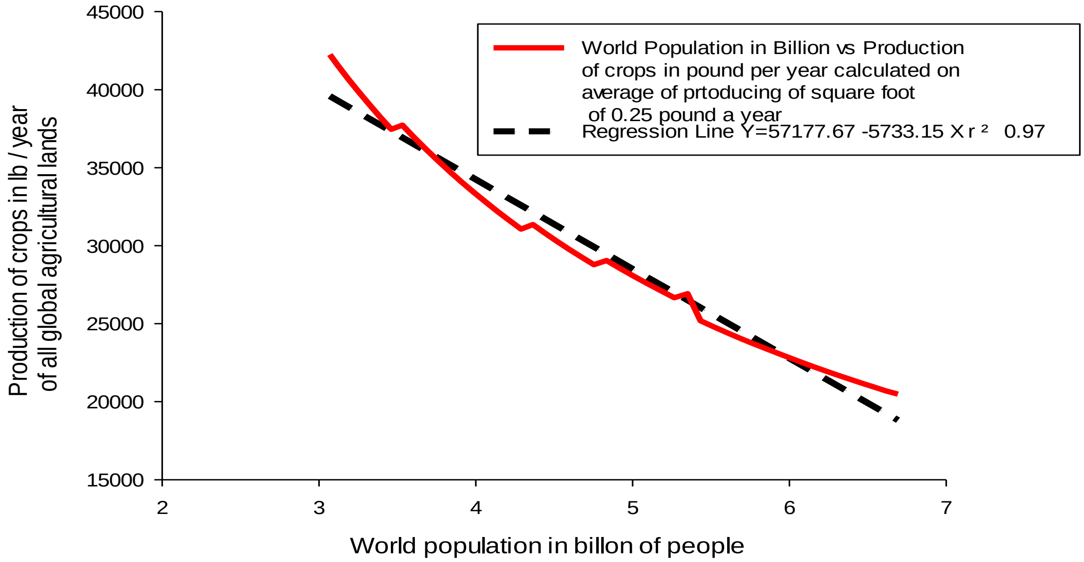

Fig. 4 – Relationship between world population in billion people and production of crops in Ibs/year per square foot of land

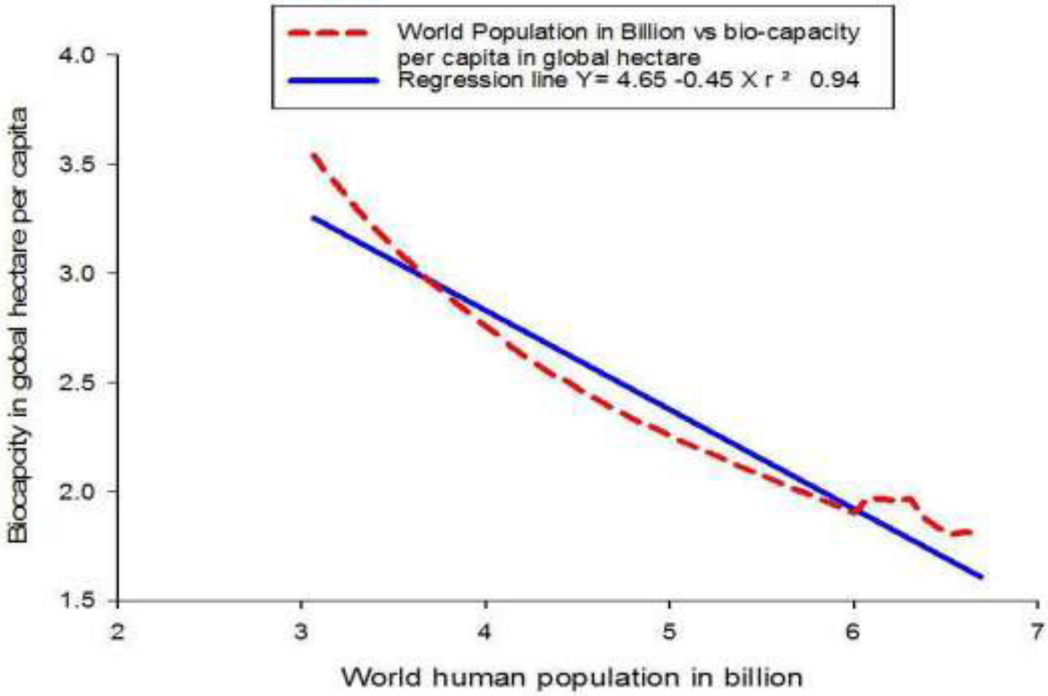

Fig. 5 – Relationship between world human population in billion and bio-capacity of Earth per capita in global hectare

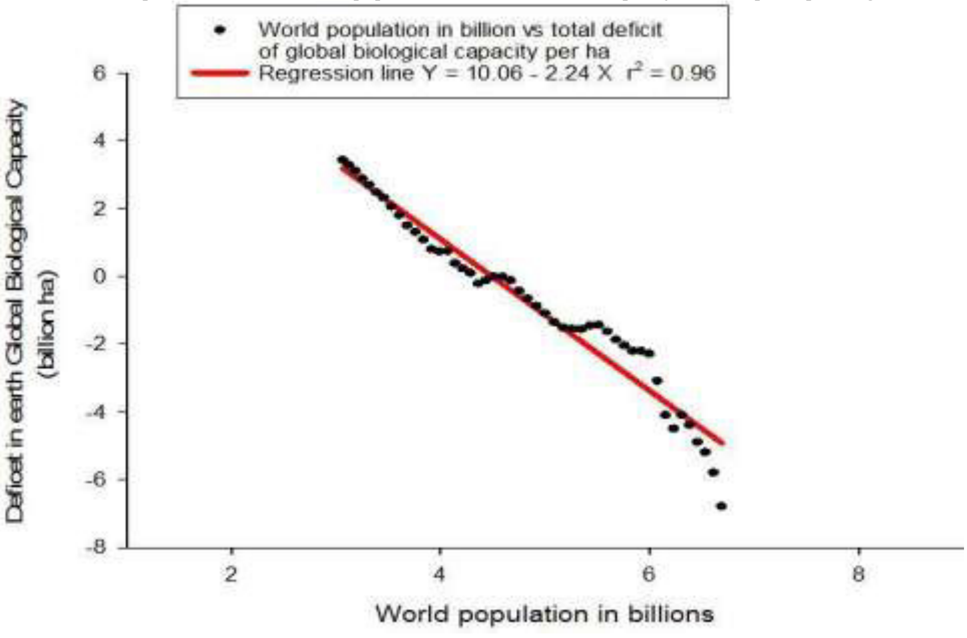

Fig. 6 – Relationship between deficit in Earth global biological capacity in billion hectare and world population in billion people

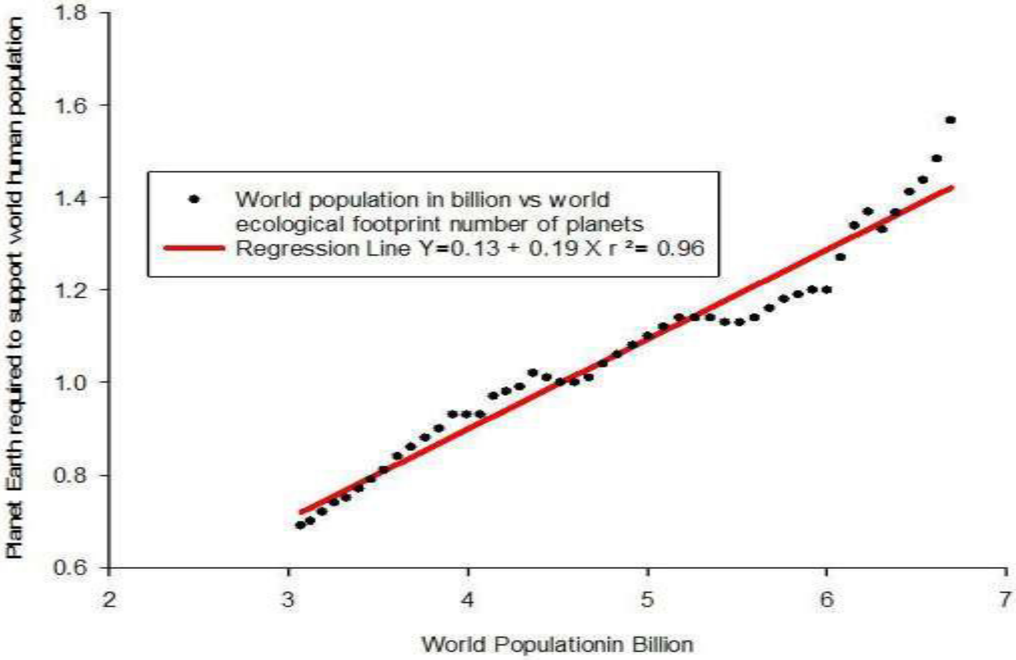

Fig. 7 – Relationship between world human population and required number of planet Earth to support their existence

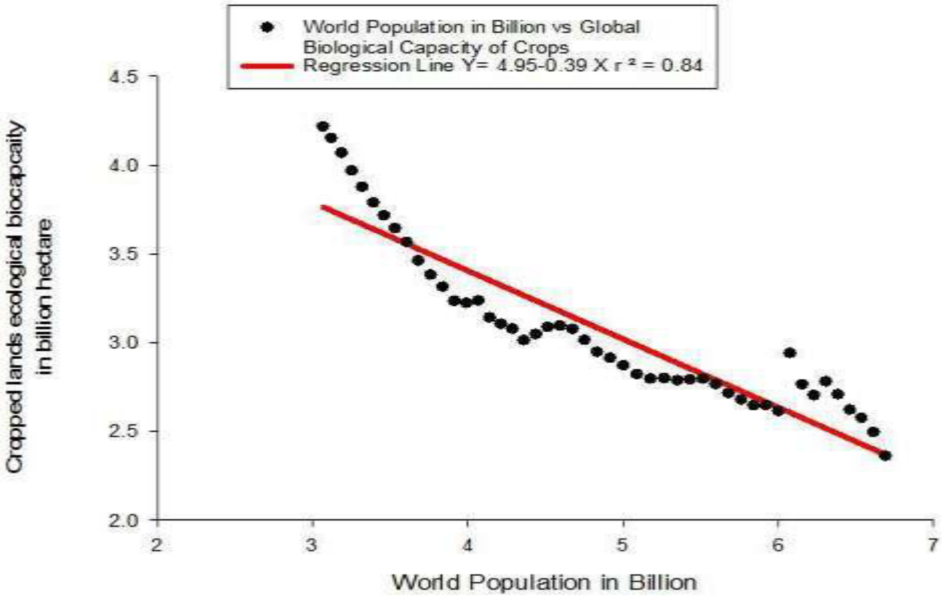

Fig. 8 - Relationship between world population in billion and global biological capacity of crops in billion hectare (GBCC)

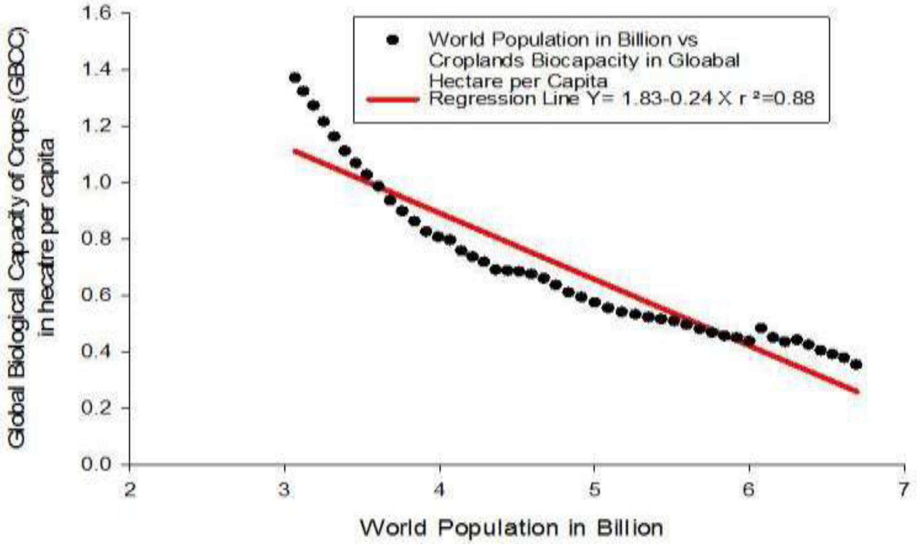

Fig. 9 - Relationship between world population in billion and global biological capacity of crops per capita in hectare

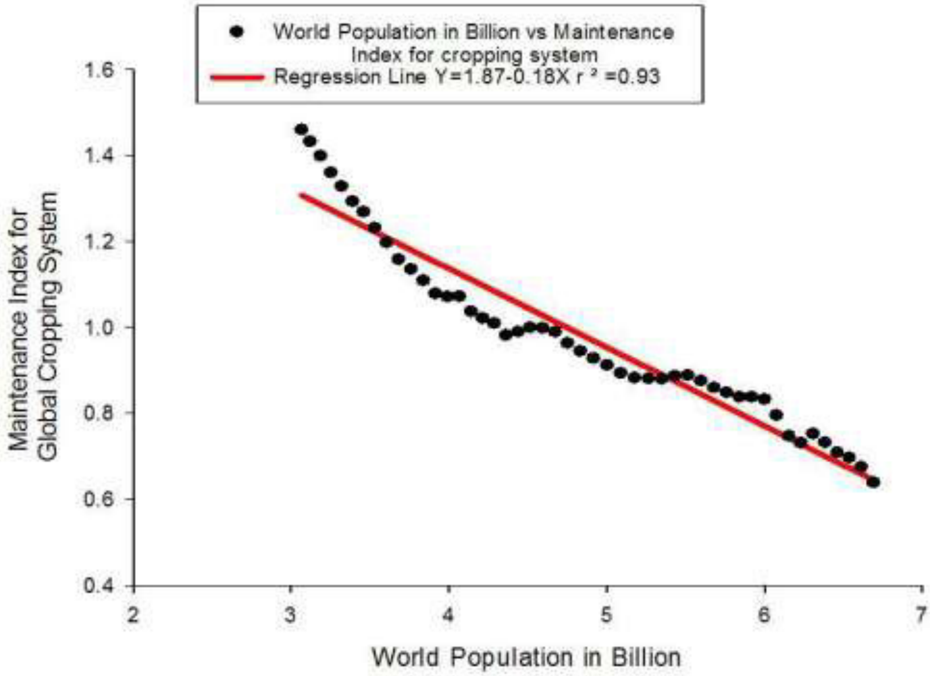

Fig. 10 - Relationship between world population in billion and maintenance index of global cropping system

3.2 Simulation and Analysis of Global Cropping System (GCM)

According to the Global Crop Model (GCM)) simulation analysis output, the used data in the model are the year, human population, and the crop production according to, ecological footprint of the cropping system, Global

Biological Capacity for Crops (GBCC), and Maintenance Index for cropping to the assumption of calculation of crop production produced from the global hectare from the Erath.

The model showed and predicted the deficit of globally cropping system per capita, the needed global Earth of cropping system, the global production of crop biological capacity. The model outputs are presented in Figures (9, 10, and 11).

It is clear from the simulation model that human population will reach 10.50 billion people when the growth rate of human population is 1.1% as the real growth rate from year 1960-2008. Accordingly, the production of global agricultural lands is between 34571lb. / hectare in the year 1961 and 19266 lb./ hectare in the year 2008. However, the simulation model predicted that the production of agricultural land is degrading and will reach the lowest point in the year 2045. The productivity of the hectare of agricultural land will be the lowest, and this prediction is calculated according to the increasing the human population to reach 9.93 billion people. Further, the deficit of global biological capacity of crops (GBCC) per capita is decreasing to reach -0.11 global hectares in the year 2050.

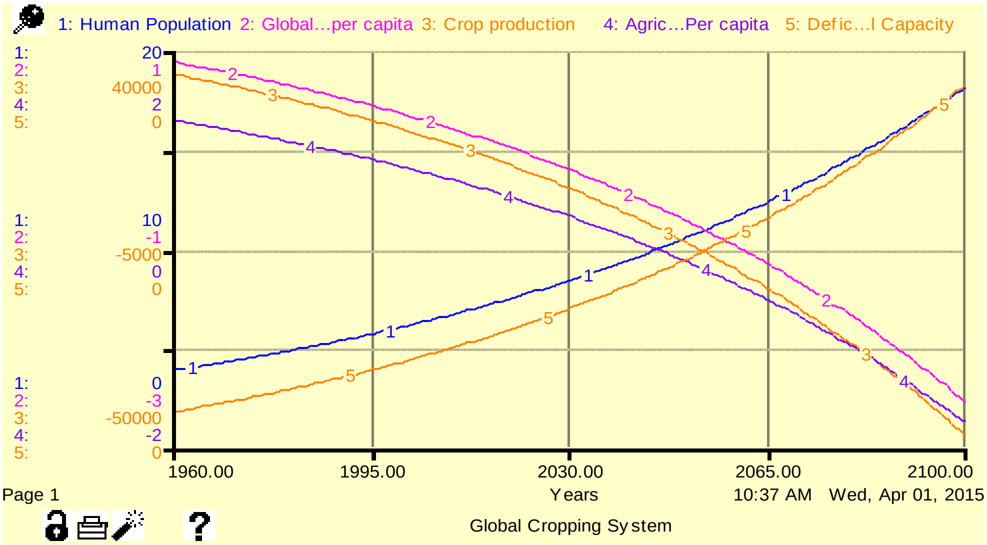

Fig. 11 Simulation Modeling for Global Cropping System on the Basis of the Assumption of Annual Human Growth of 1,1% as the Real Current Human Growth Trend in the World
The colors of the line are: blue-1 is for human population; purple-2 is for Global bio-capacity of crops per capita; red-3 is the crop production; blue-4 Is agriculture lands per capita; and red-5 is the deficit in biological capacity

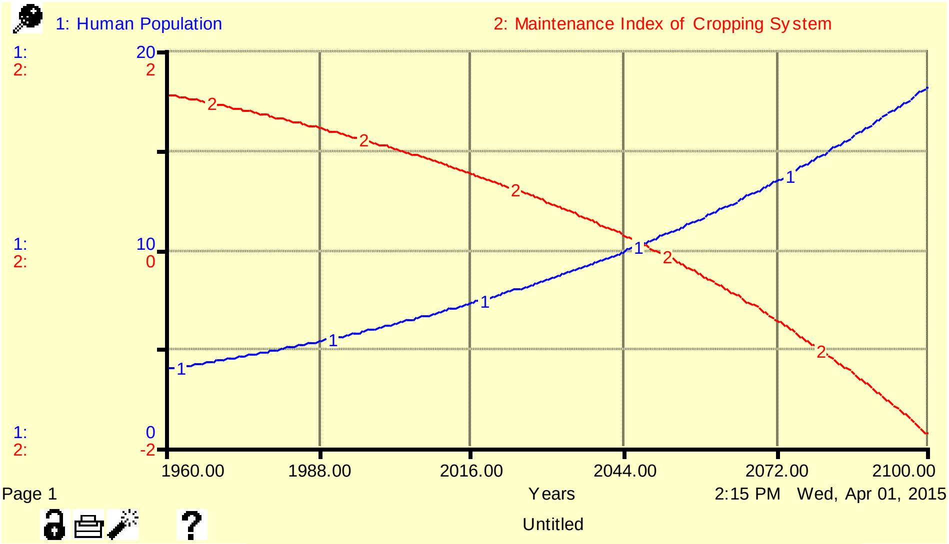

Fig. 12 Simulation Modeling for Global Cropping System on the Basis
Of the Assumption of Annual Human Growth of 1.1% as the real Current
Human Growth Trend in the World
The colors of the line are: blue-1 is for human population; and red-2 is for
Maintenance Index for Global cropping System

The model showed that the predicted cropping systems are equal to 2.3 billion hectare in the year 2008 and 4.2 billion hectare in the year 1961. This indicated that the copping system is in declining by 54%. The model outputs are presented in Figures (10).

From these figures, we can conclude that on the normal assumption of human population growth (at the current trend 1.1% globally), the human population will increase to reach in the year 2100 about 18.1 billion people globally. Further the crop production global biological capacity will be 0.89 global hectares per capita in 1961 and -2.54 global hectares per capita by 2100. This is indicating a deficit of -1.65 global hectares per capita (i.e. deficit by 185 %). This is an alarming trend in production of agricultural crops to feed the human beings that will be living on this Earth. On the normal human population growth, the global copping system will not be able to support all human beings in approximately and around year 2050-2060. This has been shown in the decline of agriculture production and deficit in biological capacity of the Earth. However, if the human population growth is reduced to become 0.5% growth rate, the human population will increase to reach in the year 2100 7.85 billion people and the cropping system will be in deficit by 94% in the year 2100. This means that the Earth will not be able to support all the human population on the Earth. The maintenance index of copping system is about -1.4, and this is meaning deficit of production of global crops by 140%.

4. Discussion

One of the most important issues of a conservative management of farms is the obtaining of a sustainable yield; nevertheless it is highly difficult to define and measure what sustainable yield is (Ferng, 2005) and (Mózner et al.; 2011). It is noticeable that yield is affected by a number of parameters, both natural, such as the pedo-climatic conditions, and artificial such as the agricultural techniques and growing structures. Agricultural practices such as fertilization, irrigation, ploughing, spraying pesticides can contribute both the yield and to the environmental burden on the production.

Fig.13 indicated the relationship between world population and agricultural value added as percentage of the global growth Domestic Product (GDP) showed that the decline of the sharing of the agriculture sector in relation to all other economic sectors has and will be causing disastrous consequences as indicated by FAO and United Nation (2014). This will lead to famine and hunger across the globe. This is an alarming trend that the nations, and all Government and Non-government Organizations (GOV & NGO) should look into this situation seriously. In this respect, according to FAO on December 18, 2014, indicated that among the most pressing challenges facing the world today is feeding a growing global population that is projected to increase from over 7 billion currently to over 9 billion by 2050. In this respect, the world population in 1992 was 5.4 billion people, 6.3 billion people in the year 2002 and reached 7.2 billion people in the year 2014 (FAO, 2014); therefore, these data indicated that every 10 years the world population increases by one billion people. Furthermore; it is importance to recognize that in about the first one thousand years of humanity the world population increased by one billion people and at the end of the last two decades; the world population has increased by two billion people. This challenge is compounded by the additional threats of climate change, increasing water and land scarcity, soil and land degradation, and a deteriorating natural resource base, threats that will mainly hurt the world's poor and vulnerable, especially those living in rural areas who represent the vast majority of the at least 805 million hungry (http://www.fao.org/post-2015-mdg/news/detail-news/en/c/273242/). Further, a total of 842 million people in 2011–13, or around one in eight people in the world, were estimated to be suffering from chronic hunger, regularly not getting enough food to conduct an active life.

EF is evaluated on the basis of the average yield of a species and the national consumption Ewing et al., 2010; Chambers et al. 2000) or using the conventional global hectare approach (Kitzes et al., 2008). In this case, the quantification of the EF of a food item can be simplified in the following equation:

$$EF(gha) = (C\ nation / Y\ World) \times EQF$$

Where, the EF is obtained dividing the annual tonnage of the food consumption by the annual average global yield and then multiplying by the cropland equivalent factor, which is 2.39 (Ewing et al., 2010).

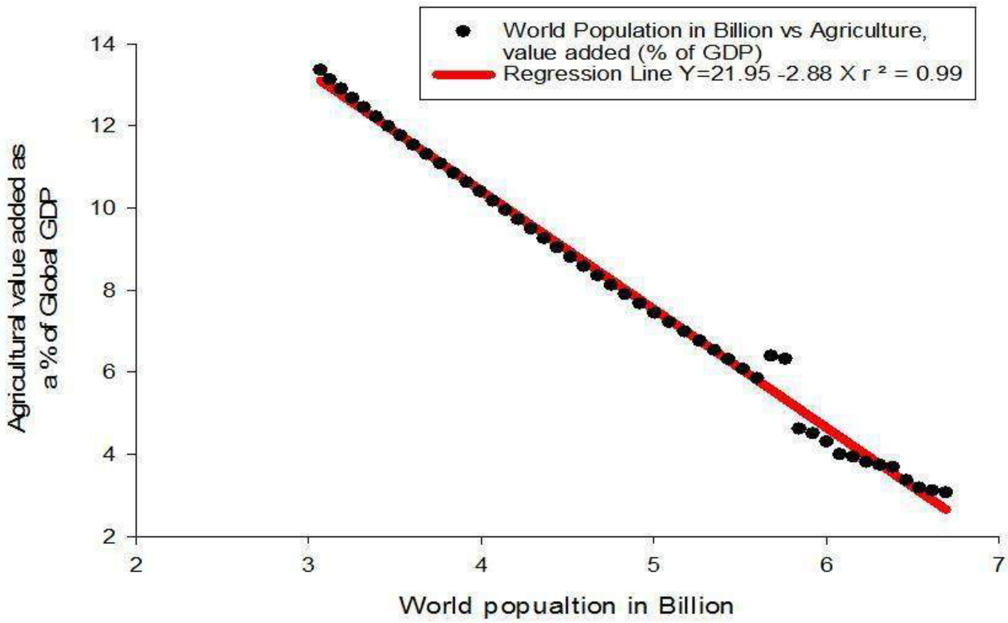

Fig. 13 – Relationship between world population in billion and the agricultural value added as % of GDP

5. Conclusions

In conclusion, the human population has grown in the last 20 years by 2 billion people by about 33% increase (i.e. about 1.41% annually) in the last two decades. However, the development of agricultural production is decreasing, and it is not meeting the growth rate of human people. In this respect, the deficient in production of crops is to be 140% according to the model of GCM. This is an alarming situation to the whole world. Therefore, the government, non-government and UN organization should take the lead to highly educate the people why increasing the human population beyond the normal is dangerous and to educate the people to slow producing children that cannot be fed, educated, and become highly productive people. In addition, it may be this can cause the decreasing of the conflicts around the world, reduction of political instability, reduction of crimes, and finally reduction of the hungers and poverty, and in consequence, increase the peace throughout the world. Further, we have to be careful in thinking that because, we have technologies that we have created, maybe not able to produce more food to feed the growing population, because the technologies or genetic engineering to produce crops, will not be able to produce the double of each crop itself, because the other requirements for crop productions such as soil, climate and water resources are not available. Furthermore, the argument of the increasing technological advances in agriculture can support production of food and crops that can feed the world; still there is an uncertainty degree to support this argument. In our own opinions that global population will have some balance correction in the growth of human population through the natural causes that will come, and the nature will act to control human population to allow the balance between the nature and human demands from it. Therefore; it is very important that humans take actions by themselves and respect the nature in order to sustain the balance between the nature and human. It is expected, that the human population growth will decline in the coming decades that allow the balance between nature and human population and in consequence, the correction of reduction of hunger and balance of agricultural production and productivity of the lands.

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