https://doi.org/10.69974/glslawjournal.v3i1.38

Future Food Demand and Food Security with Sustainable Approach

Shiv Narayan Nishad and Sandhya[1]

Abstract

The major challenges of the twenty first century have been the changing climate, sustainability and the food security with ever increasing populations. The second goal in the historic Paris agreement on Agenda for Sustainable Development is "zero hunger" since hunger and malnutrition still remain a major concern and a huge barrier to development in several developing countries like India. With the fixed primary resources for agriculture like land and water, India will have to increase the productivity to fulfill demand. Other challenges like food loss or wastage, changing rainfall patterns and hydrological cycle and potential impacts due to climate change, it is imperative to work towards sustainable growth both economically and environmentally. This paper deals with production and supply of food, increase in population, per capita consumption, nutritional requirements along with technology demand, etc. It will try to give some recommendations to improve the productivity to maintain the increasing demand with the fixed land availability and other resources in the face of changing climate through sustainable development.

Key words: *Sustainable development, food security, climate change*

INTRODUCTION

India has majorly been an agriculture economy with about 70% of the people depending on agriculture for their livelihood. Yet, even today there are people below the poverty line and people who cannot afford two meals a day. The Paris agreement on Climate Change has drafted 17 goals for sustainable development (SDG). Goal 2 of the SDG aims for zero hunger in the world for all by restricting the rise in global temperatures to 2 degree by 2030 and working towards it. Zero hunger would mean that within the gambit of impeding and imminent climate change, the agriculture has to be climate smart, with improved productivity, improved nourishment value, sustainable, minimal waste generation, etc. Smart agriculture practices would mean that the there is no wastage of water, minimum

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soil erosion, dual or multi-cropping, utilization of maximum soil moisture available, new varieties for improved productivity, dissuasion or shift from monoculture, etc.

The United Nations has defined Food Security[2] as "*access of enough food to all at all times for an active healthy life.*" Developing countries like India have the biggest and foremost challenge of providing food for all. Although there has been a rise in the food grain production in India since the green revolution, the rate at which the country's population is on the rise and the effects of climate change with the shift in employment and rapid urbanization is a cause of concern for feeding all.

The world is facing "*game-changing trends*"[3] due to the major transformation including climate change and globalization. Various studies pointed out to the threats to food security due to climate

change[4][5][6][7][8][9][10]. The various constraints on land and water have made us relook at the agricultural productivity so as to feed the millions and maintain the food security. This paper discusses the various aspects related to the food security to find if there is a way out and give suggestions for making India's agriculture sustainable for future demand of food in the face of changing climate. We have looked into the agricultural land and the land holdings that India has and the small holdings and the various facilities for irrigation. We further look into the trends in population and accordingly the demand and supply of food. The water availability and the future availability are looked at from the changing climate scenario, which has also affected the change in land use pattern. It is also important to look into the food loss and the wastage of food during various stages from production to consumption. We have taken the Agricultural Sustainability index as assessment of sustainable food availability for the future generation. Based on this we have quantified the technology demand to meet the future food demand as function of population load

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[2] FAO, The State of Food and Agriculture, Rome 1996

[3] Boratynska, K., and Huseynov R.T., An innovative approach to food security policy in developing countries, 2, JOURNAL OF INNOVATION & KNOWLEDGE, 39–44, (2017)

[4] Brown, M. E., and Chunk S., Food security under climate change, 319, SCIENCE, 580–581 (2008).

[5] Charles, H. J. et al., Food security: the challenge of feeding 9 billion people, 327(5967), SCIENCE, 812–818 (2010).

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and consumption pattern.

Population, Food Demand and Food Supply

In 1961, the population of India was about 450 million which has increased to 1293 million in 2015 (Figure 1, left top panel) and it is estimated to be 1513 million and 1658 million for the years 2030 and 2050 respectively (**FAOSTAT**)[11]. Similarly, the food demand depends on the population and per capita food consumption and this will increase with increasing population and increasing per capita consumption due to growth in income. The food demand has increased from 150 million tons to 450 million tons in the last 55 years (1960-2015) (Figure 1, right top panel) while the supply has increased from 110 million tons to 480 million tons (Figure 1, bottom left panel). The food supply will affect due to saturation in agricultural productivity and declining primary resources like land and water. Similarly, the per capita food supply has also increased from 250 kg/year to 358 kg/year from year 1961 to year 2015 (Figure 1, bottom right panel).

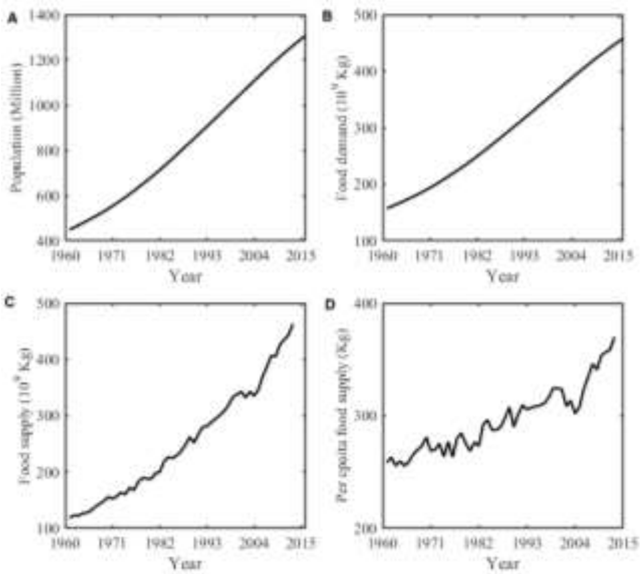

Figure 1: Population (**A**), food demand (**B**), food supply (**C**) and per capita food supply (**D**) for India for the period 1961 to 2015. The data is adopted from FAOSTAT.

The comparative analysis of per capita food supply with top 25 agricultural

[11] FAO, *The State of Food and Agriculture*, FAO, Rome (1996).

countries reveals that the per capita food supply of most of the countries is higher than India's per capita food supply (Figure 2). The per capita food consumption of the world, China, and the USA, respectively, are 480 kg/year, 684 kg/year and 483 kg/capita/year. It is interesting to note that the per capita food consumption of Turkey is the highest which is about 700 kg/year, while per capita food consumption of India is almost half of it, approximately 370 kg/capita/year (Figure 2). Analysis of per capita food consumption reveals that there is a strong relationship between per capita food consumption and per capita income; higher income implies higher food consumption- as the per capita income increases, the per capita food consumption also increases (Figure 2).

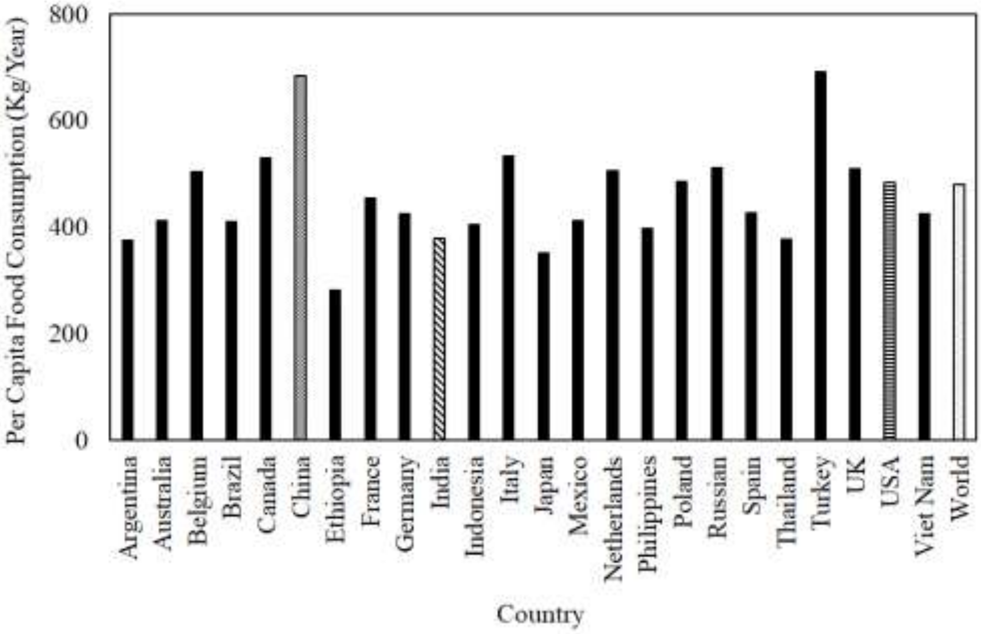

Figure 2: Current per capita food consumption of top 24 countries and the world. The observed data is adopted from FAOSTAT.

Assessment of Primary Resources

Agricultural land availability and small holdings

In India, many forest areas and fallow lands have been converted into agricultural land resulting in increase in arable land from 156 million hectares to 163 million hectares between 1961 -1985 (Figure 3, top panel). However, after 1985 there is declining trend in arable land due to land use for non-agricultural purposes and by 2016, India had been left with only 156.4 million hectares as arable land (Figure 3, top panel). Similarly, the per capita land availability has shrunk from 4000 m^2 in 1961 to 1400 m^2 in 2016 (Figure 3 bottom panel), while at the same time population has tripled from 450 million to 1293 million, putting India's food security at risk.

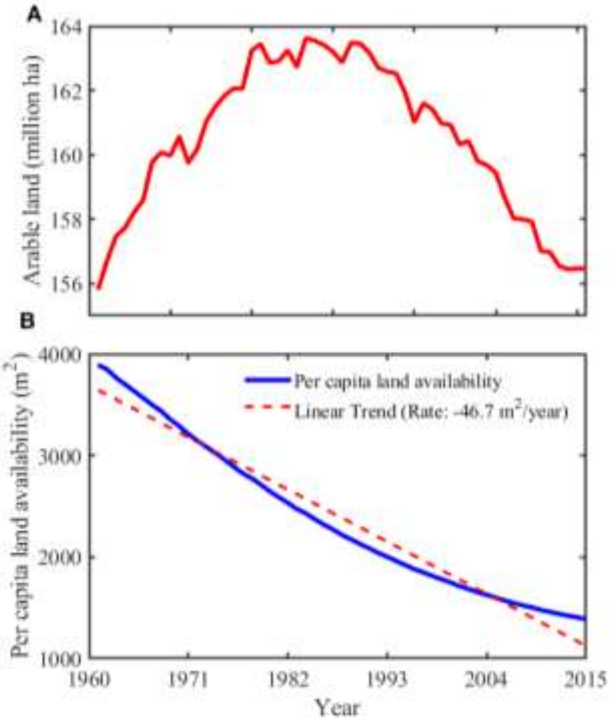

Figure 3: Arable land (**A**) and per capita land availability (blue line) with linear trend (red dash line) (**B**) of India for the year 1961 to 2016. The number in bracket represents the coefficient of linear trend for the corresponding case. The data is adopted from FAOSTAT.

About 156.2 million hectares arable land and 189.7-million-hectare crop land seems abundance of arable land available in India but it is insignificant due to division in small and scattered holdings. The problem of small holdings is more serious for a populous country like India to feed the second largest population in the world. Almost 70% of Indian population depends on agriculture sector and the small holdings play a critical role for survival of population to sustain life. The average size of holdings was 2.28 hectare in 1970-71 which reduced to 1.15 hectare in 2010-11 and 1.08 ha in 2015-16 (Figure 4, top panel). In contrast, the number of holdings increased to more than double from 71 million in 1970-71 to 146.5 million in 2015-16 (Figure 4, bottom panel).

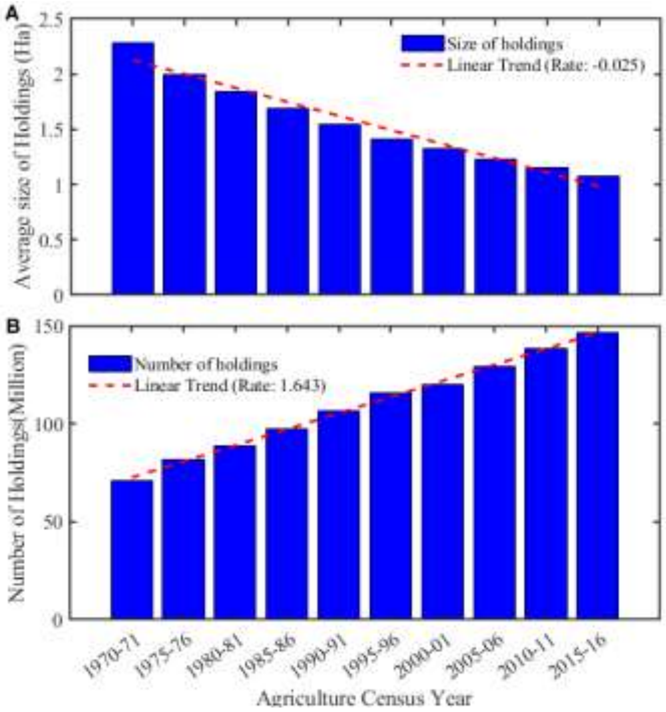

Figure 4: Average size of holdings (**A**) and number of holdings (**B**) in India in different agriculture census years. The red dash line represents the linear trend. The number in bracket represents the coefficient of linear trend for the corresponding case. The data is adopted from agriculture census 2015-16.

Land use Change and its impact

The land use change or land conversion for non-agricultural purposes refers to change in the land use for non-agricultural activities from its original use. The pressure on arable land has mounted up at an alarming rate due to land use for non-agricultural purposes. Population growth, increment in infrastructure, urbanization and industrialization are major contributors for the loss of arable land. In addition, unsustainable and unplanned exploitation of arable land make it a critical primary resource and this trend may continue in the future. For India, the land use for non-agricultural purposes has increased from 9.36 million hectares in 1950-51 to 26.9 million hectares in 2014-15 (Figure 5) which implies the high pressure on sustainability of arable land to fulfill the food demand in future and hint at a looming food security crisis. The priority of arable land must be given for the agricultural production to feed the growing population along with fulfilling their dietary needs. The conversion of arable land for non-agricultural purpose may affect the sustainable food availability in long term.

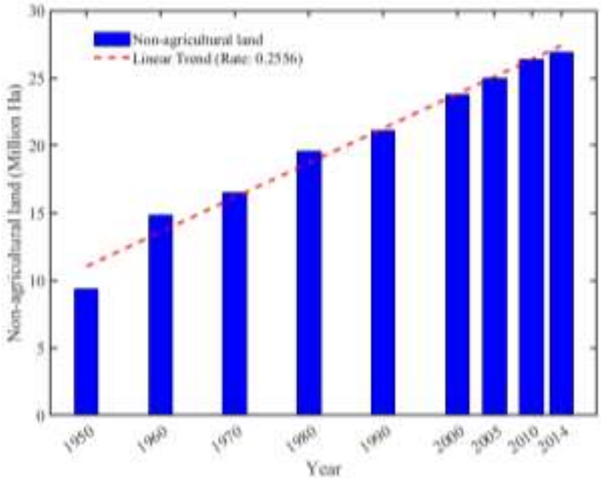

Figure 5: Land Use for Non-agricultural Purposes from 1950-51 to 2014-15. The number in bracket represents the coefficient of linear trend for the corresponding case. Data is adopted from Agricultural Statistics 2017, Department of Agricultural, Cooperation & Farmers Welfare, Govt. of India. The linear trend is represented by the red dash line.

Assessment of water availability

Increasing water demand, uneven distribution of water resources, changing rainfall pattern and potential impact of climate change have made water as a critical resource. Overexploitation, unsustainable consumption and poor management of water resources have put additional pressure on water resource. On the other hand, water demand for agriculture, domestic and industrial purposes have mounted up due to feeding and fulfilling demands of increasing population and this trend may continue. Thus, management of water resources to fulfill the current and future demand is a big concern for the populous country like India in which per capita water availability has decreased from 4200 m^3/capita/year to 1500 m^3/capita/year in the last 50 years. The current per capita water availability is lower than minimum water required for survival of a person, hinting at the water crisis in near future (Figure 6).

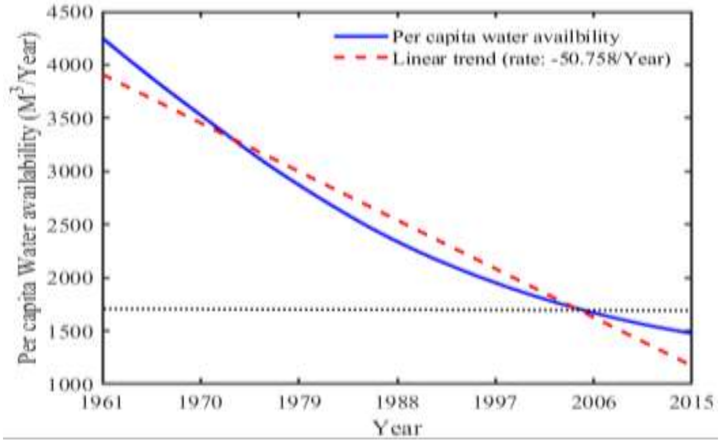

Figure 6: Per capita water availability of India from 1961 to the year 2013. The red dash line represents the linear trend. The number in bracket represents the coefficient of linear trend for the corresponding case. The horizontal dash line represents the minimum per capita water requirement (1700 m^3/year).

<u>Irrigation facility</u>

Agricultural production depends on availability of water and irrigation facilities. Though agriculture is the back bone of the livelihood of the nation, Indian agriculture is highly monsoon dependent and very few areas are equipped with irrigation facilities. With the uneven distribution of rainfall, irrigation plays an important role in agricultural production. Inadequate spread of irrigation facilities acts as barrier for improving agricultural productivity and thus agricultural production. Therefore, irrigation sector with large number of problems needs urgent attention for future course of action for improving agricultural productivity. Most of the irrigation practices/facilities are used for the crops like wheat and rice. Other crops mostly depend on monsoon rainfall.

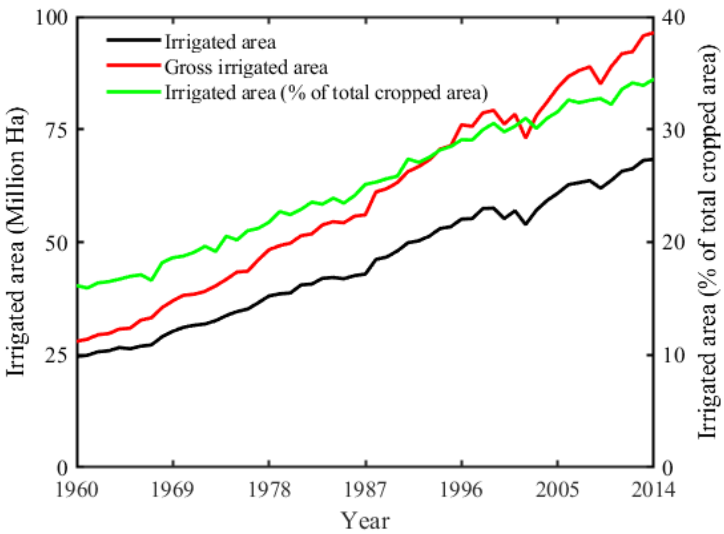

Figure 7: Net irrigated area, (black line) gross irrigated area (red line) and irrigated area as percentage of total cropped area (green line). The data is adopted from Agricultural Statistics 2017, Department of Agricultural, Cooperation & Farmers Welfare, Govt. of India.

The irrigated area of India has increased from 25 million hectare in 1960-61 to 68 million hectares in 2014-15 while the gross irrigated area has increased from 28 million hectares in 1960-61 to 96 million hectares in 2014-15. The irrigated area as percentage of cropped area has increased from 16 percent in 1960-61 to 34 percent in 2014-15 (Figure 7). Recent figures show that, only 34 percent of cropped area is equipped for irrigation and rest depends only on monsoon rainfall (Figure 7).

Food Production and agricultural productivity

Agriculture production has been improving and **Sharma (2011)**[12] has described rain-fed production improvement through water management. Although agricultural production has increased from 150 million tons to 600 million tons between 1961 to 2015, this trend may not continue in future due to world-wide evidences on reduction/saturation of agricultural productivity, declining primary resource and climate change (Figure 8, left top panel). However, the recent trends in agricultural production, rice and wheat production have increased but the trend may not continue due to non-availability of primary resources, like water and arable land, and also due to potential climate change[13][14]. The rate of rice and wheat production has slowed down in the recent years (Figure 8). Agricultural productivity of total food has increased from 0.1Kg/m^2 to 0.3kg/m^2 but this trend may not continue further. The agricultural productivity of rice has increased from 0.15 kg/m^2 to 0.35 kg/m^2 while that for wheat has increased from 0.085 kg/m^2 to 0.3 kg/m^2 in the period 1961-2015 (Figure 8). Recently, the rate of increment in agricultural productivity of

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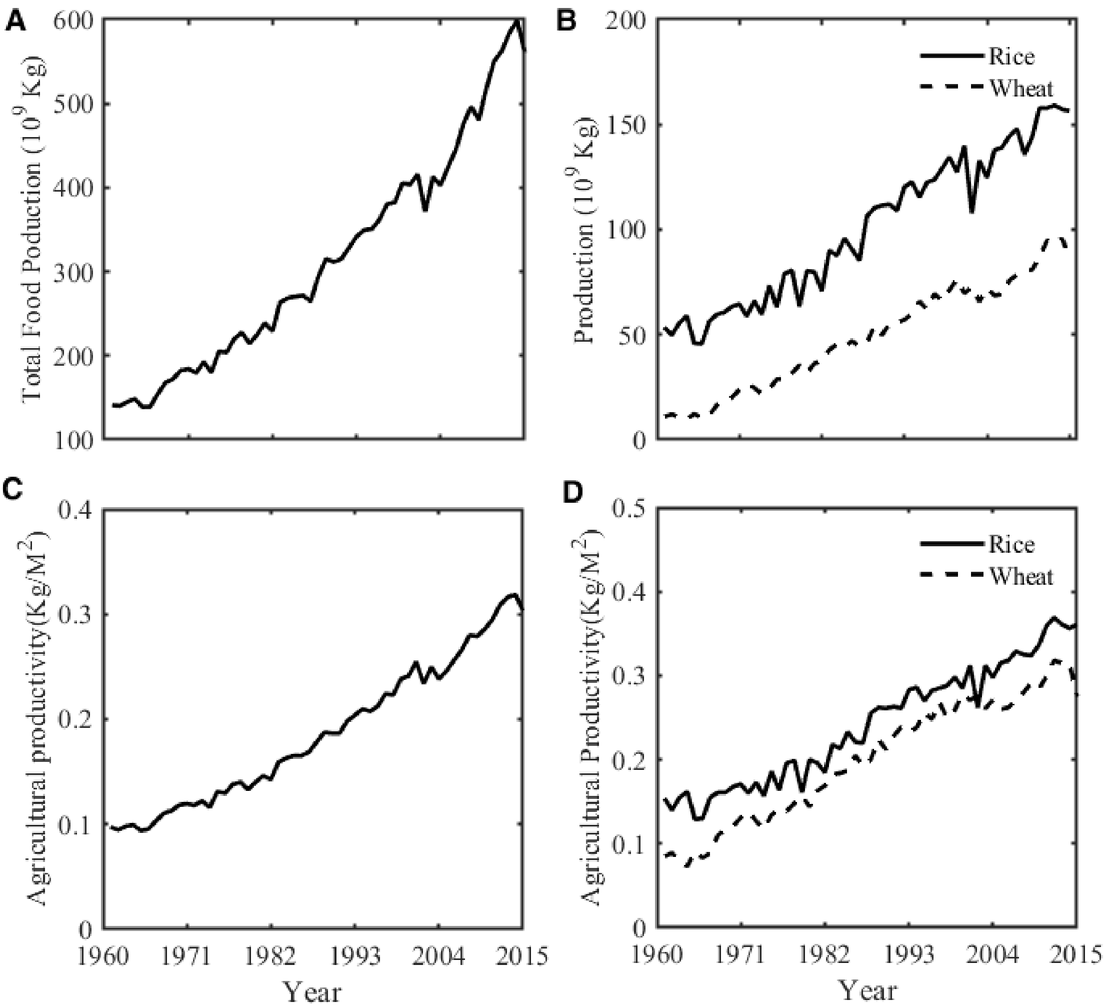
[12] Sharma, K.D., Rain-fed agriculture could meet the challenges of food security in India, 100(11), CURRENT SCIENCE, 1615-1616 (2011).

[13] Goswami, P., and Nishad S., Assessment of agricultural sustainability in changing scenarios: a case study for India, 106, CURRENT SCIENCE, 552–557 (2014).

[14] Goswami, P. and Nishad S., Dynamical formalism for assessment and projection of carrying capacity in different socio-climatic scenarios, 109(2), CURRENT SCIENCE, 280–287 (2015).

rice and wheat has slowed down and about to saturate (Figure 8).

The state-wise analysis of agricultural productivity for food grains, rice, wheat and pulses reveals a large variation. For example, the agricultural productivity of food grains is higher in the states Punjab and Haryana, moderate in Uttar Pradesh, Bihar, and West Bengal, and Andhra Pradesh. The agricultural productivity of wheat is higher in Punjab and Haryana and moderate in Uttar Pradesh, Bihar, Madhya



Pradesh, Gujarat and Haryana. Agricultural productivity of rice is higher in the states of Punjab, Andhra Pradesh in comparison to other states, while the agricultural productivity of pulses is higher in Madhya Pradesh, Jharkhand in comparison to other states. The agricultural productivity distribution (Figure 9) reveals that there is potential for increasing production in different states by developing infrastructure and facilities (Figure 9). However, I may not be necessarily inferred that increased productivity may be equivalent to increased nourishme nt. The discussion on nourishment is beyond the scope of this paper.

Figure 8: Total food production in India (**A**), rice (solid line, **B**) and wheat production (dotted line, **B**), agricultural productivity of total food (**C**) and agricultural productivity of the rice (solid line, **D**) and wheat (dotted line, **D)**. The agricultural productivity is calculated as the ratio of total food production to the total harvested area. The data of total food, rice and wheat production along with respective harvested area is adopted from FAOSTAT.

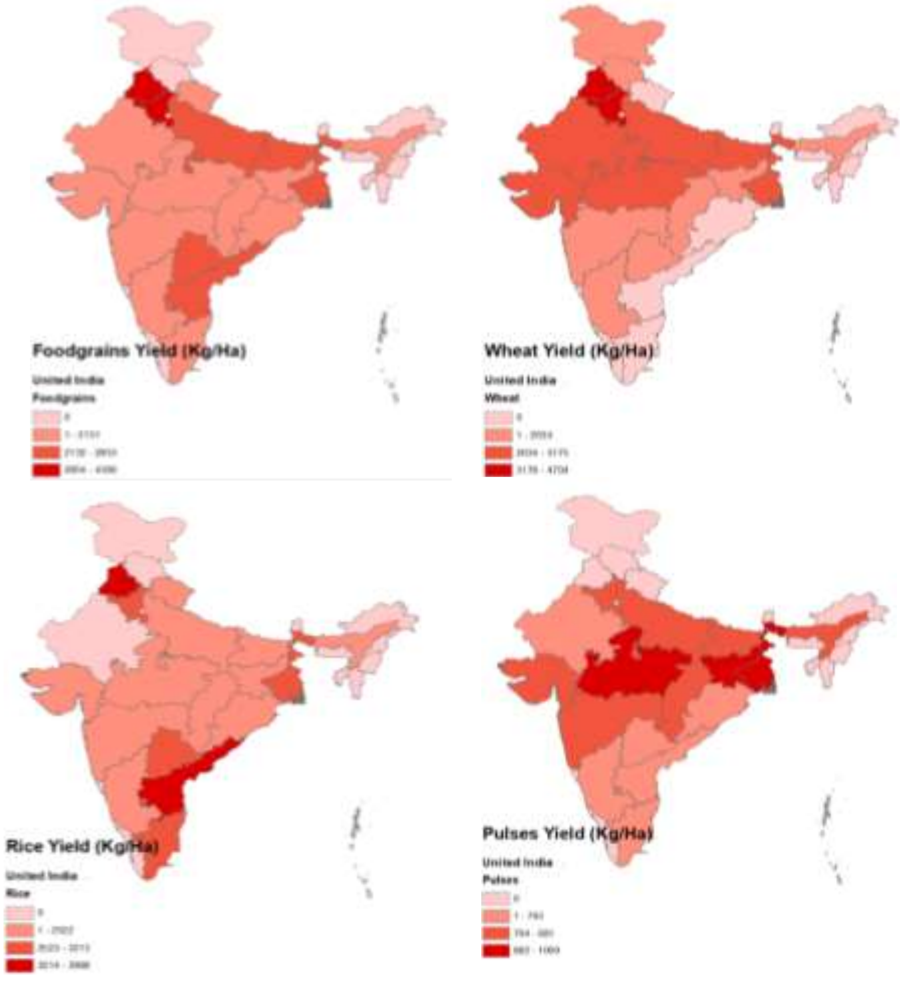


Figure 9: Regional yield of food grains, wheat, rice and pulses. The data is adopted from Agricultural Statistics 2017, Department of Agricultural, Cooperation & Farmers Welfare, Govt. of India.

Food loss/ wastage

Global food security is a burning issue, and there are many challenges to feed the growing population. Food loss and food wastage has emerged as a major challenge for maintaining food sustainability in the scenarios of increasing food demand with world-wide declining and even saturation in agricultural productivity and primary resources. It has become a huge concern due to economic, social, and environmental cost associated with it. It is estimated that about one third of all food produced equivalent to 1.6 billion tons a year ends up as waste in the world. The total food wastage in India has increased from 8 million tons to 45 million tons in the last 55 years from 1961 to 2015 (Figure 10, solid line) which is about approximately 8 percent of total food produced (Figure 10, dash line). This trend may continue due to population growth unless there is an end to food wastage (Figure 10). The food wasted is lost at the time of production, processing, distribution and consumption[15]. There is an urgent call for understanding causes of food wastage and end food wastage to maintain long term food sustainability.

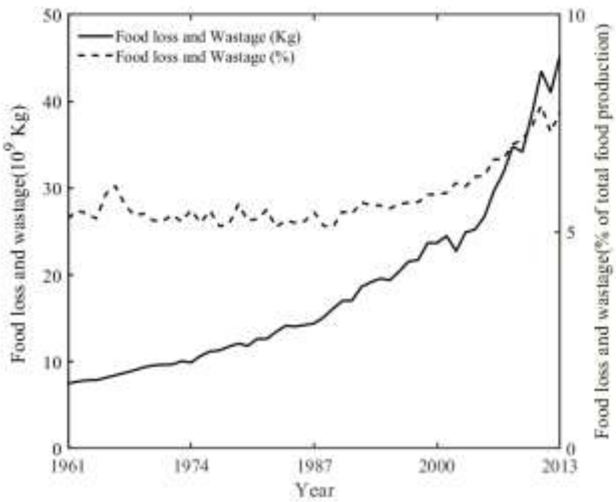


Figure 10: Food wastage (left y axis, solid line) and food wastage as percentage of total food production (right y axis, dotted line) for the year

[15] Gustavsson, J., Cederberg C., Sonesson U., Otterdijk R. V., and Meybeck A., *Global Food Losses and Global Food Waste*, FAO, Rome (2011) http://www.fao.org/3/i2697e/i2697e.pdf

1961 to 2013. The data is adopted from FAOSTAT.

Food Sustainability index

For the quantitative analysis of food sustainability, we have considered agricultural sustainability index; which is defined as ratio of total food available to the total food demand (Goswami and Nishad, 2014, 2015). Total food available depends on domestic production and external sources like import, while total food demand depends on population and per capita food consumption. The competing impacts of changes in primary resources like arable land and water, agricultural productivity and demand due to population growth and changing consumption patterns result in agricultural sustainability as a complex function. India is currently in a position of agricultural sustainability and likely to maintain this situation for long term with current per capita food consumption. Agricultural sustainability as function of population in different scenarios of per capita food consumption indicates a critical population load for India around 1500 million, for no change in per capita food consumption (350 kg/capita/year), agricultural productivity (0.3 kg/m^2), arable land (Figure 11, red line) and zero food waste (Figure 11, top panel). As expected, for a scenario of agricultural sustainability, this value of population is higher than that projected for the per capita food consumption for the countries like China, USA, Turkey and the world. As expected, the critical population load is lower in higher consumption scenarios (Figure 11). The situation is worse with inclusion of food waste and loss during production, distribution and consumption (Figure 11, bottom panel).

Technology demand

Technology demand to improve agricultural production to fulfill the food demand is considered as the demand of technology to increase agricultural productivity in different scenarios. To feed growing population, agricultural land cannot be expanded; the only option is to increase agricultural productivity through technology development. With maximum agriculture area, the agricultural productivity varies from 0.2 kg/m^2 to 1.1 kg/m^2 to feed the population from 500 million to 3000 million in different scenarios of per capita food consumption without food waste (top panel, Figure 12) and with food wastage (bottom panel, Figure 12). It is estimated that the food sustainability may be maintained for about 1400 million to 1500 million people with current agricultural productivity of 0.3 kg/m^2 and current per capita food consumption of 350 kg/capita/year. In scenarios of higher per capita food consumption, the agricultural productivity will be required to be higher than current agricultural productivity to feed current population for India. Similarly, the agricultural productivity will have to be two times of current productivity to feed double the population for current per capita food consumption (Figure 12, vertical dash line) while it will have to be tripled for higher per capita food consumption for the doubling population scenario.

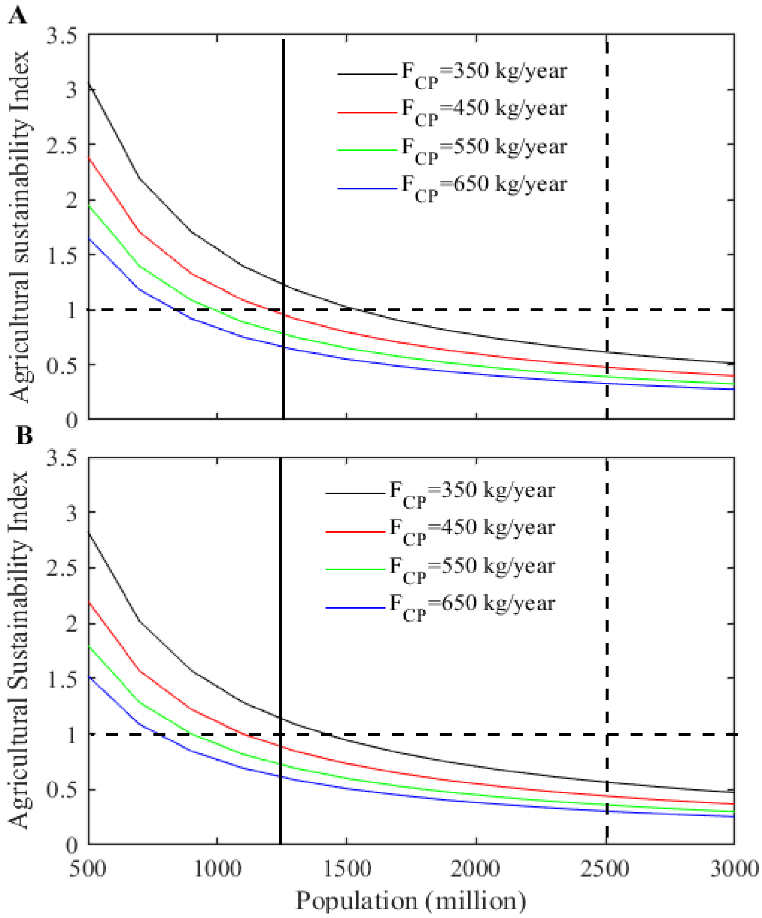


Figure 11: Agricultural sustainability index as function of population in different scenarios of per capita food consumption with zero food loss and wastage (**A**) and with food loss and wastage (~8% of total food production) (**B**) with current agricultural productivity and arable land. The horizontal dash line represents the sustainability index.

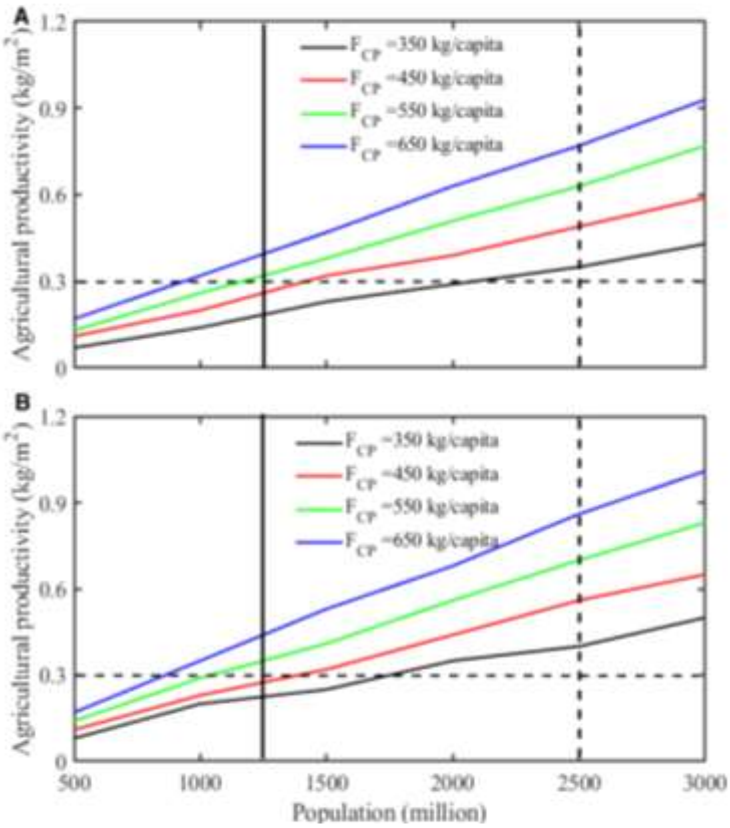


Figure 12: Technology demand (in terms of agriculture productivity) as function of population in different scenarios of per capita food consumption for India. The horizontal dash line represents current agriculture productivity. The vertical solid line and dash line, respectively, represent current population and doubling population scenarios.

Various studies have suggested the ways for improving the productivity of crops in limited water. **Passioura and Angus (2010)**[16] have talked about a framework which is used to explore a wide range of agronomic potential for managing crops so as to get close to the water-limited potential. Another way of improving the food availability as suggested by **Sastry et al (2011)**[17] is the development of an agri-nanotechnology infrastructure in India. **Fereres et al**

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[16] Passioura, J.B. and Angus J.F., Improving Productivity of Crops in Water-Limited Environments, 106, ADVANCES IN AGRONOMY, 37-75 (2010).

[17] Sastry, R.K., Rashmi H.B., and Rao N.H., Nanotechnology for enhancing food security in India, 36(3), FOOD POLICY, 391-400 (2011).

(2011)[18] have laid stress on transferring technology for the improvement in water-limited crop production.

Discussions and Conclusion

The challenges arising because of the evident and uncertain climate change, reduction in the agricultural productivity, increasing demand along with limited primary resources, food sustainability has become a tough task to maintain in the long term for a populous country like India. With the growth in population there is growth in demand for food world over. For India, the per capita food consumption is well below world average. However, the per capita food consumption in India, is expected to rise with the rise in income generation that may reduce the time scale of the loss of food sustainability.

Food security is important for modern society, our results shows that the maintaining food demand may not be sustainable with growing population, increasing food demand, declining primary resources, static productivity and changing climate. Food sustainability mainly depends on domestic food production and external sources like import. The availability of food can be sustained long term by reducing food loss and food wastage; a better management of storage capacity and distribution may increase the time scale for loss of food sustainability.

We have assumed that entire arable land could be used for agricultural production; however, there are other non-food agricultural products that will further restrict the use of arable land for food. In addition, the increasing trend of land use for non-agricultural purposes will also restrict the use of arable land for food production. Other additional constraints may be imposed by climate change that has potential to reduce the agricultural productivity and alter the hydrological cycle; however, its impact can be highly regional. Other factors that may reduce sustainability are dietary habits and consumption pattern.

The arable land and the per capita land availability in India has reduced over the years which is a great cause of concern. Along with this, an increase in the land holdings and reduction in size of holdings create additional pressure on the overall production. For maintaining the food sustainability, the priority of arable land must

[18] Fereres, E., Orgaz, F., and Gonzalez-Dugo V., Reflections on food security under water scarcity, 62, J. EXP. BOT., 4079–4086 (2011).

be given for the agricultural production. Similarly, the per capita water availability has already gone below the minimum per capita water requirement for the dietary needs for survival. Hence the role of technology becomes much more evident and necessary. Although the net irrigated area in India has been rising, there is a need for larger coverage of irrigation facilities to reduce the burden on rain-fed agriculture for improving the agriculture productivity to maintain food sustainability.

We have considered current agricultural productivity for the agricultural production (non-food items are excluded). Several studies have shown world-wide saturation and even decline in agricultural productivity. With limited arable land and its constraints, agricultural productivity is the only option for maintaining agricultural sustainability for long term. Agricultural productivity can be increased through many ways and through technological advances. Therefore, there is an urgent need of advanced technologies to improve the agricultural productivity like the development of an agri-nanotechnology infrastructure and transferring technology for the improvement in water-limited crop production. Present study quantifies the technology demand in terms of agricultural productivity for maintaining food sustainability in the long term.

It must be emphasized that the present analysis can lead to initiative policies to optimize land and water management. Food sustainability can be maintained by better management of primary resources and reducing food loss and food wastage. The likely impact of climate change can introduce further complexity into the dynamics of food, water and land and hence agricultural sustainability.

Early warning systems and development programs need to be used more efficiently[19]. **Charles et al (2010)[20]** have talked about 'sustainable intensification' for producing more food. The new artificial intelligence can be explored for potential ways for minimizing food wastage. The twentieth century focused mostly on the biotechnology as a solution for crop yield, but the artificial intelligence would have

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[19] Brown, M. E., and Chunk S., Food security under climate change, 319, SCIENCE, 580–581 (2008).

[20] Charles, H. J. et al., Food security: the challenge of feeding 9 billion people, 327(5967), SCIENCE, 812–818 (2010).

to drive way in the twenty first century which is crucial in the face of changing climate and the growing population.

Awareness among farmers and people alike on climate change and resilience is the need of the hour. Smart agriculture techniques as suggested can still keep India as a major agriculture economy and achieve the 'zero hunger' goal.