Crop Production Sustainability: with a Global Perspective

Master of Science Thesis in the Master Programme Applied Environmental Measurement Techniques

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Energy and Environment
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ABSTRACT

Agriculture is a global system, and for its sustainable solutions is acute almost everywhere to pressing environmental and production challenges. These solutions might be crop and region-specific, although the principles on which individual solutions are based will be widespread.

The world is facing many challenges to feed the growing population around the globe. In 2040, the world population of 10 billion people would require, at least, a triple food production as a result of population growth and dietary changes. The green revolution between 1940s and 1960s contributed much production with modern varieties of rice, wheat and maize, in combination with the more intensive use of fertilizers and pesticides. However, keeping in view the population growth, limited growth in yields and degradation of arable land and other agricultural resources, the future production capacity is in question.

To make certain the adequate food supplies for future generations, it is assumed that from now until an optimum population is achieved, strategies for the conservation of land, water, energy, and biological resources are successfully implemented for ensuring a sound and productive environment.

The aims of the research are 1) to study the status of cereal crops such as rice, wheat and maize essential for human survival, 2) to identify the major issues and challenges due to which crop production is being stressed, 3) to find out the inadequacies in available data and future projection concerning the future crop production sustainability and 4) to make a generalised view of the environmental impacts regarding crop production.

ACKNOWLEDGEMENTS

Many persons have contributed to the success of this project in my award of a Master's Degree in Applied Environmental Measurement Techniques. The list is inexhaustible and only few have to be named given the limited space. Firstly, we would like to thank Sverker Molander who supervised us throughout the project. His patience and guidance kept us on the proper track of our research. Without this course our knowledge on the subject would have been very limited.

The most and above all, we missed our family while living far from them but they always motivated and fervently encouraged us to complete our work. We don't forget to thank all our friends who helped us morally to continue and finish this work.

6th June, 2007
Mohammad Shumsul Karim
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1. INTRODUCTION

Agriculture is a global system, and for its sustainable solutions is acute almost everywhere to pressing environmental and production challenges. These solutions might be crop and region-specific, although the principles on which individual solutions are based will be widespread.

The world is facing many challenges to feed the growing population around the globe. In 2040, the world population of 10 billion people would require, at least, a triple food production as a result of population growth and dietary changes. The green revolution between 1940s and 1960s contributed much production with modern varieties of rice, wheat and maize, in combination with the more intensive use of fertilizers and pesticides. However, keeping in view the population growth, growth in yields and degradation of arable land and other agricultural resources, the future production capacity is in question.

1.1 Problem

Sustainability of human society is being debated all around the globe because of extensive pressure on natural resources upon which human survival depends. The agricultural activities are providing the human race with food to survive. The growing population and increasing pressures on agricultural resources such as arable land and water are raising questions about whether the agricultural production will be sufficient to feed the growing population in coming decades or not.

In the past decades, the vast cereal production was the outcome of the expansion in the harvested area, increased intensity of land use and increase in yields. The land suitable for agriculture has already been brought under cultivation leaving little room for future expansion of cultivated land. However, 1.2 to 1.5 billion ha of the most productive land is already cultivated from the world’s total suitable arable land of 3 billion hectares. Most of the potentially available land is presently under tropical forests, which are not desirable for cultivation with respect to biodiversity conservation, greenhouse gas emissions and regional climate and hydrological changes, and would incur high costs to provide the necessary infrastructure (Maarten et al., 2002). Besides, the estimation of FAO states that 5 to 7 million ha are being lost each year to land degradation and in the same time the water scarcity is remained. The current view is that the future food production necessarily comes mainly from increased productivity i.e. yield. Already increasing productivity in many countries is putting stress on the natural resource base.

1.2 General Aspects

The concepts of sustainability, sustainable development and sustainable agriculture are defined and explained before proceeding towards aims and hypotheses of the study.

1.2.1 Sustainability

To sustain means "to maintain; keep in existence; to prolong". Human societies can be sustainable if they are able to maintain themselves in space and time. The rate of change of a system threatens sustainability when it approaches the speed with which the system responds to the change. Both the factors are threatening the sustainability of human society. The social and environmental changes are accelerated by technological development and population growth where, as the increasing structural inertia is reducing the ability of society to respond in time (Bossel, 1998).

Usually, it is thought to be an integration of social, economic and environmental issues, even where these are traded off against each other. Therefore, the idea of maintenance, as the prime meaning of sustainability is substituted with the idea of integration. But maintenance and major trade offs are mutually exclusive (Sutton, 2001). Therefore, sustainability can only be achieved by making a system prolong without major trade offs.

1.2.2 Sustainable Development

Sustainable development is "the development that meets the needs of the present generations without compromising the ability of future generations to meet their own needs" (Brundtland, 1987).

Further broadening the above definition, sustainable development encompasses three major areas of economic, social and ecological aspects. The sustainable development can only be achieved by the integration of all three aspects without any major tradeoffs against each other, which is the ultimate essence of sustainable development. According to Mawhinney (2002) "Sustainable development delivers basic environmental, social and economic services to all residents of a community without threatening the viability of the natural built, and social systems on which the delivery of these services depends".

The three aspects of sustainable development can be rightly extended to legal, cultural, political and psychological dimensions. A just and fair society is likely to be more securely sustainable than a materialistic society with unjust, undemocratic and cruel political set up. If the environmental sustainability is achieved , together with the present trend, where a small number of people lives lavishly, partially at the cost of underprivileged majority, this is likely to be socially unsustainable in the long term due to the pressures exerted by the institutionalized injustice. On the other hand, an environmentally and physically sustainable society that utilizes the environment at the maximum sustainable rate is likely to be psychologically and culturally unsustainable (Bossel, 1999).

1.2.3 Sustainable Agriculture

The sustainable agriculture addresses the social problems of people associated with food production along with the conservation and protection of natural environment without compromising the production of food needed to meet the food security. Sustainable agriculture incorporates three main goals of environmental health, economic profitability and social and economic equity. Many philosophies and concepts are developed in search of achieving these goals with different perspectives.

Sustainable agriculture maintains biodiversity, conserves soil fertility and biological and physical health, preserves water quality, recycles natural resources and conserves energy. It seeks to use local renewable resources and minimizes the external and purchased inputs, in search of self dependence and a stable income for rural communities. It tries to integrate the rural communities to their natural environment and less dependence on external resources. The knowledge of modern science is used to augment the traditional wisdom of farmers acquired over centuries to preserve the ecological principles of diversity and interdependence.

1.2 Aims of the study

Following aims are made to cover the above discussed problem.

1. To study the status of cereal crops such as rice, wheat and maize essential for human survival. This status is reviewed on the basis of production, consumption and ending stocks of cereal crops.

2. To identify the major issues and challenges due to which crop production are being stressed.

3. To find out the inadequacies in available data and future projection concerning the future crop production sustainability.

4. To make a generalised view of the environmental impacts regarding crop production.

1.3 Hypotheses

Following hypotheses are made to meet up the aims of the study.

- To meet the human food demand, the cereal crops are more valuable concerning the sustainability.

- The sustainability of cereal crop production is being threatened by rapid population growth, crop land availability and degradation, crop productivity and climatic alteration.

- The future projection made by different international organisation and governmental agencies might affect the future crop production sustainability.

- The practices of high input agriculture are causing many negative effects on the environment concerning the crop production sustainability.

1.4 Methodology

To link between theory, aim and reality, methodology is used as a helping tool. It is used to approach the task in a structured way. Depending on the nature of the problem different methods are used. The following discussion presents the methodology that we adopted for gathering theoretical and empirical data for this study. The validity and reliability of the methods that we used are also discussed.

1.4.1 Overview

A simplified model of the workflow of the thesis is shown in the figure 1.1. It presents the work from the very start of reading and collecting relevant material to the end of the analysis and conclusion.

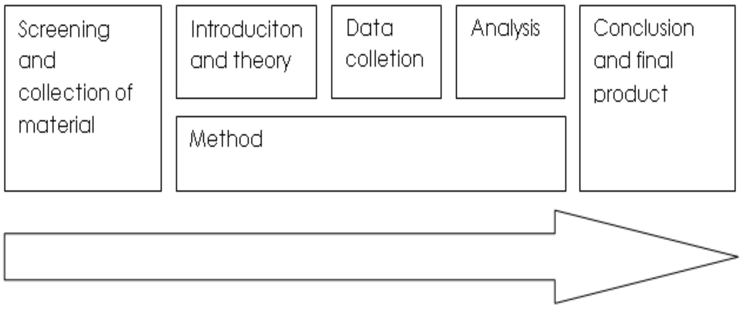


Figure 1.1 Work Flow Diagram for the Thesis

We screened all the relevant literature in the field of crop production sustainability in the beginning of the work with the purpose of writing a first draft of the introduction and develop research questions. To the best of our knowledge, we consulted most of the papers pertaining to the crop production sustainability that has been published in the past and current decades.

1.4.2 Approach

At start, the both primary data collection and secondary data collection were tried to be used for this research. The use of the primary data collection stage was very limited because all of the needed and necessary data was obtained during the secondary data collection. However, the methodology has been developed all throughout the thesis in order to be able to be flexible for changes during the work process. During the secondary data collection, published articles in press, literature available from the organizations and companies and online archives are consulted.

1.4.3 Data Sources and Collection of Data

For our qualitative and quantitative research, there were several ways of collecting data. Data is collected through published books and papers, selected comprehensive reports, relevant journal's articles in printed and electronic resources.

In this study, both the theoretical data and empirical data is utilized. In order to develop an understanding of the theories and concepts pertaining to sustainability and crop production, we carried out a careful literature review. In the following, we discussed the details of the data sources and collection of data.

The main type of information used in the study is categorized broadly in three sectors such as crop production, environment and sustainability. Our main source of data and information about agriculture and food in general and crop production in different regions of the world with their appropriate utilization and consumption in particular is the FAO (Food and Agriculture Organization). On the agricultural production, consumption, trade, aid etc. FAO published a huge quantity of material each year. These statistics covers all of the regions of the world and different kinds of foodstuffs. The graphical illustration of cereal crops are made by the utilization of data provided by FAO, WRI (World Resources Institute) and USDA (United States Department of Agriculture).

1.5 Structure of the Thesis

The thesis work is divided into the following major segments according to the aims and hypotheses of the study.

In the first part, general aspects that are used in this research such as sustainable development and sustainable agriculture are elaborated. The problem formulation, aims and hypotheses of the study are also discussed in this part that is spread on chapter 1.

In the second part of the thesis, the general view of the world crops and their contribution to global food demand is focused. Efforts are also carried out to discuss the status of the major cereal crops such as rice, wheat and maize on the basis of the production, consumptions in the past recent years. This description is illustrated in chapter 2.

In the third part of the thesis, the different issues and challenges associated with crop production sustainability such as population growth, land availability and degradation etc. are discussed. This is illustrated in chapter 3. On the basis of the obtained information and data about sustainability of different cereal crops, reliability of data and future projections are analyzed in the chapter 4.

The last part of this thesis, the analysis and discussion along with the future of crop production sustainability and environmental impacts are discussed with conclusion and recommendations made in the chapter 5 and 6.

2. STATUS OF CROP PRODUCTION

The world now stands in the 21st century with much concern of future food availability regarding global crop production. Because the issue global crop production is very closely related and connected to the other resources like land, water and the mass population which is projected to be 7.9 billion in 2025 (Mark et al. 2002). According to the report of Mark (2002), 250 million hectares of area irrigated worldwide and without irrigation it is not possible to increase the crop yield to meet up the food demand of world's growing population. In the contrary, land availability for crop production is in question as the land degradation is major significance for its impact on food security and the quality of environment. Only about 11% of the global land surface can be considered as prime land which must feed the 6 billion people today (WMO, 2006) and the 7.9 billion expected in the year 2025.

Besides long-term food productivity is threatened by soil degradation, which is now severe enough to reduce yields on approximately 16% of the agricultural land (WMO, 2006). Moreover, land degradation's impacts on productivity vary widely as low as 0.1 percent per year due to all forms of soil degradation on a global scale (USDA, 2006). In contrast of the soil science literature, it has been estimated that the potential yield losses to erosion average 0.3 percent per year across regions and crops (Wiebe, 2003) Whereas the total agricultural area in the world is 5.0 billion ha and of this, about 1.5 billion ha (30.4%) is arable land and land under permanent crops (FAO). In connection with some question e.g. how much of future food production will come from rain fed and irrigated areas, how much land need for food production, how the crop production can be affected by the on growing world's population, it is needed to have a view of present scenario of global crop production. But in perspective of sustainability which crops are carrying the more human demand will try to be highlighted. Here the certain crops are to be highlighted relating to the total production amount, harvested area, and yield productivity in contrast with the other crops.

Table 2.1: Contribution of crops to global food demand

Crops	Contribution to total food demand	Change in demand 1974 – 1994 (%)	Change in area of production 1974-1994 (%)
Rice	30	71	52
Wheat	18	97	96
Maize	13	115	72
Cassava	12	40	17
Potatoes	5	115	25
Sorghum	4	54	18
Food legumes	3	32	13
Barley	3	79	22

Source: Clay (2004).

Table 2.1 presents that the increases in consumption of major food crops are significantly larger than the increase in lands devoted to produce these crops (Clay, 2004). From this table it is also been revealed that the cereals (Rice, wheat and maize) are the major contributor to meet the food demand. Besides, more lands are also being used by these crops which are concerned to the sustainability than the other commodities.

Table 2.2: Global Land Area by Use (Billion hectares)

	1961	1970	1980	1990	2000	2003
Total agricultural area	4.41	4.50	4.72	4.91	4.982	4.982
Total arable land	1.27	1.30	1.33	1.38	1.39	1.40

Source: Clay (2004) and FAO (2006).

Table 2.2 presents the global land area used by agriculture in several decades and among them arable land has increased from 1.27 in 1961 to 1.40 billion hectares in 2003. Area used by cereals increased from 648 in 1961 to 683 million hectares in 2005 and the average share of global arable land by cereals is 51% as presented in Table 2.3.

Table 2.3: Area used by cereals (million ha) and share of global arable land (%) and cereals production.

	1961	1970	1980	1990	2000	2003	2005
Total Harvested area	648.05	675.64	717.41	708.43	674.15	671.64	682.90
Share of global arable land	51%	52%	54%	51.3%	48.3%	48%	-
Global cereal production (million tonnes)	876	1192	1549	1951	2060	2085	2227

Source: FAO (2006).

Based on projected changes in population, income, and urbanization, FAO and IFPRI project that global demand for cereals will increase by 1.2-1.3 percent per year over the next two to three decades (Wiebe, 2003)

Though it is estimated by FAO that the 1.5 billion hectares of land currently in crops represents only about 35 percent of the world's land (4.2 billion hectares) judged to be suitable for crop production. The remaining land suitable for crops, however, is unevenly distributed among regions; 90 percent is located in Latin America and Sub-Saharan Africa, whereas pressure on land is greatest in Asia. Furthermore, FAO's estimate of suitable land includes all land with the potential to generate yields as low as 20 percent of those on the best land already in production, suggesting that the economic returns to bring additional land into crop production would typically be low. Bringing additional land into crop production may also involve significant environmental costs, such as lost wildlife habitat and biodiversity and increased soil erosion and downstream flooding.

2.1 Cereal Crops

Concerning the above discussion it is needed to have more study about the cereals (rice, wheat and maize) which will be discussed as follows.

2.1.1 Rice

Rice is consumed by more than half of the global population as the staple food. It is cultivated on 155.5 million ha with an average growth rate of 0.39% per year during the last three decades. 27% of dietary energy supply and 20% of dietary protein are taken from rice by humans globally. The production experienced a doubling at global scale from 316 M tones in 1970 to 592.8 M tones in 2001 with an average growth rate of 2.29 percent (Table 2.4). Unluckily, with the start of new century in 2000, the global growth rate has declined and global consumption has been more than the production (Figure 2.1).

Table 2.4: Population and rice production, harvested area, and yield during 1970-2001

	1970	2001	Growth rate (%) per year
Population	3.69 billion	6.13 billion	1.66
Rice produced	316.3 M tonnes	592.8 M tonnes	2.29
Rice harvested area	133 Million ha	155.5 Million ha	0.39
Rice yield	2,377 kg/ ha	3,912 kg/ ha	1.90

Source: Nguyen and Ferrero (2006).

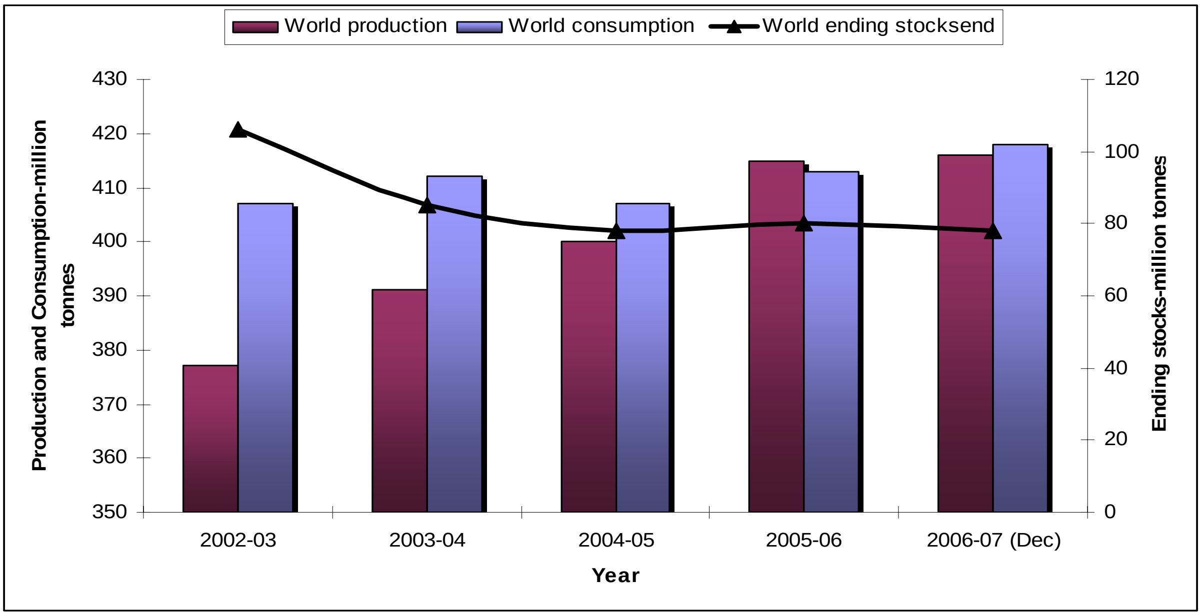


Figure 2.1: World Rice Production, Consumption and Ending Stocks from 2002-03 to 2006-07 (Dec).
Source: USDA (2007)

The global milled rice production and consumption for the years 2002-03 to 2006-07 (dec.) is shown in figure 2.1. The production kept well paced with growing consumption from 1993 till 2000-01, followed by a remarkable gap between production and consumption till 2004. The world closing stocks and stocks to use ratio has declined during the past six years to fill the gap between production and consumption.

Asia accounts for 90 % of the global rice production. China, India, Indonesia, Bangladesh and Vietnam are the five largest rice producing countries in Asia, along with Thailand, Philippines, Burma, Japan, Republic of Korea and Pakistan as significant producers of rice based on the last recent three years statistics (USDA, 2006).

2.1.2 Wheat

Global wheat production has been growing at a rate of 0.5% per year and consumption at a stable rate of 1.5% per year during the last two decades (1984-2003).The production fell in the bracket of 495 million tons to 610 million tons during the past two decades where as global import ranged from 77.2 million tons to 109.6 million tons during 1984-2003. The global production, consumption and ending stocks are shown in figure 2.2. The world consumption of wheat was well above the production in 2002-03 and 2003-04 followed by a gradual increase in 2004-05 and 2005-06. The fluctuating ending stocks responds to the difference in production and consumption reaching to its lowest level of 121 million metric tons in 2006-07. In terms of production and consumption difference, 2002-03 showed the largest and 2005-06 a least difference in recent years (USDA, 2007) as shown in figure 2.2.

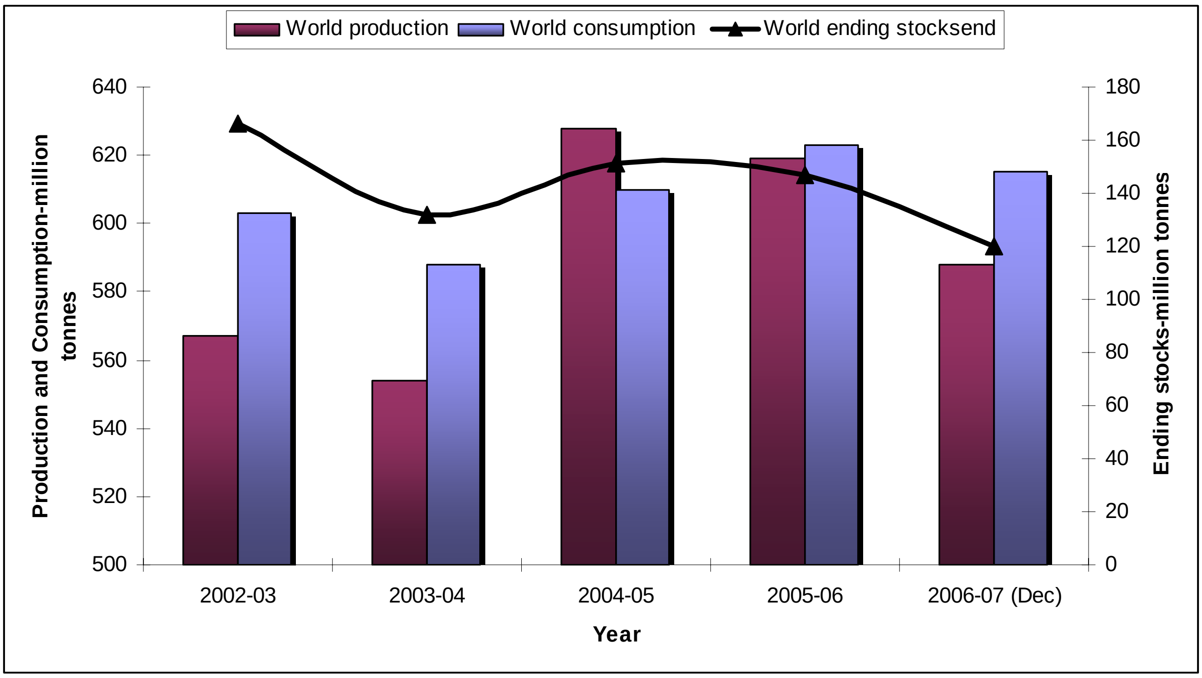


Figure 2.2: World Wheat Production, Consumption and Ending Stocks from 2002-03 to 2006-07 (Dec). Source: USDA (2007)

Major wheat producing countries include EU-25, China, India, United States, Russia, Canada, Pakistan, Turkey, Argentina, Kazakhstan and Ukraine. Most of the quantities produced is used up to meet the local demands in many countries like China, India, Russia, Pakistan, Turkey, Kazakhstan and Ukraine. The major exporters of wheat are United States, Australia, Canada, EU-25 and Argentina. Some non-traditional exporters of wheat, such as Russia, Ukraine, Kazakhstan, India and Pakistan have also come into the world stage as considerable exporters. Major wheat importing countries include Brazil, Egypt, Japan, Algeria, Indonesia, South Korea, Mexico, Morocco, China, Iraq and Iran.

2.1.3 Maize

Among all the three major cereals, maize is grown in greater quantities than rice and wheat. In 2005-06, 695 million metric tones of maize were grown worldwide. U.S. produces almost half of the total global quantities. A large quantity of corn is fed to the livestock. 37% of the world grain and 66% of U.S grain is used to feed the livestock. (Horrigan et al., 2002). Major maize producing countries include U.S.A., China, Brazil, France, Indonesia, India and South Africa. Maize is cultivated on 140 million ha on a global scale. In developing world, 96 million ha is dedicated for the production of maize. It is anticipated that the demand for maize will be more than the demand of wheat and rice by 2020. The global demand of 558 million metric tones in 1995 is projected to be 837 million metric tones in 2020, an increase 0f 50% (CIMMYT, 2000). Figure 2.3 shows a steadily increasing trend of maize consumption during the five recent years. The difference between consumption and production is slight compare to rice and wheat. The ending stocks in 2006-07 touched as low level as 86 million metric tons reflecting a rise in demand in the most recent year. It is note worthy that the ending stocks remained at or above 125 million metric tons in 2004-05 and 2005-06, when the production was almost the same as 2006-07 (USDA, 2007).

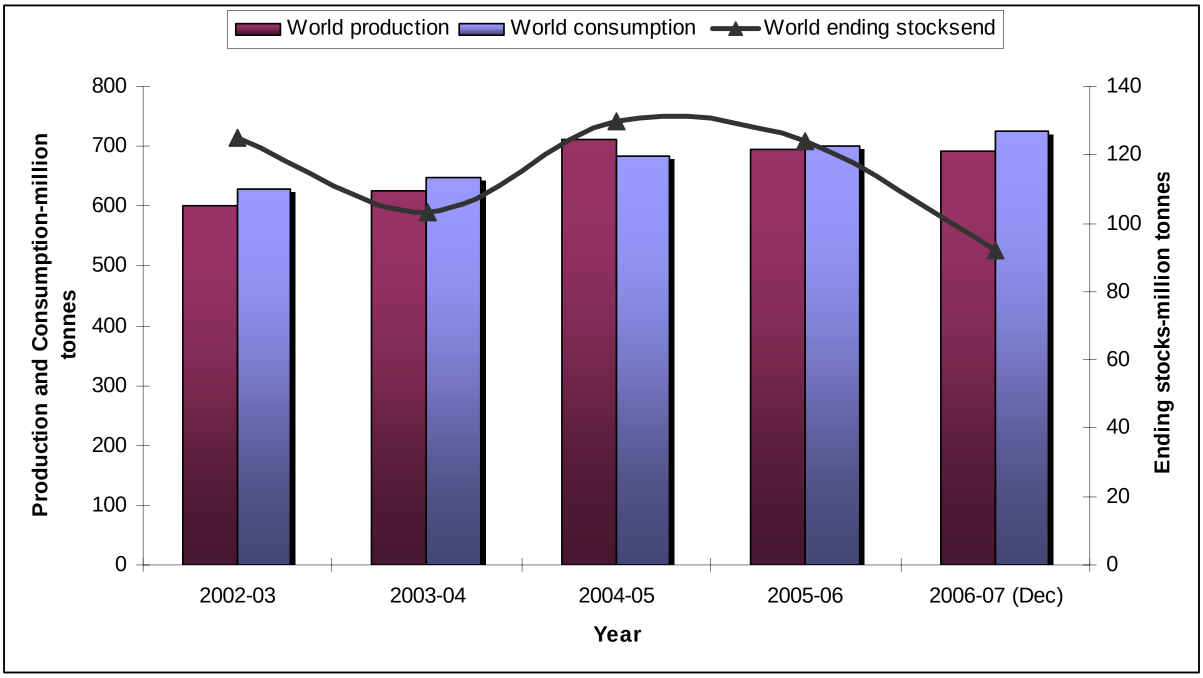


Figure 2.3: World Maize Production, Consumption and Ending Stocks from 2002-03 to 2006-07 (Dec).
Source: USDA (2007)

2.2 Regional trend of cereal crops

A better picture is seen when regional per capita cereal production is analyzed.

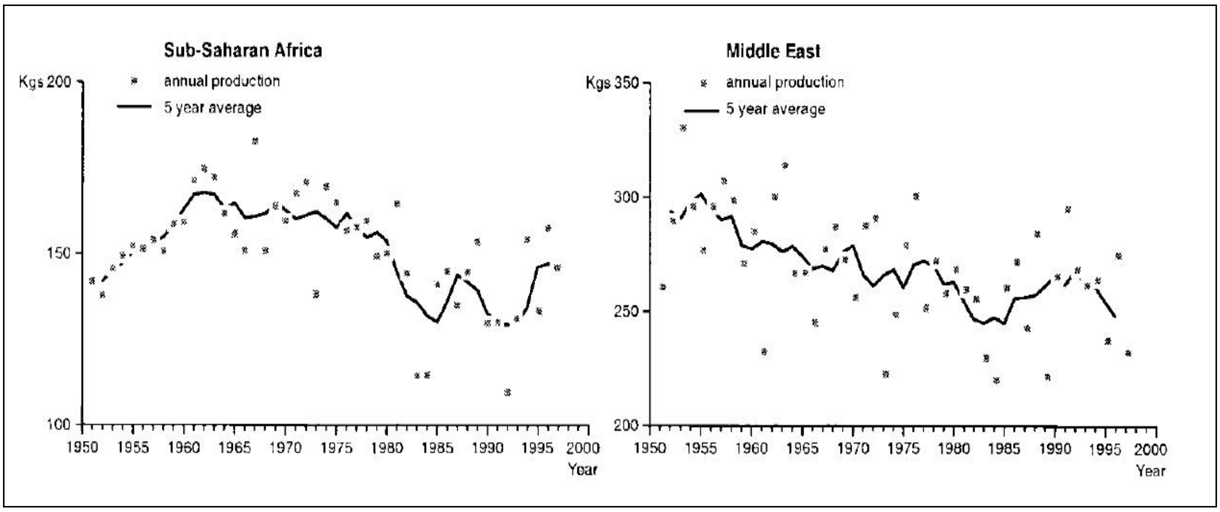


Figure 2.4: Per-capita cereal production in Sub-Saharan Africa and Middle East. Source: Dyson (1999).

The sub-Saharan Africa has the least global per capita cereal production trend as shown in figure 2.4. The region suffers from political instability, poverty and lack of government interest to improve agriculture. Despite of AIDS epidemic, the population growth is extremely high compared to other regions. The speciality of crops specific to the region and farming methods did not allow the region to take benefit of high yielding varieties of wheat and rice or the green revolution. The droughts of 1983, 1984 and 1992 are evident in the figure. The region shows great volatility in yearly harvest.

The Middle East joining North Africa and West Asia shows a decline from the early 1950s till late 1990s.The yearly harvest variability is also alarming in this water scarce region. The region has record of large imports from North America. Around 1990, this region imported one third of the regional consumption from other countries.

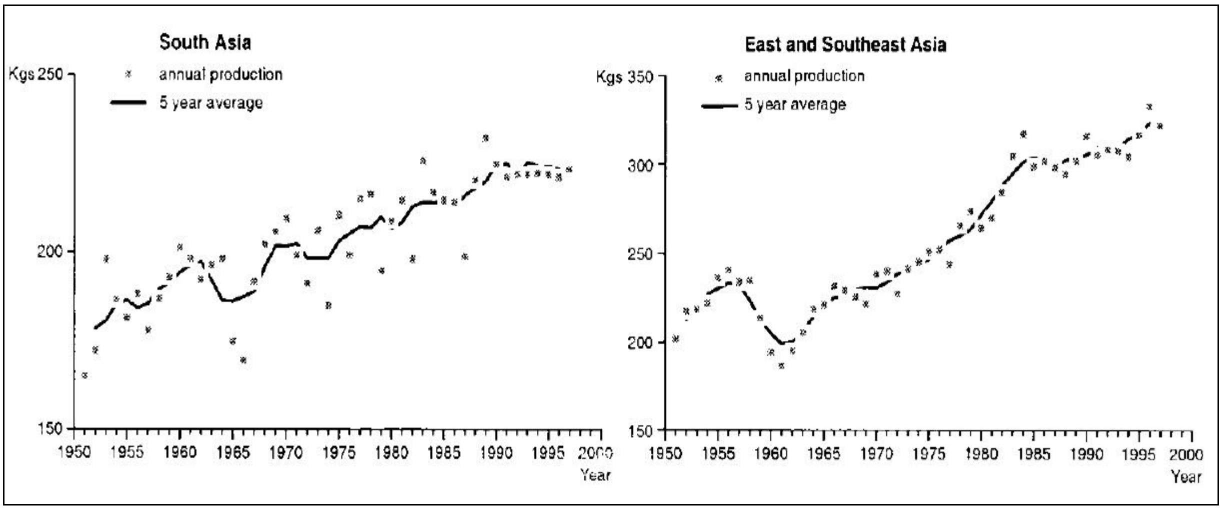


Figure 2.5: Per-capita cereal production in South Asia, East and Southeast Asia. Source: Dyson (1999).

South Asian region is dominated by the heavily populated countries of India, Pakistan and Bangladesh. The famine of mid 1960s and early 1970s is clear in the curve which took many lives. The region has almost a linear growth of per capita production since then. There is remarkable decrease in yearly harvest variability. The per capita cereal production has reached to 225kg in mid 1990s.

China is the dominant country in East and Southeast Asia along with the populous countries of Indonesia and Japan. The Mao´s "leap" is evident around 1959-1964 in China, when around 20-30 million people died in famine. The region has an upward growth since then. The 1978 agricultural reforms in China further accelerated the speed of growth. In mid 1990s, the per capita production was 316 kg, remarkably higher than South Asia as shown in figure 2.5.

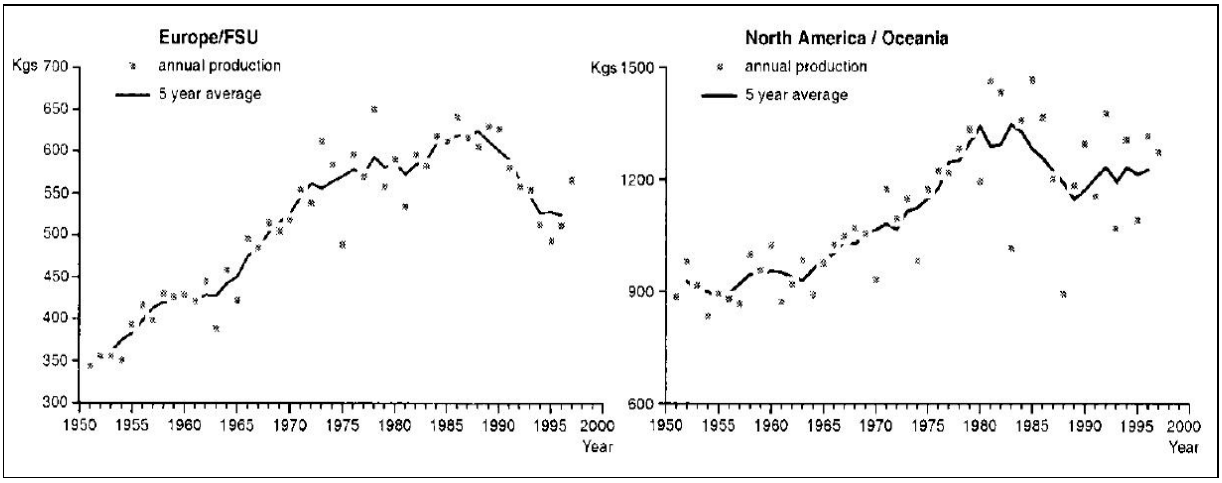


Figure 2.6: Per-capita cereal production /Oceania, 1951–1997. Source: Dyson (1999).

Europe/FSU and North America/Oceania consists of Australia, Canada, U.S.A. and Europe with Former Soviet Union. These two regions are the main reasons behind the declining global per capita cereal production since 1984.The per capita output in mid 1990s was 530 kg in Europe/FSU and more than 1.2

tons in North America and Oceania as shown in figure 2.6. USA, Australia and Canada make 6% of the global population where as account for the 20% of the global cereal production.

There are two main reasons behind the remarkable decrease in per capita cereal production in the last two regions. The countries of EU were net importers of cereals after the Second World War until 1970s. The three traditional exporters, U.S.A., Canada and Australia, fulfilled the need of European countries and as well as other countries. After the Common Agricultural Policy of EU, it became a significant net exporter of cereal competing the traditional exporters. In response from the traditional exporters, the global cereal prices came significantly down, at nearly 60% of their 1980 level. The political and economic disruption of Former Soviet Union and Eastern Europe is another major cause of declining production in Europe/FSU. In 1990, FSU had a cereal harvest of 227 million tons where as in 1995; the FSU countries produced only 105 million tons.

Latin America, the region not shown in the above figures, has a similar trend like North America. The relatively low per capita production was 260 kg in mid-1990s.The production declined from a peak in early 1980s to a trough around 1990, followed by a recovery in 1990s.The similar trends reflects the affects of international market conditions.

3. ISSUES AND CHALLENGES

The main issues and challenges to the sustainability of crop production such as land availability, land degradation, crop yields / productivity, population growth, water scarcity and food supply are discussed in this chapter. Besides these main challenges and issues against the crop production sustainability, other issues and challenges like energy demand, climate alteration (green house gas, ozone depletion) will be continued and the political instability, socio-economical constraints will be remained around the world.

3.1 Land Availability

More than 99 per cent of the world's food supply comes from the land, while less than 1 per cent is from oceans and other aquatic habitats (Pimentel et al. 1994). The continued production of an adequate food supply is directly dependent on ample fertile land, fresh water, energy, plus the maintenance of biodiversity. As the human population grows, the requirements for these resources also grow. Even if these resources are never depleted, on a per capita basis they will decline significantly because they must be divided among more people.

At present, fertile cropland is being lost at an alarming rate. For instance, nearly one-third of the world's cropland (1.5 billion hectares) has been abandoned during the past 40 years because erosion has made it unproductive (Pimentel et al. 1995). Solving erosion losses is a long-term problem: it takes 500 years to form 25 mm of soil under agricultural conditions.

Most replacement of eroded agricultural land is now coming from marginal and forest land. The pressure for agricultural land accounts for 60 to 80 percent of the world's deforestation. Despite such land replacement strategies, world cropland per capita has been declining and is now only 0.27 ha per capita. Other factors such as political unrest, economic insecurity, and unequal food distribution patterns also contribute to food shortages (Pimentel et al. 1996).

Less than one half of the world's land area is suitable for agriculture, including grazing; total arable (crop) land, in use and potential, is estimated to comprise about 3000 million ha (Lal, 1990). However, nearly all of the world's productive land, flat and with water is already exploited. Most of the unexploited land is too steep, too wet, too dry, or too cold for agriculture (Buringh, 1989).

There are difficulties in finding new land that could be exploited for agricultural production. Expansion of cropland would have to come at the expense of forest and rangeland, much of which is essential in its present uses. In the 1970s, there was a net annual gain in world cropland of nearly 0.7%. The rate of gain has slowed and, in 1990, the net annual gain was about 0.35% yr, largely as a result of deforestation. As much as 70-80% of ongoing deforestation, both tropical and temperate, is associated with the spread of agriculture.

For these reasons it can be estimated that the world's arable land could be expanded at most by 500 million ha, or a net expansion of roughly one-third. However the productivity of this new land would be much below present levels in land now being cropped (Pimentel et al. 1994).

Considering the global cereal production compared with global harvested area for cereals, it is seen that cereals production has been increasing gradually but the total harvested area is more likely to the same or constant in 2005 as in 1961 (shown as figure 3.1). Almost all the expansion of production is from yields.

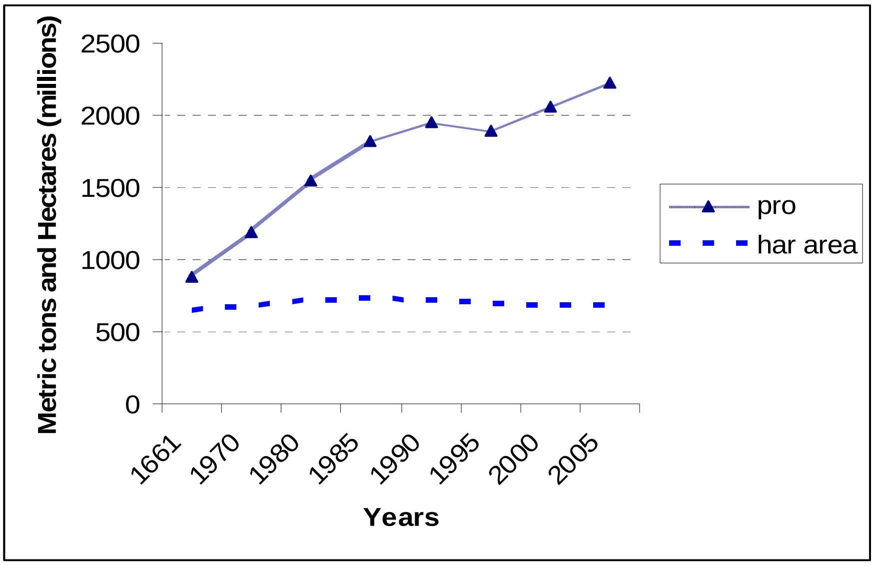


Figure 3.1: World Cereal Production and Harvested Area, Source: FAO (2006).

3.2 Land Degradation

Land degradation is a change in one or more of land's properties that results in a decline in land quality defined by Wiebe (2003). Land degradation defined as any chemical, physical, or biological change in the soil's condition that lowers its agricultural productivity contributes to the economic value of yields per unit of land area, holding other agricultural inputs the same (Lindert, 2000).

Furthermore, UNCCD defines land degradation as a "reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation." And according to the UNCCD, over 250 million people are directly affected by land degradation. In addition, some one billion people in over one hundred countries are at risk. These people include many of the world's poorest, most marginalized, and who tend to lack strong political leverage (WMO, 2006).

The impact of land degradation on global food security and the quality of the environment has major significance and concern when it has been considered that only about 11% of the global land surface can be considered as prime land, and this must feed the 6 billion people today and the 7.9 billion expected in the year 2025. Long-term food productivity is threatened by soil degradation, which is now severe enough to reduce yields on approximately 16% of the agricultural land, especially cropland in Africa, Central America and pastures in Africa. Sub-Saharan Africa has the highest rate of land degradation, where the livelihood of the inhabitants of the dry land areas is constantly under threat. It is estimated that losses in productivity of cropping land in sub-Saharan Africa are in the order of 0.5–1% annually, suggesting productivity loss of at least 20% over the last 40 years (WMO, 2006).

Each year about 15 million hectares (1 hectare is about 2.5 acres) of new land are required to support the expanding population. However, more than 10 million hectares of arable land are severely degraded and deserted each year due to water and wind erosion, salinization, and water logging. Since topsoil formation proceeds at a slow rate of about 2.5 cm every 500 years, arable soil is being degraded at a rate that far exceeds our environment's replacement capacity. The 15 million hectares of new land required each year to sustain growing population are thus being taken largely from the world's forests (Preiser, 1994).

3.2.1 Impact of Land Degradation on Productivity

Land units may differ in their resistance to erosion and in their resilience to human- induced and climatic changes. Moreover, the impact of degradation on functional properties of land and its productive capacity may differ between land units and or soils.

This loss can affect productivity and biodiversity and is thus defined as a permanent loss of the original functions. One of the major processes that cause land degradation is soil degradation that can consist of loss of topsoil caused by wind /water erosion (Mantel, 1997). Human-induced soil degradation by water erosion is one of the most destructive and certainly most extensive phenomena worldwide, and is fast becoming recognized as a key issue in affecting global food security (Barrow, 1991).

3.3 Crop Yields / Productivity

Between 1961 and 2000, average world crop yields grew rapidly (figure 3.2), much more quickly than they had in the preceding millennia that humans have been growing domesticated crops. The rapid growth was a result of the Green Revolution, a concerted international effort to exploit advances that had been made in crop breeding, fertilizers and herbicides.

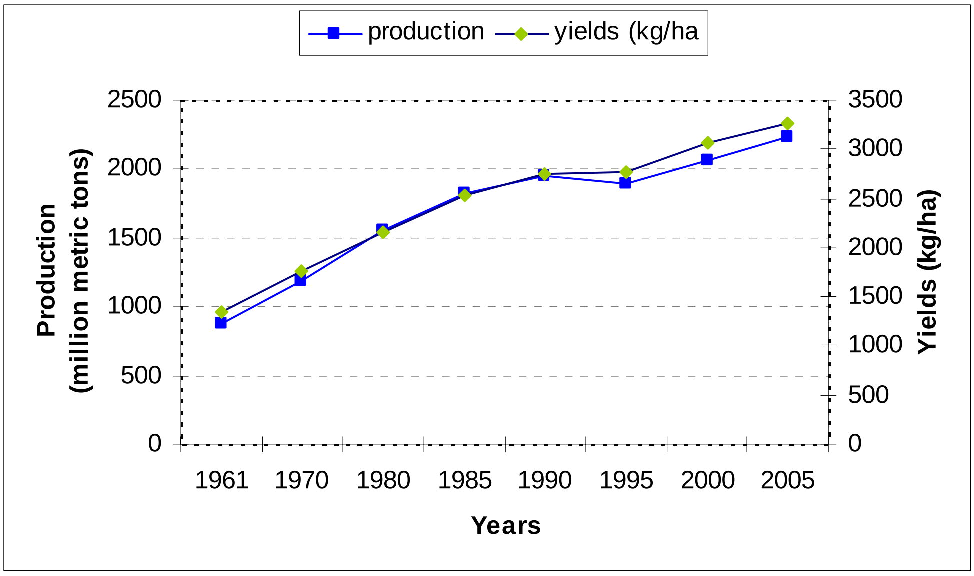


Figure 3.2: Trends of Global Cereals Production and Yields. Source: FAO (2006).

This crop yields could be depressed by the possible consequences of climatic changes and the increase of ground-level ultraviolet radiation, coupled with the high UN population growth projection, leading to nearly 13 billion people in 2050.

A better scenario could be possible in accordance with assumption that the rapid population growth stabilization with a 2050 population of 7.8 billion, significant expansion of energy-intensive agriculture and improved soil and water conservation with some reclamation of now-abandoned land. By this way, the developed countries provide the developing nations with increased financial resources and technology and a more equitable distribution of food can be achieved.

3.4 Population Growth

The world population increased steadily over the past centuries, for example the world population of 1 billion in the year 1800 took a time of more than one and a quarter century to double in 1930. The accelerated increase was observed from the year 1900 onwards, when the population reached to 6 billion in 1999 from 2 billion in 1930 (USCB 2006), due to significant decrease in mortality rates. During the past years, however, the growth is declining and the United Nations has reset the 1995 projections of 7.2 billion people in 2010 to 6.8 billion people. The world population growth has declined from 2.1 percent per year in the latter half of the 1960s to 1.3 percent in the late 1990s. Projections towards 2050 suggests that the growth will further decline in coming decades, approaching 0.7 percent by 2030 and even 0.3 by 2050 (UCS,2005).The recent projections of U.N for the future decades indicate, a remarkable slow down in the global population growth. According to the U.N the world population will increase to 7.2 billion in 2015, 8.3 billion in 2030 and 9.3 billion in 2050 (FAO, 2003).

It is very important to note that the global population growth will take place chiefly in the developing world, consisting of the poor regions of Africa, Asia, and Latin America. On the contrary, the developed world-Australia, Europe and North America- will experience either a negligible increase or even zero or negative growth. The world still stands at the steep part of the population curve. There was a large growth in population during the past few decades, about three quarters of a billion per decade. The past trend is likely to continue for more one or two decades. The curve is likely to taper off and finally approach zero some time during the present century (IFPRI, 2002).

The population growth trends and future prospects are not same for the various regions of the world. It is therefore, reasonable to investigate the regional trends of demography to understand the alarming differences in regional trends which in turn affects the demand for food, and food trade within the various regions.

Asia is the largest region of the world, with a population of 3.7 billion people in 2000 and an expected population increase of 1 billion by 2025.The huge population of Asia is therefore a major likely driving factor for the international production, consumption and trade of international food. Comparing Asia, Africa is a smaller region, with a population of about three quarters of a billion in 2000. Africa experienced a doubling in population in the last quarter of 20th century. By the year 2025, about half of the present population is expected to add up, instead of very serious effects of AIDS epidemic in population growth. Latin America has a record of moderate growth in the past and the same trend is expected in the future (IFPRI, 2002).

There was very little growth in Europe during the past decades. Europe is expected to experience a modest decline till 2025. There is a fairly rapid growth rate in North America and the same trend is expected in near future.

In the developed world, some areas like Europe will see a decline in growth, where as some areas, such as North America and Australia will experience an increase. The overall growth in the developed world, however, will remain around zero.

It is therefore evident that Asia, Africa and Latin America are the regions where major population growth and hence food demand will take place. North America is a major exporter of cereals there fore the modest increase in population growth coupled with huge food productions poses no threat to meet the future food demands.

3.5 Water Scarcity

Agricultural activities require tremendous quantities of fresh water. More than two thirds of the global fresh water withdrawn is used for irrigation (FAO, 1993). A human needs a little more than 1 litre of drinking water every day where as it takes 1600 litre of water to produce the food to feed a human each day (Pimentel et al. 2004). The future of crop production for human survival is linked with availability of adequate fresh water to meet the global demands of food. In order to understand the supply and demand of water on global scale for agriculture, a broader insight into the water is needed.

Solar energy drives the hydrological cycle, evaporating water from the oceans and giving it back in the form of precipitation to the land. The global precipitation is estimated to be 110, 000 km^3. Around 70, 000 km^3 of this precipitation is lost in evaporation before reaching the sea. The remaining 40, 000 km^3 is potentially available for human consumption. Interestingly, the global consumption is just 10% or 4, 000 km^3 of the yearly renewable fresh water supply (FAO, 1993).

Although the figures above portrays a satisfactory picture of global fresh water demand and supply, but the reality is complicated and needs a further insight. Firstly, the precipitation is very unevenly distributed around the world. Secondly, two thirds of 40, 000 km^3 of the available water runs off as floods, leaving 14, 000 km3 as a comparatively steady supply. A major part of this supply follows the natural course to recharge wet lands, deltas, lakes and rivers. For example, 6000 km^3 of water is utilized to dilute the 450 km^3 of waste water now polluting the World Rivers annually. In absence of investment in waste water treatment, a further quantity of water will be needed to dilute the waste water in coming years (FAO, 1993).

Keeping in view the current global consumption of 4000 km^3 or 3700 km^3 ,according to Rosegrant and Ringler (1999), the reliable estimated fresh water runoff of 14, 000 km^3 or 9000-14000 km^3, according to Rosegrant and Ringler (1999), will be sufficient enough to meet the world demand, provided the water is distributed equally around the globe. Unfortunately, the water is highly unevenly distributed around the globe. Furthermore, the availability of per capita fresh water is decreasing as a result of increasing population and constant annual fresh water supply. Per capita availability of fresh water has decreased from 9600 m^3 to 5100 m^3 in Asia, and from 20,000 m^3 to 9400 m^3 in Africa between 1950 and 1980 (Ayibotele, 1992).

Water use increased significantly over the past few decades. Between 1950 and 1990, water consumption rose by more than 100% in North and Latin America, 300% in Africa, and 500% in Europe (Clarke, 1993). The water withdrawals can be seen as a reflection of socio-economic conditions of various regions. For example, in 1995, the yearly per capita domestic withdrawals were as high as 240 m^3 in USA and as low as 11 m^3 in Sub Saharan Africa. According to Gleick (1996), the minimum per capita requirement to meet the most basic human needs is 20 m^3, which is almost double the per capita withdrawals by Sub Saharan Africa in 1995.The developing world countries, such as China, India and other South Asian countries are at or just above the basic need of 20 m^3 level. Besides the basic needs of domestic and sanitary uses, it is estimated that from 400 m^3 to 1000-2000 m^3 water per capita per year is needed for food production. However, the actual minimum levels are often larger in urban areas.

There have been three factors behind the increase of water demand :(1) population growth;(2) changing standards of living; and (3) expansion of irrigated agriculture. The world population of 1,600 million in 1900 grew to 6,000 million in 2000, where as the irrigated land increased from 50 million hectares to 267 million hectares in 2000. As a result of these factors the water withdrawals have increased to seven fold from 1900 to 2000 (Gleick, 2000).

3.7 Climatic Changes

The continuing emission of a number of gases into the atmosphere caused by human activities, including chlorofluorocarbons (CFCs), methane, and most important carbon dioxide, is now thought likely to alter the global climate in the years ahead, a consequence arising from the greenhouse effect. Worldwide changes in rainfall distribution are expected as well as possible increases in climatic variability. In many circumstances, increased variability in temperature and rainfall can be damaging to agricultural productivity. CO_2-induced effects on productivity and growth of plants, including crops and weeds, and collateral effects on plant pathogens and insect pests could be expected. There may be decline or loss of ecosystems that are unable to accommodate a rapid climate change. The major impact will be caused by changes in rainfall and water availability to crops (Pimentel, 1994).

The overall effect of global warming on world crop production is likely to be small, because decreased yields in some region is likely to offset by an increase in other. However, tropical regions are at risk. The inverse relationship of temperature and evapotranspiration put these regions at risk for droughts, even though climate changes in these regions are thought to be less. Such regions may also face more difficulties in shifting planting dates, as they are limited more by rain fall than the temperature (Reilly, 1995). Although many studies are undertaken for global warming impact on agriculture since 1980s, there is no consensus on the impacts of three major variables on agriculture: the magnitude of regional changes in temperature and precipitations, the magnitude of the beneficial effects of higher CO_2 on crop yields and the ability of farmers to adapt to climate change (Wolfe, 1996).

4. RELIABILITY OF AVAILABLE DATA AND FUTURE PROJECTION

Every country in the world somehow depended on each other through export-import and various socio-economical activities. Through these multi dimensional activities they are also influenced by each other to make their intergovernmental, regional and even the foreign policies. In these circumstances, data reliability plays a significant role to undertake these polices. The data or information regarding the different issues gathered by the foreign governments' often outmoded systems and its release may be delayed out of economic self-interest. Therefore, the available information is often inadequate and at best untimely (MacDonald and Hall, 1980).

Estimating any future projection could be scarce, because accurate data are limited to a very few locations where long-term experiments have been conducted (Wiebe, 2003). Concerning these it is needful either to have reliable information or apparent analyses of the gathered information on fluctuating global and regional crop production.

Reliable data and analysis, these issues have been of concern for decades, but the constraints of data and methodology have limited analysis of the interactions between resources and food security. Because, leaving latitude for widely varying claims and widely differing beliefs about the urgency of policy response (Wiebe, 2003). Estimated or projected data can be incorporated in simulations of agricultural production and trade to evaluate their impacts on food security at national, regional, and global scales.

Based on projected changes in population, land degradation, water scarcity, crops productivity, urbanization and other issues, many international, regional and national organizations project the future global demand or sustainability of cereal crop.

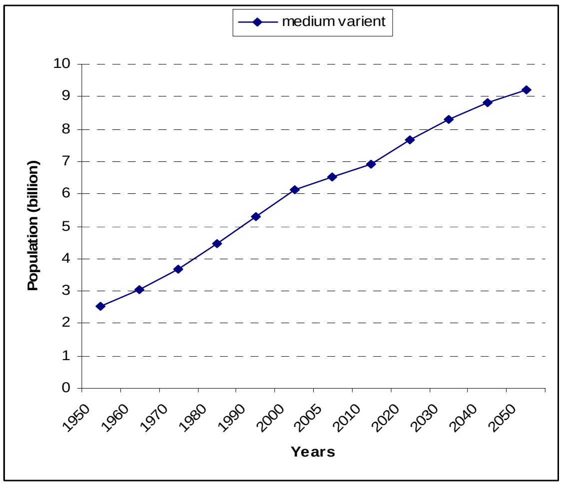
In this chapter, the reliability of this projection or how it can affect or influence the global crop production sustainability will be analyzed than the problems of providing energy, capital, and other needs to support increasing numbers of people.

4.1 Projection of Population

World population is projected to continue increasing well into the next century. If it is then the fact is whether and how global food production may be increased to provide for the coming population expansion. For meeting up the future food demand it would be necessary to increase current levels of food production more than proportional to population growth. But there are a number of constraints that make expansion of food production difficult. This difficulty is closely linked between projection of population growth and the potentially available arable land, rates of land degradation, crop productivity and the limitations of water and biological resources. In this chapter, the reliability of this projection or how it can affect or influence the global crop production sustainability will be analyzed than the problems of providing energy, capital, and other needs to support increasing numbers of people (Kindall and Pimentel, 1994).

The world population increased from 2.5 billion in 1950 to 6 billion by 2000, a more than doubling that occurred over 50 years. The UN latest projections imply that population growth will continue into the

21st century, although more slowly. The world population is projected to grow from 6 billion in 2000 to 9 billion by 2050, an increase of 50 percent that will require 50 years (figure 4.1).



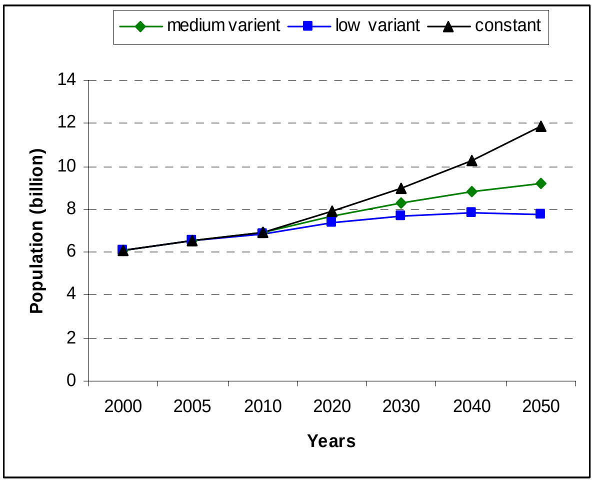


Figure 4.1 and 4.2: World population projection, Source: UNPD (2007).

These projections made concerning the assumption of future trends in fertility, mortality, and migration as shown figure 4.2. Since the future trends cannot be known with certainty, a number of projection variants are produced underlying the derivation of demographic indicators for the period starting in 2005 and ending in 2050.

Concerning the above projection scenario it is essential to consider the future sustainability of crop production. As the crop production directly depended on the land availability and water supply or irrigation, in the future, the real population trail of regions will almost deviate to some extent from those now projected because current forecasts rely on inaccurate assumptions. Deviations could in a few instances exceed 10 percent by 2025, but for the whole world as a whole the error is likely to be smaller. In all major developing country regions, the fertility is still well above the replacement level. Although declines are now under way, replacement fertility is not expected to be reached. Even if fertility drops eventually below two births per woman in some regions, the average fertility for the entire period 1990 to 2025 is likely to make a positive contribution to population growth. Besides, the existence of population momentum, which is the tendency of developing country population to continue growing for decades even if replacement fertility could be achieved immediately. In sum, for all practical purposes, it is wise to assume that the population expansion over the next few decades will not be very different from the medium variant of the United Nations projections or from quite similar World Bank projections (Islam, 1995).

4.2 Productivity

The trends have been made regarding the crops productivity in past decade as shown in the chapter 3. Moreover, these trends of yield and production depend on variables factors most of which are uncertain. It is concerning matter that the crop production and yield are being increased during the several decades. Though the production and yield are being increased for decades, the overall growth rates have been decreased compared with previous years and it is shown the decline trend (Figure 4.3). From 1961 till 1990 it had declining trend but after 1990 to 1995 the trend increased dramatically due to different factors such as favourable climate or modern technologies. But after this period this trend goes onward like down-up-down way. This could be happened due to different uncertainties like less productivity, degradation of land, technological changes, environmental impacts and other regional problems.

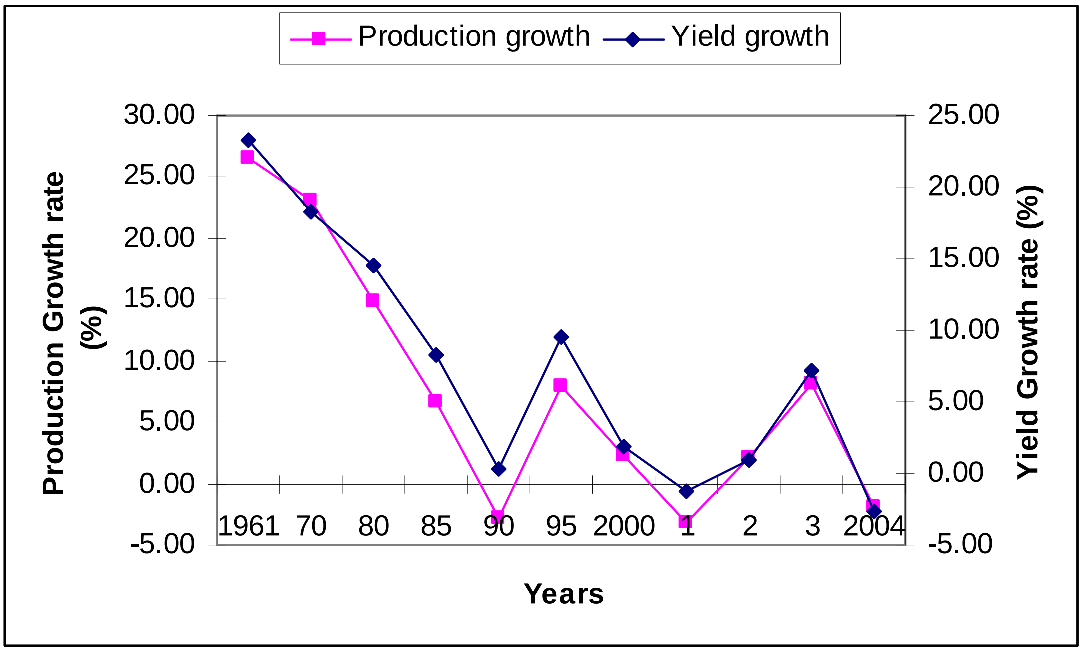


Figure 4.3: Trends of Global Cereals Growth Rate (%) 1961 to 2005.

There is considerable uncertainty about the future of global crop yields. The large range of plausible outcomes leads to a similarly large range of outcomes for future changes in crop area. The debates between technological optimists and pessimists rages today, and are likely to continue to rage in coming decades, because the implications of the different positions will not become clear for some time. In the face of uncertainty, scenario exercises are a useful way to look at the range of possibilities. According to Kemp-Benedict (2003), "The two Technological Optimist variants lead to either a shrinkage of global cropland by 260 million ha between 2000 and 2050 or a growth 215 million ha – a 475 million ha difference, or nearly one-third of total cropland area in 2000". It is alarming to note that even within the optimistic school of thought, large variations in the projection exist. Therefore, it is essential to be careful about the prospects for agricultural productivity, the availability of cropland, or for the environmental resources (Kemp-Benedict, 2003).

The yield losses may accelerate, remain constant, or decelerate as soil erodes, depending on soil type and other factors. Evidence suggests that accelerating losses are characteristic of many temperate soils, while decelerating losses are characteristic of many tropical soils. Recognizing that yield losses cannot accelerate or remain constant indefinitely, and lacking sufficient data to estimate precise functional forms for each crop, soil, and region, a constant percentage change in yields is assumed, corresponding to the case where absolute yield losses decelerate as soil erodes. While this would certainly be an oversimplification over the long term, it should not introduce unreasonable bias for incremental losses of soil and yields over the shorter term (Wiebe, 2003).

Projections for twenty or thirty years ahead can be invariably wrong. This is partly because of questionable assumptions, limited models, and poor information, but also because a dynamic world economy is self-adjusting since it does not tolerate disequilibrium easily (McCalla, 1994).

4.3 Water Scarcity

Water is critical for all crops which require and transpire massive amounts of water during the growing season. For example, a hectare of corn will transpire more than 5 million litres of water during one growing season. This means that more than 8 million litres of water per hectare must reach the crop. In total, agricultural production consumes more fresh water than any other human activity. Specifically, about 87 percent of the world's fresh water is consumed or used up by agriculture and, thus, is not recoverable (Pimentel et al., 1996).

Competition for water resources among individuals, regions, and countries and associated human activities is already occurring with the current world population. About 40 percent of the world's people live in regions that directly compete for shared water resources. Worldwide, water shortages are reflected in the per capita decline in irrigation used for food production in all regions of the world during the past twenty years. Water resources, critical for irrigation, are under great stress as populous cities, states, and countries require and withdraw more water from rivers, lakes, and aquifers every year. A major threat to maintaining future water supplies is the continuing over-draft of surface and ground water resources (Robertson and Swinton, 2005).

It is difficult to make future prediction with high level of confidence about the availability of water for agricultural purposes. Rosegrant, Ringler, and Gerpacio (1997) project that global water withdrawals will raise by 35%, from 3745 billion cubic metres in 1995 to 5060 by 2020, when future growth in income, industrialization and irrigation development is taken into consideration. Therefore, this projection implies about one half of the accessible run off from precipitation. The competition for water from industrialization and urbanization will be significantly higher than agriculture in developing countries by the year 2020 (Rosegrant and Ringler, 1999).

The future projections of water demand for all the uses are uncertain. Interestingly, many projections made in the past quarter century proved to be overestimated during past years. It is evident that the earlier projections, assuming the historical trends of growth to continue, greatly over estimated the future needs. The recent projections for 2025, 2050 and 2075, still take into account exponential growth .On the contrary, the global withdrawals for 1995 were only about half of what was expected 30 years ago (Gleick, 2000).

4.4 Land Availability/ Degradation

Regarding the projection or assumption of future land degradation or availability or impact, it is needed to be careful because of some variations among the researcher. As for example, The two Technological Optimist variants lead to either a shrinkage of global cropland by 260 million ha between 2000 and 2050 or a growth 215 million ha – a 475 million ha difference, or nearly one-third of total cropland area in 2000" (Kemp-Benedict, 2003).

According to Rosegrant and Ringler (1997) land degradation at existing rate is not a serious threat to global food security. In the contrary, Lal and Pierce (cited Kindall and Pimental, 1994) stated that land degradation has become a major threat to the sustainability of world food supply.

According to Rosegrant and Ringler (1997) crop production impacts of land degradation are rare. In the contrary, soil erosion is a serious cause of degradation of arable land owing to its adverse effect on crop productivity as cited by Kindall and Pimental (1994).

But it is considerable to find the basis of this projection or assumption as it greatly influences the global, regional or national policy making on future food demand. For achieving the reliable data regarding land degradation, to survey the status of, and summarize the information on, trends in land degradation at the national and regional levels and to review and assess the extent to which weather and climate data and information are currently used at the national and regional levels in order to adequately monitor and assess land degradation and to develop sustainable land management practices to combat land degradation (Arusha, 2006).

5. ANALYSIS AND DISCUSSION

Present status of the crop production on the basis of their production, yield and area harvested for past decades is analyzed to find out the reason of changing production during decades. Efforts are also done to analyze the future perspective of crop production for meeting up the future food demands.

5.1 Perception and representation of crop production

The area of crop land per person is the reason of resulted the world per capita cereal production that is harvested of cereals and the level of the average cereal yield. Compared with 2005 from early 1961s, the total global area harvested of cereals rose from 659 to 214 million hectares as illustrated in Table 5.1. The per capita area harvested of cereals has declined steadily from about 0.197 to 0.103 hectares per person because of the world population that according to the statistics of UNPD (2007) has become doubled. On the other hand, the world cereal yields rose from about 1.44 to 3.1 metric ton per hectare during the same period as pointed in Table 5.1.

The modern increase in yield has more than offset the decline in per capita area harvested, thus producing general rise in world per capita cereal production. In fact, about 86% of the increase in the size of the global cereal harvest since the early 1960s has been due to increases in total harvested cereal area. Furthermore, since the early 1980s the change in yield has been entirely responsible for rises in the global harvest. This is because the total area of crop land harvested of cereals has declined quite sharply as discussed in Table 5.1.

Table 5.1: Summery measures of average annual world cereal production, selected periods

	1961-65	1971-75	1981-85	1990-95	2001-2005
Production (000 mt)	951,907	1,320,305	1,711,862	1,923,951	2,146,846
Per capita production (kg)	284	323	352	336	329
Total area harvested (000 ha)	659,754	695,239	716,344	698,109	674,579
Per capita area harvested (hectare)	0.197	0.171	0.145	0.121	0.103
Yield (mt per hectare)	1.44	1.94	2.308	2.737	3.106
Percent of production increase between periods due to:					
Area change	14	10	-21	-29	
Yield change	86	90	121	129	
	100	100	100	100	

Source: WRI (2006) and idea from Dyson (1996)

The allocation of cereal production as shown in Table 5.1 increases between area and yield changes are approximate. To illustrate the method used, between 1961-65 and 1971-75 average annual world production increased by 368,397 thousand tons, and the area harvested of cereals increased 35,485 thousand hectares. Assuming that cereals yields stayed constant at their 1961-65 level (i.e. 1.44 metric tons per hectare) the proportion of total production increase due to area change was about 14%, i.e. [(1.44×35485)/ 368397] ×100, leaving about 86% due to increased yields.

Analysis has been carried out by using world cereal production, land used for harvesting, crop yield and the population for decades. The world food situation has improved dramatically during the past thirty years and the prospects are very good that the twenty-year period from 1990 to 2010 will see further gains. However, these gains depend on continued increases in food production along the trends of the past. This will not occur automatically; rather it will require continued investments in research to increase crop yields and in other factors of production. If past crop yield trends continue and if population growth rates slow as projected, then the gains in the world food situation seen during the past thirty years should continue.

The scenario suggests that the world is unlikely to see food production keep pace with population growth if things continue as they have. If it is continuing as such then the world will experience a declining per capita food production in the decades ahead. This decline would include spreading malnutrition and increased pressure on agricultural, range, and forest resources.

Concerning above discussion it can be assumed that the crop productivity could be the way out for meeting up the future food demand regarding the crop production sustainability. Reason behind this, the population growth can not be controlled totally or can not be stopped, the land degradation will be continued, water scarcity will be remained, and the total land for crop can not be increased except using the forest land. If it is, then it is essential to give more concentration on crop productivity.

5.2 Future of Crop Production Sustainability

Regarding the crop productivity several questions can be arisen. Such as how much productivity can be increased for certain crops, the present productivity ratio of crops, if it is possible to increase the productivity to a certain extent then how possible, what type of technology can be applied, in such case the applied technology how much environmentally sound and if not how it could be minimized concerning the socio-economical aspects. Projected increases in the global human population together with an improved diet indicate that the current crop production will need to increase substantially over the next few decades. The estimation of future global crop production show that most of the required increases in production will come about by greater intensification (producing more of the desired products per unit area of land already used for agriculture) with substantial extensification (altering natural ecosystems to generate products) only in limited areas for example harvested area for cereal production remained constant for several decades as depicted in Figure 3.1.

Past increases in agricultural production have occurred as a result of both extensification and intensification. Where other economic activities allow, purchasing food from elsewhere can enhance food supply locally. Globally, no one means will be adopted and different regions will increase production in different ways. About 3 billion ha of the world's land is suitable for arable agriculture and 1.2 to 1.5

billion ha of the most productive land is already cultivated. Most of the potentially available land is presently under tropical forests. Cultivation of more of this land is undesirable with respect to biodiversity conservation, greenhouse gas emissions and regional climate and hydrological changes, and would incur high costs to provide the necessary infrastructure. In general, then, further extensification of agriculture will likely provide only a small fraction of the increased production needed (Maarten et al., 2002).

Typically new areas of crop land will only contribute 7.4% (51 Mha) to cereal production on a global basis by 2020. Contributions to crop production are estimated to range from 47% in sub-Saharan Africa to 18% in South Asia.Intensification will thus be the dominant means for increasing production. This will be achieved largely by increased yields per area rather than increased number of crops grown in a seasonal cycle. For instance, average cereal yield has already increased from 1.35 t/ha in 1961 to 3.26 t/ha in 2005 and is projected to be about 4.1 t/ha in 2025. Simultaneously per capita arable land area has declined from 0.24 ha in 1951 to 0.13 ha in 1993. The FAO estimates that 5 to 7 million ha are being lost each year to land degradation (Maarten et al., 2002).

There is also considerable uncertainty about the future of global crop yields as discussed in chapter 4. Moreover, the climatic alteration, land degradation, fresh water availability could be the uncertainties for future crop productivity. Besides, the intergovernmental policies, socio-economic infrastructure, political concerns might further enhance these uncertainties.

The practices of high-input agriculture are causing concerns about the sustainability of crop production. There are many negative effects on the environment, including pollution by pesticides, emission of greenhouse gases, soil degradation, air pollution by dust, and loss of landraces and other biodiversity as discussed in the following chapter. People need to develop new techniques that will keep agriculture both profitable for the farmer and make it sustainable for the future.

5.3 Environmental Impacts

Growing populations and increasing affluence demand ever-increased output from agricultural systems. Concerns are now being raised about the sustainability of this ever intensifying productivity. The environmental consequences of the increased production may occur either on- or off-site or both, and will vary regionally depending on whether intensification or extensification is the main pathway for achieving the increases.

The World Commission on Environment and Development defined sustainable development as “development which meets the needs of the present without compromising the ability of future generations to meet their own needs.” To understand sustainability, it is necessary to look at the rate of losing productive soils as a result of present agricultural practices. The FAO of the United Nations has estimated that salinization, soil erosion, and desertification have degraded a quarter of the world’s arable land. Second, there may not be enough energy resources to maintain high-input agriculture. Third, the increasing use of pesticides is arousing concern that people are polluting ecosystems with synthetic chemicals. Fourth, the trend toward genetically uniform crops increases the potential for serious disasters by eliminating the many different strains of a given crop that farmers previously used. Fifth, government policies perpetuate conventional agriculture and discourage farming practices that could make agriculture more sustainable (Maarten et al., 2002).

6. CONCLUSION AND RECOMMENDATION

Agriculture is a global system, and for its sustainable solutions is acute almost everywhere to pressing environmental and production challenges. These solutions might be crop- and region-specific, although the principles on which individual solutions are based will be widespread.

The world is facing many challenges to feed the growing population around the globe. In 2040, the world population of 10 billion people would require, at least, a triple food production as a result of population growth and dietary changes. The green revolution between 1940s and 1960s contributed much production with modern varieties of rice, wheat and maize, in combination with the more intensive use of fertilizers and pesticides. However, keeping in view the population growth, limited growth in yields and degradation of arable land and other agricultural resources, the future production capacity is in question.

Attempts to markedly expand global food production would require massive programs to conserve land, increase of crop productivity, and much larger energy inputs than at present and new sources as well as more efficient use of fresh water. The rates of food grain growth required to increase the per capita food available in the light of present projections of population growth.

A productive and sustainable agricultural system depends on maintaining the integrity of biodiversity. The policies for the future are necessary to be based on the conservation and careful management of land, water, energy, and biological resources needed for food production. The conservation of these resources will require coordinated efforts and incentives from individuals and among the countries. These resources cannot be replaced by human technology if once these limited resources are exhausted. Furthermore, to support the continued productivity of agriculture, efficient and environmentally sound agricultural technologies need to be developed and put into practice.

To make certain the adequate food supplies for future generations, none of the above measures will be sufficient unless the growth in the human population is simultaneously incompleted. This assumes that from now until an optimum population is achieved, strategies for the conservation of land, water, energy, and biological resources are successfully implemented for ensuring a sound and productive environment.

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