

# **Carrying Capacity of Indian Agriculture**



**NATIONAL ACADEMY OF AGRICULTURAL SCIENCES, NEW DELHI  
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## Preface

Carrying Capacity (CC), a measure of maximum rate of resource consumption and waste discharge that can be sustained indefinitely in an area under consideration without impairing the productivity and ecological integrity, is a dynamic factor which can be altered by input of water, energy, plant nutrient, crop genotypes, use of advanced technologies, total factor productivity etc. A single vital resource limits CC. Currently India is self-sufficient in foodgrains, barring pulses and oilseeds. But, nearly one-fourth of our people are food-insecure. The Global Hunger Index places India low at rank 67 amongst 84 countries. Food security of the growing population that is likely to reach 1.44 b in 2020 and 1.64 - 1.74 b by 2050 is a cause of concern with steady decline in per capita arable land and water availability. Already feed and fodder resources are deficient for maintenance ration by 36.2% and by 56% for production ration for the livestock. Emergent issues of climate change, global warming, urbanization, shift in dietary preferences, soil erosion, depleting water resources, and rising cost of commercial energies aggravate the situation.

With the above backdrop, the Academy sponsored a Brain Storming Session (BSS) on CC of Indian Agriculture under the leadership of Dr. C.R. Bhatia, Ex-Secretary, DBT, GOI and Ex-Vice President of NAAS. Over 20 leading experts in soil, water, energy, fertilizers, crop production, animal production, climate change, and rainfed agriculture had participated. It emerged that agricultural productivity cannot increase without increasing use of water, energy, plant nutrients and agro-chemicals and enhancing their use efficiency. Prevention of post-harvest losses and strengthening of value addition along the producer-consumer chain were essential for increased food availability and improved quality of life. Estimates of the population level that can be adequately fed without hunger or hidden hunger in ecologically sustainable manner should help in designing robust science-based integrated farming systems. Paradigm shift is called for developing and deploying resource conservation technologies that improve input use efficiency and conserve and protect our natural resources. Awareness about CC amongst the scientists and people at large needs to be created.

I compliment Dr. Bhatia for this contribution. Our thanks are also due to the "brain stormers" and the Editors.



**(R B Singh)**

President, NAAS



# Carrying Capacity of Indian Agriculture

## PREAMBLE

Ecologists define the Carrying Capacity (CC) of the ecosystems as the population of humans and animals that can be sustained, based on the primary productivity of plants, with the available resources and services without damaging the resource base – soil, water and environment. Others identify CC as the maximum number of individuals of a given species that can be supported on a sustainable basis. A more detailed definition is the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a defined region without progressively impairing the productivity and ecological integrity. *CC is not a static number* as land productivity can be enhanced with inputs of water, energy, plant nutrients, crop genotypes and using advanced technologies / products from these.

Carrying capacity provides the physical limits for the maximum rate of resource consumption and waste discharges. The concept further implies that improvement in the quality of life is possible only when the patterns and levels of production and consumption do not have more than the acceptable adverse ecological impact. Further, CC following the law of limiting factors, is determined by the single vital resource in least supply, such as water in the rain-fed agriculture.

Global food productivity has increased several folds with the inputs of chemical fertilizers, that provided crop nutrients, and inputs of energy derived from fossil fuels. Estimations of human CC are not easy due to large number of variables involved including variation in the consumption of food and use of resources in different societies. Maximum human population that can be sustained biophysically in an area is referred as biophysical CC, while social CC is the maximum population that can be sustained under different social systems. **However, in considering the CC of Indian agriculture, the question of sustainable food production or sustainable CC based on food production was considered.**

The issue of the carrying capacity of Indian agriculture was addressed in a Brain Storming Session in the premises of the National Academy of Agricultural Sciences, New Delhi on October 28, 2010. It was convened by Dr. C.R. Bhatia, Ex Secretary, Department of Biotechnology, Govt. of India and Ex Vice-President, NAAS. Invited participants included subject experts in soils, water, energy resources,

fertilizers, primary productivity, animal production, climate change and rain-fed crop production.

## PRESENT SCENARIO AND MAJOR ISSUES

Current escalation of food prices in the country, caused by demand – supply mismatch, leading to overall increase in inflation has once again drawn attention to food – energy - poverty – depleting natural resources - environment and population. Following the successful Green, White and Blue Revolutions by the efforts of the agricultural scientists, and the farmers, the food situation had considerably improved.

During the period 1990-91 to 1996-97 the annual growth rate of the agricultural sector was close to four percent. Growth rates during the period 1998-99 to 2006-07 were 0.62 for cereals, 0.47 for pulses, and 1.96 for oilseeds. Fruits and vegetables and animal products showed growth higher than 3% and helped in keeping the overall growth rate of the agricultural sector close to 2%.

Currently, the country is nearly self sufficient in cereals, and an exporter of rice; edible oil or oilseeds and pulses are imported. Country's ability to provide food security to its growing population, in future, is a matter of concern. Population of the country in 2009 was estimated at 1.17 billion. Even with near self sufficiency for the present population, a large section, particularly preschool children and women, suffer from protein calorie malnutrition and / or micronutrient deficiencies - the hidden hunger. The Global Hunger Index 2010 placed the country at a low rank of 67 among the 84 countries, with 42% underweight children under five years.

During the period of last census (1991-2001) population growth rate was 1.9% which is currently estimated at 1.5 – 1.6%. Annual increase is estimated at 18 million. Early estimates of the census in 2010 are expected shortly. Even with some anticipated decline in the population growth rate, country's population is estimated to exceed 1.44 billion in 2020 and range between 1.64 -1.74 billion in 2050. At the time of the Independence centenary in 2047, the population would be four times of the population since Independence. India would be the most populous country in the world, exceeding China's population. India with 2.4% of the world's surface area and about 4% of the world's fresh water supports 16.7% of the world's population. The present per capita availability of net cultivable land is less than 0.13 ha, and 1020 m<sup>3</sup> of utilizable water. In 2050, 17.2% of the world's population would be living in India with such more reduced land, water and biodiversity resources.

According to 2007 census, the country has 486 million livestock, comprising of bovines, equines, sheep, goats, camels and pigs. The present feed and fodder resources are deficient for maintenance ration by 36.2%, and for production ration by 56%.

Besides the above, environmental issues, climatic change including global warming, rapid urbanization, loss of top soil, competitive demands for fresh water and large increase in the cost of crude oil / energy are expected.

### Carrying capacity based planning

The CC based planning process involves the integration of societal expectations and ecological capabilities by minimizing the difference between the demand and supply. It uses various modeling and computation techniques to estimate changes in CC indicators. It identifies the socially acceptable tradeoffs, and use of improved technologies.

Currently, India has a growing population, with a fairly large upwardly mobile middle class segment with increasing affluence. Further, the poor aspire to reach the middle level. Aspirations of the different sections of the population and the lifestyle they wish to live cannot be ignored. Reducing the consumption of resources by changing the life styles and food habits is an option for increasing the CC that may not be socially acceptable widely. It has been suggested that a much larger world population can be supported by reducing the consumption of meat, fats and sugars.

Population has also an impact on the environment, which can be expressed by the formula of P.R. Ehrlich and J.P.Holdren (*Science* **171**:1212-1217,1971).

$$I = P \times A \times T$$

where:

I = Impact on the environment,

P = Population

A = Affluence of the population

T = Technology factor (the available technology)

It is apparent that the population and its affluence are the key determinants, while technologies that improve the resource base can reduce the negative impact of P and A. Even though the agricultural research has no direct control over P and A,



T can have both positive and negative effects. Technologies such as “no till” can reduce soil erosion or use of Neem-based pesticide or insect-resistant cultivars can reduce the environmental pesticide load.

Climate change is also going to have a bearing on the carrying capacity of Indian agriculture. It is likely to lead to more frequent temperature extremes, floods, droughts, cyclones and gradual recession of glaciers, which in turn would result in greater instability in food production. Crop as well as animal agriculture would be adversely affected; it is estimated that the reduction in crop production in India by 2100 AD could be 10-40% despite the beneficial effects of higher CO<sub>2</sub> on crop growth. Dynamics of pests and diseases will be significantly altered. Country could lose 4-5 million tons of wheat with every rise of 1°C temperature. Heat, drought, salinity and submergence stresses would increase in the rice crop. Development of varieties resistant to climate change and the concomitant incidences is an imperative.

## 2.2. Natural Resources

### 2.2.1. Land / Soil

- ◆ Land area is finite, and limited.
- ◆ Indian farmland, in general, is low in organic matter.
- ◆ High rate of land degradation continues due to current cultivation practices.
- ◆ It is estimated that 39% of the area suffers soil loss levels more than the permissible levels and 11% of the area falls in very severe category where the soil loss is more than 40 tons/ ha/year
- ◆ Loss of prime crop land for non-agricultural uses for industry, housing, transport infrastructure, education, recreation and entertainment would put burden on agriculture.
- ◆ A large part of the degraded lands are in rain-fed areas.
- ◆ Lands and water bodies are getting polluted due to excessive and improper use of agro-chemicals to an extent that the human health is affected.
- ◆ The per capita availability of land has fallen drastically from 0.91 ha. in 1951 to about 0.32 ha. in 2001, and it is projected to decline further to 0.09 ha by 2050.

### **2.2.2. Water**

- ◆ Water in the atmosphere, surface, soil and ground essentially constitutes a single interconnected resource.
- ◆ Per capita availability of water is going down rapidly. It is estimated that the demand would grow to almost 1.5 trillion m<sup>3</sup>, driven by demand for crops such as rice, wheat, and sugarcane. The current water supply is approximately 740 billion m<sup>3</sup> only.
- ◆ The cost of water would go up with increasing demand.
- ◆ Exploitation of groundwater has reached critical levels in several districts.
- ◆ Indiscriminate overexploitation is shrinking the resource base.
- ◆ There is a growing consensus that the current pattern of water resource development and management is not sustainable.
- ◆ Many river basins are likely to witness physical water scarcity by 2050.
- ◆ Water may not be a constraint if low cost energy is available for desalinization and transport of sea water.
- ◆ Conservation agriculture that includes minimum soil disturbance, retention of the crop residues and appropriate crop rotations and optimal use of natural resources has many advantages and ameliorates the resource base.
- ◆ Drip and sprinkler irrigation contributes to nearly 50% saving in the amount of water use and enhances crop yield thus enables coverage of much larger area with the available resources.

## **2.3. Inputs**

### **2.3.1. Energy**

- ◆ Indian agriculture is increasingly dependent on commercial energy.
- ◆ Agricultural production and productivity are closely linked to energy inputs in the production system.

- ◆ Increasing mechanization in agriculture, and irrigation using ground water requires electricity or diesel.
- ◆ Production of fertilizers and agro-chemicals are energy-intensive.
- ◆ Current per capita consumption of electricity is 704 kWh in India, against 2,328 in China, 11,216 in Australia and 13,616 in USA and 16,995 in Canada.
- ◆ Currently there is deficit of over 9% between demand and supply of electricity in the country.
- ◆ Quality of electric supply is also poor.

### 2.3.2. Seed

- ◆ Good quality seed of the identified improved varieties / hybrids is in short supply for most crops, as shown below:

#### Certified Seed Availability in the Year 2007-08

(000 t)

Crop	Demand	Supply
Rice	2,142	1,329
Wheat	3,275	538
Sorghum	138	77
Maize	178	53
Chickpea	528	56
Groundnut	1,262	53

- ◆ Only in pearl millet, pigeonpea and rapeseed/mustard availability of certified seed exceeded the demand.
- ◆ Seed replacement rates are very low. In the year 2006-07 it was 25% in rice, 18% in wheat, 19% in sorghum, 36% in maize, 10-16% in pulses and 7% in groundnut.

### 2.3.3 Fertilizer

- ◆ The carrying capacity of Indian soils is very low. Without fertilizers yield levels are 1 – 2 t/ha in cereals and 0.5 t/ha in pulses and oilseeds.
- ◆ Based on nutrient uptake data cereals, other than pearl-millet, require 50-60 kg N + P<sub>2</sub>O<sub>5</sub> + K<sub>2</sub>O per ton of grain produced and for increasing carrying capacity of soil, most of it has to come from fertilizers.

- ◆ Low amount of organic matter in Indian soils and deficiency of micronutrients often limit the fertilizer response.
- ◆ Despite all the advancements made in Indian agriculture the production and productivity of land in cereals has declined over recent years.
- ◆ N use efficiency in crops is low (30 – 50%) and possibilities of substantially enhancing N use efficiency or increasing the biological nitrogen fixation in near future are not very promising.
- ◆ There is urgent need for higher use of balanced fertilizers, growth regulators and pesticides.
- ◆ There is need of timeliness in field operations through appropriate mechanization and assessing placement of fertilizer at proper depth.

## 2.4. Field Crops

### 2.4.1. *Wheat*

- ◆ Of the average buffer foodgrain stock of about 50 Mt in 2009-10, wheat comprised about 46 % and most (about 80%) of it was drawn from Punjab and Haryana.
- ◆ The projected demand of wheat by 2020 circa 109 Mt. and to meet it wheat production must increase by 2.5 Mt per year from the base level of 2005.

### 2.4.2. *Rice*

- ◆ Largest area (about 45 million ha) under rice cultivation in a country in the world.
- ◆ The annual growth rate of rice production has reduced from 3.25 during 1980-90 to 1.54% during 1990-2000.
- ◆ Rice cultivation as currently practised contributes to green house gases – methane and nitrous oxide.

### 2.4.3. *Pulses*

- ◆ From 1990-91 to present, area under pulses is around 22-23 million ha. and production around 14-15 Mt, although in recent years some increase has been recorded.

- ◆ Imports have increased from 1.27 to 2.35 Mt.
- ◆ Availability of pulses has declined from 41.6 g/person/day in 1991 to 35.5 g/person/day in 2007.
- ◆ Present productivity growth rate is 0.69% per annum. Productivity growth rate required is 1.98% per annum.
- ◆ Large increase in market price.
- ◆ National Institute of Nutrition, Hyderabad recommends 14.6 kg/person/year. Based on this, the demand for pulses by 2020 would be 26.49 Mt/yr.

#### **2.4.5. Oilseeds**

- ◆ The per capita consumption of vegetable oils has increased from around 3 kg/year in 1950 to 14.2 kg/year during 2009-10.
- ◆ During 2009-10, the import bill of vegetable oils crossed Rs. 26000 crores while export earnings from oilseeds were little more than Rs. 16000 crores.
- ◆ The vegetable oil consumption is both income and price-elastic.
- ◆ Intake of 29 g per person per day is adequate which translates into annual vegetable oils (including butter fat) requirement of 10.585 kg. Assuming butter/*ghee* consumption of 0.585 g/person/year, 10 kg vegetable oil head/year is adequate to meet nutritional needs of fats.
- ◆ Country needs to produce about 55 Mt of oilseeds by 2020 to achieve near self-sufficiency in vegetable oils production. Given that oilseeds output during 2009-10 was just 26.73 Mt, the country needs to double the oilseeds production in the next 10 years, requiring an annual growth rate of nearly 6-7%.

#### **2.4.6. Sugarcane**

- ◆ Sugar production is likely to be higher than the demand in 2030.
- ◆ Estimated sugar production in 2030 is 46.46 Mt; against the projected demand @30 kg/capita/year of 44.1 Mt. Thus a surplus production of 2.3 Mt.
- ◆ High water requirement of sugarcane crop and wide fluctuation in sugar prices remain a matter of concern.

- ◆ Diversion to ethanol production if the crude oil prices shoot up remains a threat as well as an opportunity.

## 2.5. Rain-fed agriculture

- ◆ Rain-fed agriculture with nearly 58 per cent of the cultivated area contributes 40 per cent of country's food production.
- ◆ Even after full irrigation potential of the country is realized, half of the cultivated area will continue to be under rain-fed farming. Rain-fed regions are home to about 40% of the human and 60% of the livestock population.
- ◆ Rain-fed agriculture is critical to achieve and sustain higher growth in agriculture.
- ◆ Sustainable, high productivity agriculture in the rain-fed areas is essential for sustainability of the society.

## 2.6. Horticulture

- ◆ Growing population and rise in income level will lead to increase in demand of high value agriculture (HVA) produce that includes fruits, vegetables, meat, eggs, milk, fish and value added food products.
- ◆ The annual growth rate in domestic demands for fruits and vegetables are estimated at 3.34% and 3.03% respectively.
- ◆ The required growth rates to meet projected demands in horticulture sub-sector may be lower than the growth already achieved during 1998-99 to 2006-07.
- ◆ Economic considerations could lead to diversification of cereal land to HVCs like horticultural crops, as in the Southern parts of the country where cultivation of spices generate more income for the farmers than the food crops.

## 2.7. Livestock

- ◆ Animal agricultural products such as milk, meat, eggs and fisheries can contribute a great deal in eliminating the nutritional deficiencies in the Indian population.
- ◆ Integrated farming approach envisages a judicious mix of crop production, and animals for milk, poultry, piggery, fisheries and sericulture depending on the location.

- ◆ With shrinking land holdings and common property lands, grazing, fodder and feed for animals is under stress.
- ◆ There is large deficit in the present demand and availability of green as well as dry fodder in the country. The estimates have been made till 2025, and the deficit is likely to increase. At the same time large quantities of paddy and wheat straw is being incinerated to dispose-off which can be conserved through feed block technology, thus also lessening the environmental pollution.
- ◆ The requirement of concentrates that includes grains, oilcakes, bran is presently in deficit and the projected demand and availability shows deficit for 2020.
- ◆ Intensive livestock production is the best alternative as it gives higher returns per animal as well as per unit of land. Commercial animal production can meet the nutrient and protein needs but brings conflict of land use. Urban dairies raise environmental issues, especially methane emission.

## 2.8. Increasing crop productivity- a major concern

It is now widely realized that following the Green Revolution, the input intensive agriculture technology that contributed to self sufficiency in food production for a growing population has also caused adverse environmental effects in the intensively cropped areas. Improper use of crop nutrients and pesticides has contributed to degradation of the resource base – soil, water, and environment. Water bodies are contaminated and ground water levels are depleted. The fertilizer response has also declined due to limitations in soil organic matter and micro-nutrient deficiencies. Therefore, there is an urgent need for developing sustainable farming systems that conserve and ameliorate the resource base. At the same time, the sustainable agriculture should meet the nutritional needs of the population. Sustainable agriculture that improves soil, water and environment can support only a sustainable population for the land area. Hence, it is important to have robust estimates of the carrying capacity of Indian agriculture. Obviously, infinite growth with a finite resource base and environment is not possible.

The only option available is to increase productivity of the major crops and farming systems per unit of land, water, nutrients, energy and human labor. Following points need consideration.

- ◆ Productivity increase is not possible without increasing use of water and energy – plant nutrients, and other agro-chemicals and enhancing their use efficiencies.

- ◆ Indian farmers are willing to produce more through adopting appropriate practices and technologies, provided they receive remunerative prices for their produces. This contributes to financial loss to the farmers especially for crops that cannot be stored such as vegetables, potato and sugarcane. This remains a major disincentive for the farmers to use the recommended levels of fertilizers and pest control measures.
- ◆ Limiting post-harvest losses and adding value along the producer-consumer chain will contribute to increased food availability, quality and income farmers and to others along the value chain.

### 3. RECOMMENDATIONS

#### 3.1. Policy

- ◆ Robust, science-based estimates for sustainable CC are urgently needed for different agro-climatic zones of a rapidly modernizing and globalizing India. This should include possible scenarios for the unknown and unpredictable changes. Later, CC estimates can be advanced to the district level for local planning of sustainable agriculture as well as sustainable development.
- ◆ *Estimating the population level that can be adequately fed without hunger or hidden hunger without adversely affecting the resource base (land, water and environment) is urgently needed.* This would need collective efforts of scientists from different disciplines as well as social and political scientists, and trade representatives. Considering the number of variables involved and complexity, such estimates may not be perfect, but certainly far better than having no estimates of the number of people that can be supported from the limited available resources.

#### 3.2. Research

- ◆ Though sustainable agriculture has been a topic of interest for a long time – demonstration of sustainability of the systems; yield levels harvested from such farming systems, and the effect on resource base needs to be collected for evolving truly sustainable systems.
- ◆ Long term experiments on sustainability of the farming systems need to be initiated.



- ◆ With a new emphasis on agricultural research for development (AR4D) which combines conservation agriculture with high yielding varieties, the emphasis should shift to efficient management of natural resources of land, soil, water and biodiversity.
- ◆ India's primary agricultural production based on the technologies already in the field, as determined by satellite images should be checked with ground level data base to fully exploit the space technologies in developing sustainable agriculture.
- ◆ Estimates of agricultural production potential based on the adoption of the available improved technologies should be obtained. A road map for sustainable agriculture should be prepared.

### Public Awareness

- ◆ Awareness should be created for the concept of carrying capacity in the media and public, similar to the current increasing consciousness on the environmental issues.

## LIST OF PARTICIPANTS

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17. Dr Tapan Adhya, Director, Central Rice Research Institute, Cuttack.
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23. Dr B. Venkateswarlu, Director, CRIDA, Hyderabad.

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