Achieving food security in times of crisis

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In spite of several World Food Summits during the past decade, the number of people going to bed hungry is increasing and now exceeds one billion. Food security strategies should therefore be revisited. Food security systems should begin with local communities who can develop and manage community gene, seed, grain and water banks. At the national level, access to balanced diet and clean drinking water should become a basic human right. Implementation of the right to food will involve concurrent attention to production, procurement, preservation and public distribution. Higher production in perpetuity should be achieved through an ever-green revolution based on the principles of conservation and climate-resilient farming. This will call for a blend of traditional ecological prudence with frontier technologies, particularly biotechnology and information communication technologies.

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Mahatma Gandhi said in 1948 "God is bread to the hungry".

Food security involves physical, economic, social and environmental access to balanced diet, and clean drinking water for every child, woman and man. Physical access is a function of the

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availability of food in the market and is related to both in-country production and imports, when needed. Economic access is related to purchasing power and employment opportunities. Social access is conditioned by gender equity and justice. Environmental access is determined by sanitation, hygiene, primary healthcare and clean drinking water. Thus, both food and non-food factors determine food security.

The hunger crisis

In spite of the highest priority accorded to hunger elimination among the UN Millennium Development Goals (UN-MDGs), the FAO (Food and Agriculture Organisation) estimates that the number of people going to bed hungry is increasing. When UN-MDGs were adopted in 2000, about 820 million were estimated to be under-nourished. Now, it is over a billion. Why are we in this condition? The hunger crisis facing us has the following principal short-term dimensions:

- Environment
- Economics
- Equity
- Employment
- Energy

The long-term dimension relates to global warming and climate change.

Dealing with crisis

Environment

Among the key areas needing attention are:

- Conservation of prime farm land for agriculture, soil healthcare and enhancement
- Irrigation water availability and quality and rain water harvesting
- Biodiversity loss
- Damage to ecosystem services
- Ecological footprint (related to life styles) and population supporting capacity of ecosystems

Aristotle said long ago that the soil is the stomach of the plant. Exploitative agricultural practices lead to soil mining and damage to the physical, chemical and microbiological properties of the soil. Every farm family should have a soil health card giving integrated information on all aspects of soil health, like organic matter status, macro- and micro-nutrient availability and the hydraulic conductivity of the soil. Mobile Soil Health Vans should be organised. A national land care movement should deal with both the conservation of prime farm land for agricultural purposes and the prevention of soil erosion and degradation. The fertility of waste or wasted land should be restored. Building a sustainable water security system involves concurrent attention to supply augmentation and demand management. Supply augmentation involves harnessing all the major sources of irrigation water, namely rain, ground, surface, effluents and waste water and seawater. Rain water harvesting through a pond in every farm must become a way of life. Sea water constitutes over 97% of the water resources available in our planet. There is vast scope for sea water farming through agri-aqua farms. Conjunctive use of water like fresh water and treated industrial effluents should become institutionalised. Industry should give back the water it consumes in a good condition.

Demand management in agriculture should come from the adoption of 'more crop and income per drop of water' techniques. Agronomists should indicate in their publications not only yield per hectare, but also yield per unit of water. Micro-irrigation methods need to become universal.

Biodiversity loss and damage to ecosystem services is taking place at an alarming rate. This has serious implications in relation to our capacity to deal with the new challenges arising from climate change and transboundary pests. The loss of every gene and species limits our options for the future, particularly when recombinant DNA technology affords an opportunity to create novel genetic combinations capable of conferring resistance to abiotic and biotic stresses.

An institutional method to address environmental threats to food security is the organisation of community managed food and water security systems at the village level. This will comprise field **gene bank** through *in situ* on farm conservation of local land races, **seed bank** for ensuring the availability of seeds during times of drought and flood, **grain bank** involving storage of local food crops (often belonging to the category of orphan crops) and **water bank** in the form of ponds and reservoirs capturing rain water. Thus, conservation, cultivation, consumption and commerce can be linked into a **food security continuum**. A reason why malnutrition is increasing in the world is the centralised approach to both analysis and action. A decentralised, community centred approach to food security will help us to reach our nutrition goals speedily and surely.

Economics in relation to food security

The cost-risk-return structure of farming determines the decisions of farmers with reference to the choice of crops and investment on inputs. Input costs are going up partly due to the escalation in the price of petroleum products. Output prices are not increasing in tandem with a rise in the cost of production. Due to inadequate availability of institutional credit and effective insurance, small farmers get caught in a debt trap, with much of the borrowing coming from private money lenders at very high interest rates. **If farm ecology and economics go wrong, nothing else will have a chance to go right.** Public policies in the field of agriculture should give over-riding priority to safeguarding and improving the ecological foundations essential for sustainable agriculture, on the one hand and assured and remunerative marketing opportunities, on the other.

Equity

The social, economic, environmental and gender dimensions of equity must receive integrated attention. An area in intra-generational equity which needs urgent attention is the elimination of maternal and foetal under-nutrition resulting in the birth of children with low birth weight (LBW). Such LBW children suffer from several handicaps including impaired cognitive abilities. At the other end is the growing damage to our life support systems of land, water, biodiversity and climate, leading to reduced opportunities for a healthy and productive life to the children yet to be born.

A method of overcoming problems in the areas of environmental, social and gender inequity is to subject all the development programmes to a matrix analysis designed to ascertain whether the programme is pro-nature, pro-poor and pro-woman. A pro-nature, pro-poor and pro-woman orientation is also essential in the area of technology development and dissemination.

Employment

The famine of jobs or purchasing power is often the cause of famine of food at the household level. Modern industry often leads to jobless economic growth. Agriculture including crop and animal husbandry, fisheries, forestry, agro-forestry, agro-processing and agri-business promotes job-led growth. Crop-livestock integrated farming systems enhance both income and nutrition security. In the developing countries of the Asia-Pacific Region, what we need is job-led economic growth, so that the goal of food for all coupled with human dignity can be achieved. The economics of human dignity demands that everyone should have an opportunity to earn his/her daily bread.

There are several successful models of promoting job-led economic growth in this region. One model relates to the successful experience in China of promoting higher small farm productivity and profitability on the one hand, and opportunities for skilled and remunerative non-farm employment through township–village–enterprises (TVE) on the other. This two pronged strategy has helped China to achieve both high farm productivity and impressive manufacturing capacity. 'Jobs for All' then becomes a reality.

The other model, developed at the MS Swaminathan Research Foundation (MSSRF), is known as the 'Biovillage' model of human-centred development. The Biovillage model involves the following three concurrent steps.

- Conservation and enhancement of the ecological foundation for sustainable agriculture, with particular attention to soil health care, rain water harvesting and efficient water use, biodiversity conservation and sustainable and equitable use, climate risk management, and the protection and development of village common property resources.
- Improving on-farm productivity based on ever-green revolution principles, which help to enhance farm productivity in perpetuity without associated ecological harm. This calls for mainstreaming ecological principles in technology development and dissemination.
- Generation of skilled and market-driven non-farm employment opportunities through improved post harvest technology and value addition to primary products.

Processing, storage and marketing require greater investment of technology and finance.

The Biovillage Council, which manages the biovillage activities through group co-operation, ensures that every adult in the village has an opportunity for a healthy and productive life

Energy

Each Biovillage Council develops a strategy for energy security involving a feasible and affordable blend of renewable and non-renewable sources of energy. Among the renewable sources solar, wind, biogas and biomass are particularly important.

Bridging the technology divide

Starting from the industrial revolution in Europe nearly 4 centuries ago, technology has been a major factor in North–South, rich–poor, rural–urban and gender divides. **If technology has been the primary cause of such divides, we should now enlist technology as an aid to bridging the divides.** An important requirement for promoting the 'Bridging the Divides Movement' is knowledge and skill empowerment. Harnessing modern Information and Communication Technologies (ICT) is a powerful method of empowerment of rural communities. The Village Knowledge Centre movement, launched in India by MSSRF in partnership with a multi-stakeholder National Alliance for Village Knowledge Revolution, is based on the principles of community ownership, demand driven and dynamic information, use of local language and capacity building. Capacity building and content creation are two key elements of this programme.

Biotechnology is becoming an important tool in creating novel genetic combinations. Action is needed at two ends of the spectrum for harnessing novel genetic combinations to meet current and future challenges arising from global warming and climate change. First, in village schools DNA Clubs should be organised to spread genetic literacy. Second, each Nation should have a statutory, professionally led National Biotechnology Authority. The bottom line of a Nation's Biotechnology Regulatory Policy should be:

> ***"the economic well being of farm families, food security of the nation, health security of the consumer, protection of the environment, biosecurity of the country and the security of national and international trade in farm commodities".***
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> ***(Report of the M S Swaminathan Committee, 2004)***

Developing countries should develop regulatory procedures which ensure the safe and responsible use of biotechnology, particularly recombinant DNA technology. In India, a National Biotechnology Regulatory Authority is being created through an Act of Parliament.

From green to an ever-green revolution: Indian experience

In India, the 20th century was a period of agony and ecstasy on the farm front. The colonial period (1900–1947) was characterised by insignificant growth in food production and frequent famines. The last part of the colonial period witnessed the Bengal Famine of 1942–1943, when over 2 million children, women and men died from hunger. This led to Jawaharlal Nehru's famous statement soon after independence in 1947, **'everything else can wait, but not agriculture'**.

The Nehru period (1947–1964) was marked by emphasis on irrigation, power generation, production of mineral fertilisers, chemical pesticides, community development, national extension service, and above all strengthening of agricultural research and education through the establishment of agricultural universities. A post-graduate school was set up at the Indian Agricultural Research Institute, New Delhi, which was conferred in 1958 the status of a deemed university under the UGC Act of 1956. The first Agricultural University based on the Land Grant University system of the United States of America started functioning in 1960 at Pant Nagar in Uttar Pradesh (now in Uttarakhand).

In spite of all the measures taken to strengthen agricultural research, education, extension and development, the gap between food production and food requirement continued to grow between 1950 and 1960. Consequently, food imports, largely under the PL-480 programme of the United States, grew year after year, reaching a peak level of 10 million tonnes in 1966. Globally and nationally, there was scepticism about India's capacity to feed its growing population.

To meet this challenge, an Intensive Agriculture District Programme (IADP) was started in the early 1960s to maximise the output of cereals like rice and wheat in districts where irrigation water was available. The strategy was to provide seeds, fertiliser and other inputs to improve productivity. During the first 15 years after independence, production increase was largely associated with area expansion and not due to higher yield. Consequently, the average yield of rice and wheat continued to stagnate at less than 1 tonne per hectare. It is under such circumstances, that I pointed out that the IADP, also referred to as the package programme, had one important missing ingredient, namely a genetic strain which can respond to the rest of the package, particularly soil nutrients and irrigation water.

The search for high-yielding varieties which can convert sunlight, water and nutrients into grains in an efficient manner first began in rice with the initiation of the *indica–japonica* hybridisation programme at the Central Rice Research Institute, Cuttack, in the early 1950s. Similar work was started in wheat in the mid-1950s, using mutation breeding techniques as well as hybridisation between *Triticum aestivum* varieties and sub-species *compactun* and *sphaerococum*. The *indica–japonica* hybridisation programme resulted in varieties like ADT-27 in Tamil Nadu and Mashuri in Malaysia. The programme did not make much headway due to sterility problems. In the case of wheat also, the expected improvement in yield potential did not take place because a short plant stature was also associated with short panicles and reduced yield potential. Fortunately, Japanese scientists led by Dr. Gonziro Inazouka identified Norin 10 and other genes which helped to break the negative correlation between plant height and panicle length. The Norin dwarfing gene was used by Dr. Orville Vogel in Washington State University, Pulman, to breed high-yielding winter wheats like Gaines. The same genes were used by Dr. Norman Borlaug in Mexico to develop semi-dwarf spring wheats. By adopting a shuttle breeding technique, Dr. Borlaug also made the wheat plant insensitive to photo-period and temperature. This gave birth to high-yielding spring wheat varieties Lerma Rojo-64A, Sonora 63, Sonora 64, Mayo 64 and other strains in Mexico. We obtained seeds of these varieties, as well as a wide range of segregating material from Dr. Borlaug in September 1963. The details of the semi-dwarf wheat programme initiated with the Norin dwarfing genes are contained in the publication 'Wheat Revolution – a Dialogue' [1]. Production advances were rapid resulting in the green revolution in 1968, due to the growth of a **Green Revolution Symphony**, consisting of mutually reinforcing packages of technology, services, public policy in input and out pricing and marketing, and above all farmers' enthusiasm.

In the area of technology, some of the significant steps taken included (a) the organisation of multi-location trials with 4 Mexican Semi-dwarf varieties during 1963–1964; (b) the organisation of National Demonstrations in the fields of resource poor farmers with small holdings from 1964 to 1965 onwards; (c) the import of 200 tonnes of seeds of Lerma Rojo-64A and Sonora 64 during 1965–1966 to expand the National Demonstration Programme throughout the wheat growing areas; (d) import of 18,000 tonnes of seeds from Mexico, mainly of the variety Lerma Rojo-64A for increasing the area under semi-dwarf wheat varieties; (e) selection of amber grain wheat varieties from the segregating populations sent by Dr. Borlaug and development of high-yielding amber wheats like Kalyan Sona and Sonalika, and initiation of a dynamic programme of cross-breeding both in *aestivum* and *durum* wheats to incorporate the Norin dwarfing genes into high quality Indian Wheat varieties like C306, bred by Chaudhury Ram Dhan Singh in the Punjab.

In the area of services, the important measures taken included (a) the setting up of a National Seed Corporation, (b) rural electrification, (c) rural communication, and (d) enlarged credit supply. The public policy measures led to the establishment of an Agricultural Prices Commission, the enforcement of a minimum support price through the Food Corporation of India, and the building up of grain reserves to feed the public distribution system. Because the new technologies are scale neutral but not resource neutral, special programmes like the small and marginal farmer support programmes were initiated. The aim was to ensure social inclusion in access to high-yield technologies.

The integrated packages of technology, services and public policies ignited farmers' enthusiasm and a small government programme became a mass movement. Writing in the Illustrated Weekly of India (May 11, 1969), I made the following remarks on the Punjab Wheat Miracle.

"Brimming with enthusiasm, hard-working, skilled and determined, the Punjab farmer has been the backbone of the revolution. Revolutions are usually associated with the young, but in this revolution, age has been no obstacle to participation. Farmers, young and old, educated and uneducated, have easily taken to the new agronomy. It has been heart-warming to see young college graduates, retired officials, ex-army men, illiterate peasants and small farmers queuing up to get the new seeds. At least in the Punjab, the divorce between intellect and labour, which has been the bane of our agriculture is vanishing".

To bring this significant development in India's agricultural evolution to public attention, the then Prime Minister Smt. Indira Gandhi released a special stamp titled 'The Wheat Revolution' in July 1968.

Similar opportunities for enhancing production through productivity improvement soon became available in rice, maize, sorghum and peal millet. Hence, the US scientist Dr. William Gaud coined the term 'Green Revolution' to indicate productivity triggered production increase. To ensure that a productivity based agriculture does not result in ecological harm due to the unsustainable exploitation of land and water, adoption of mono-culture and excessive use of mineral fertilisers and chemical pesticides, I appealed to farmers in the following words, not to harm the long-term production potential for short-term gains in my address to the Indian Science Congress held on Varanasi in January 1968:

"Exploitative agriculture offers great dangers if carried out with only an immediate profit or production motive. The emerging exploitative farming community in India

should become aware of this. Intensive cultivation of land without conservation of soil fertility and soil structure would lead, ultimately, to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water will lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high-yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened prior to the Irish potato famine of 1854 and the Bengal rice famine in 1942. Therefore the initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture, and without first building up a proper scientific and training base to sustain it, may only lead us, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity."

I pleaded for converting the *green revolution* into an *ever-green revolution* by mainstreaming the principles of ecology in technology development and dissemination. I defined 'ever-green revolution' as increasing productivity in perpetuity without associated ecological harm [2–5]. I pleaded for avoiding the temptation to convert the green revolution into a greed revolution. Unfortunately, ecologically unsound public policies, like the supply of free electricity, have led to the over-exploitation of the aquifer in the Punjab, Haryana and Western UP region. The heartland of the green revolution is in deep ecological distress [6]. The need for adopting the methods of an ever-green revolution has therefore become very urgent.

There are two major pathways to fostering an ever-green revolution. **The first is organic farming.** Productive organic farming needs considerable research support, particularly in the areas of soil fertility replenishment and plant protection. Soils in most parts of India lack organic matter and are also deficient both in macro- and micro-nutrients. A majority of farmers cultivate one hectare or less. Crop-livestock integrated farming will help to build soil fertility, but most small farm families have only 1 or 2 farm animals like cows, buffaloes and bullocks. Green manure crops and fertiliser trees can help to build soil fertility. Also, commercially viable organic farming methods will spread only if there is a premium price for organic products. Organic farming should be promoted in the case of vegetable and fruit crops and medicinal plants, where the danger of pesticide residues should be avoided.

The second pathway to an ever-green revolution is **green agriculture**. In this case, ecologically sound practices like conservation farming, integrated pest management, integrated nutrient supply and natural resource conservation and enhancement, are promoted. Green agriculture techniques could include the cultivation of crop varieties bred through the use of recombinant DNA technology, in case such varieties have advantages like resistance to biotic or abiotic stresses, or other attributes like better nutritive quality. In organic farming, the cultivation of genetically modified crops is prohibited. The cultivation of varieties bred with the help of molecular marker assisted selection is however allowed.

New possibilities can be envisaged by a combination of organic farming and high-yield agriculture. **Eco-agriculture** aims at mutually reinforcing relationships between agricultural productivity and conservation of nature. Innovative eco-agriculture approaches can draw together the most productive elements of modern agriculture, new ecological insights and the knowledge that local people have developed from thousands of years of living in harmony with nature. Eco-agriculture is defined as an approach that brings together agricultural development and conservation of biodiversity as explicit objectives in the same landscapes [4,7,8].

For resource poor farmers, green agriculture is the method of choice for producing more in an environmentally benign manner. The smaller the farm, the greater is the need for marketable surplus. Research on efficient micro-organisms which can help to build soil fertility, as well as fertiliser trees like *Faidherbia albida* will help both organic farming and green agriculture. The National Commission on Farmers NCF recommended in 2006 the initiation of a conservation farming movement in the heartland of the green revolution, to halt the damage now occurring to the ecological foundations essential for sustainable agriculture. NCF suggested the allocation of Rs. 1000 crores (US$ 200 million) to start with, for achieving a paradigm shift from exploitative to conservation farming in the Punjab-Haryana-Western UP region.

Sustainable food security

Despite the large number of nutrition safety net programmes introduced by the Central and State Governments from time to time, India still remains the home for the largest number of malnourished children and adults in the world. We should ask why we are in this regrettable and unacceptable situation. The answer lies in the basic structure of our consumption pattern.

Nearly two thirds of our population lives in rural areas. A majority of them are small and marginal farmers and landless labourers. They fall under the category **producer–consumer**. We have thus two categories, that is about 700 million **producer–consumers** and about 400 million **consumers**. In industrial countries, consumers will be about 97% and producer–consumers will be about 3%. Therefore widespread malnutrition and endemic hunger will persist unless the producer–consumer can consume a balanced diet. This situation also prevails in most countries in the Asia-Pacific Region. This will call for higher small farm productivity and profitability, on an environmentally sustainable manner. **An ever-green revolution accompanied by a small farm management revolution are hence vital components of a freedom from hunger movement.** How can we develop a sustainable and equitable food security system?

As pointed out earlier, food security at the level of each individual child, woman and man involves physical, economic and social access to balanced diet, including the needed macro- and micro-nutrients, safe drinking water, primary health care, sanitation and environmental hygiene. Thus, concurrent attention is needed to both food and non-food factors. Any national legislation related to food security should deal with production, access and absorption in a holistic manner. The following three steps are

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urgently needed for ensuring adequate availability of home-grown food.

- First, we must take steps to **defend the gains** already made. This will involve integrating ecological principles in technology development. At the same time, public policies should promote the sustainable use of land, water, biodiversity and common property resources through conservation farming. If the regions, which now provide most of the grain for the public distribution system, do not shift to an ever-green revolution pathway of productivity improvement, the nation's food security system will be jeopardy.
- Second, we must **extend productivity gains** to the 'green but no green revolution' areas like the entire eastern India, where there is adequate water availability. These areas constitute the 'sleeping giant' of Indian agriculture and should be enabled to take to green agriculture in a big way through appropriate packages of technology, services and public policies.
- Third, we should **make new gains**, particularly in rainfed areas, which constitute 60% of the farm area in the country. Available data show that the yield gap (i.e. gap between potential and actual yields) in such rainfed semi-arid areas is as high as 200–300% in the case of pulses, oilseeds, millets, semi-arid horticulture, etc. Work on 'more crop and income per drop of water' and on planting a billion fertiliser trees like *Faidherbia albida* should be promoted. Water harvesting and efficient water use should become a way of life in such areas. A *Pond in Every Farm* should become a habit and where appropriate, labour from the National Rural Employment Guarantee Act (NREGA) programme should be utilised for constructing farm ponds in the fields of small and marginal farmers in drought-prone areas.

India has nearly a billion farm animals including poultry. Livestock and livelihoods are intimately inter-related in all major agro-ecosystems, but more particularly in arid and semi-arid areas. Also, the ownership of livestock is more egalitarian than that of land. Therefore, crop-livestock integrated farming systems should be promoted because this confers multiple benefits, like income and nutrition security.

There are several other areas involving a blend of technology and social engineering which need immediate attention.

The first area relates to giving the power and economy of scale to small and marginal farmers, who constitute the large majority of the farming population of this region. The average size of holding is declining year after year. Yet, Green Agriculture, involving Integrated Pest Management IPM, Integrated Network solutions INS, rain water harvesting and watershed management, requires cooperative efforts among the farm women and men living in a watershed or the command area of an irrigation project. Hence, efforts to promote either cooperative or group farming or the formation of Small Farmers' Self-help Groups, should be intensified with the help of Agricultural and Animal Sciences Universities. Contract farming can be promoted if it represents a win–win situation to both producers and purchasers.

Second, there is increasing feminisation of agriculture. All agricultural research and development programmes must be gender sensitive. Taking into consideration the multiple burdens on a woman's time, every effort should be made to reduce the number of hours of work of rural women and increase their earning per hour of work. Also, support services for women in agriculture like crèches and day care centres, as recommended by the National Council of Farmers, should be provided. The gender dimensions of the impact of climate change should be studied because women generally tend to be in charge of water, fodder, fuel wood and livestock.

Third, 70% of populations in rural India are young women and men below the age of 35. A survey of the National Sample Survey Organization (NSSO) has revealed that over 45% of farmers would like to quit farming, if there is any other livelihood option. Attracting and retaining youth in farming are hence major challenges. This is where a technological upgrading of agriculture and multiple livelihood occupations become important. We must make agriculture economically rewarding and intellectually satisfying. This will call for blending traditional wisdom and ecological prudence with frontier technologies like biotechnology and information and communication technologies.

Fourth, we should enhance the coping capacity of farm families to the adverse impact of climate change. For this purpose, at least one woman and one male member of every local self-governing bodies should be trained as **Climate Risk Managers**. They should become well versed in the art and science of monsoon and climate management. '**Weather information for all**' should become a reality through the establishment of a national grid of mini-agro-meteorological stations.

Fifth, there are new pathways offered with the help of modern breeding technology in the area of biofortification of crops, such as the golden rice.

Overcoming hidden hunger caused by micronutrient deficiencies

The challenge of micronutrient deficiencies in diet is becoming great especially for the chronically poor. Iodine, vitamin A and iron deficiencies are serious in many parts of the developing world. Worldwide, iron deficiency affects over one billion children and adults. Recent analyses from the United States Institute of Medicine [9–12] highlight the effect of severe anaemia in accounting for up to one in five maternal deaths. Maternal anaemia is pandemic and is associated with high MMR; anaemia during infancy, compounded by maternal under-nutrition, leads to poor brain development. Iron deficiency is also a major cause of permanent brain damage and death in children and limits the work capacity of adults [12–17]. There is not enough appreciation of the serious adverse implications to future generations arising from the high incidence of low birth weight among newborn babies. LBW is a major contributor to stunting and affects brain development in the child. The new millennium will be a knowledge century, with agriculture and industry becoming more knowledge intensive. Denial of opportunities for the full expression of the innate genetic potential for mental development even at birth is the cruelest form of inequity that can prevail in any society [15]. We must take steps to eliminate as soon as possible such inequity at birth leading to a denial of opportunities to nearly one out of every three children born in South Asia, for performing their legitimate role in the emerging knowledge century.

Wherever rice is the staple, a multi-pronged strategy for the elimination of hidden hunger should be developed by rice scientists. IRRI has undertaken research on enriching rice genetically with iron and other micro-nutrients. Fortification, promotion of balanced diets, new semi-processed foods involving an appropriate blend of rice and micro-nutrient rich millets as well as genetic improvement, could all form part of an integrated strategy to combat the following major nutritional problems in predominantly rice eating families:

- Protein-energy malnutrition
- Nutritional anaemia (iron deficiency)
- Vitamin A deficiency
- Iodine deficiency
- Dietary deficiencies of thiamin, riboflavin, fat, calcium, vitamin C and zinc, as I suggested [12] that the International Rice Commission could include nutrition security aspect as an integral part of the International Network.

We must fight the serious threat to the intellectual capital of developing countries caused by low birth weight children and hidden hunger [18]. Some of the research areas worthy of attention in this context are described below.

Breeding for nutritional quality

Nutritive quality is as important as cooking quality for countries in tropical Asia, where rice is the principal source of dietary protein, vitamin (B_1) and minerals (Fe, Ca) [19]. Rice provides about 40% of the protein in the Asian diet. Among the cereal proteins, rice protein is considered to be biologically the richest by virtue of its high digestibility (88%), high lysine content (+4%) and relatively better net protein utilisation. Yet, it is nutritionally handicapped on account of two factors *viz*: (i) its inherently low protein content (6–8%) and (ii) inevitable milling loss of as much as 15–20%. Unlike other cereals, increased protein content in rice does not result in decreased protein quality as all of its fractions (glutelin 65%, globulin and albumin 15% and lysine–cysteine-rich prolamin 14%) are rich in lysine and other essential amino acids. Even a marginal increase of 2 percentage points of protein, therefore, would mean 10–15% increase in the nutritionally rich protein intake in our diet.

Genetic engineering approaches for correcting micronutrient deficiencies

Breeding for Nutritional Improvement was recommended at the 19th Session of the International Rice Commission, which called for an increase in focus on strategies to combat malnutrition [20,21]. There are four categories of direct intervention believed to be successful in reducing micro-nutrient malnutrition; supplementation, fortification, dietary diversification and genetic enhancement [22]. Nutritional status of populations will focus on the potential for improving malnutrition, primarily micronutrient malnutrition through genetic improvement.

Golden rice

About 250 million people worldwide are deficient in vitamin A. Over five million children in South and South-east Asia are reported to suffer from the serious eye disease 'xerophthalmia' every year and about 5,00,000 of them eventually become partially or totally blind due to deficiency of vitamin A. Besides affecting vision, vitamin A deficiency predisposes children to varied respiratory and intestinal diseases resulting in high mortality. Researchers from Swiss Federal Institute of Technology inserted these genes from daffodil and a bacterium into temperate rice plants to produce a modified grain, which has sufficient β-carotene (precursor of vitamin A) to meet total vitamin A requirements in a typical Asian diet [23]. Golden rice technology was made available to developing nations for research. If this technology can be moved to the production stage, it could represent an important contribution to improved human nutrition. In particular, rice fortified genetically with vitamin A and iron will be very useful to improve the nutritional status of pregnant and nursing women.

Iron deficiency

Iron deficiency anaemia (IDA) is the world's most common nutritional deficiency. It affects pregnant and nursing women and young children most commonly. IDA in mothers predisposes to still births, neonatal mortality, anaemia and low birth weight in infants, and increases the risk of maternal mortality [10,12]. Regular intake of iron or administration of iron prevents anaemia. Daily supplementation with iron–folic acid tablets is a low-cost and effective intervention. Genetic enrichment of iron in rice has also been accomplished through recombinant DNA technology [24].

To sum up, Indian agriculture is at the crossroads. Our population may reach 1750 million by 2050. Per capita crop land will then be 0.089 ha and per capita fresh water supply will be 1190 m^3/year. Food grain production must be doubled and the area under irrigation should go up from the current 60 million ha to 114 million ha by 2050. Degraded soils should be restored through increase in carbon pools in soils. How are we going to achieve a match between human numbers and human capacity to produce adequate food for all? To quote Edward O. Wilson [25] in *The Future of Life:*

> ***"The problem before us is how to feed billions of new mouths over the next several decades and save the rest of life at the same time without being trapped in a Faustian bargain that threatens freedom from security. The benefits must come from an evergreen revolution (as proposed by Swaminathan). The aim of this new thrust is to lift production well above the levels attained by the Green Revolution of the 1960s, using technology and regulatory policy more advanced and even safer than now in existence".***

Making hunger history in the Asia-Pacific Region

With the spread of democratic systems of governance in most parts of the world, a world without hunger is an idea whose time has come. Access to balanced diet and clean drinking water must be a fundamental right of every human being. **This will call for a shift from a charity based approach to hunger elimination to a right based one.** The Government of India is currently developing legislation to ensure food security for all. Such a National Food Security Act, to be effective, should deal with food availability, access and absorption in an integrated manner. Food availability can be ensured by launching a 'bridge the yield gap' movement, which is designed to help in narrowing or eliminating the gap between potential and actual yields through packages of technology, services and public policies.

Food access can be ensured through making food availability at affordable cost and by generating sustainable livelihood opportunities in the farm and off-farm sectors. **A rights based approach to access can provide for common and differentiated entitlements.** The common entitlement should aim to ensure adequate availability of food in the market coupled with an effective public distribution system which will enable all citizens to access essential quantities of staple grains at a reasonable price. Differentiated entitlement will refer to providing food at low price to the socially and economically underprivileged sections of the society. Thus, there will be universal access to the needed calories and proteins, making the goal of food for all a reality.

A National Food Security Act should in addition to aiming to end poverty induced protein–energy malnutrition, should also provide for the following:

- Elimination of hidden hunger caused by the deficiency of micro-nutrients like iron, iodine, zinc, vitamin A and vitamin B_{12} through a food cum fortification approach. In particular, emphasis should be placed on providing horticultural remedies for the nutritional maladies prevailing in an area, based on local foods.
- Provision of clean drinking water to ensure food assimilation in the body.
- Attention to non-food factors like primary health care, environmental hygiene and sanitation.
- Launching of a nutrition literacy movement and training one woman and one man in every village as 'Hunger Fighters'.

In the ultimate analysis we will succeed in achieving food security in an era of global change, only through a well planned and concerted endeavour at the global, national and local levels. Centralised goals and resource allocation should be coupled with decentralised planning and action. Community food and water security systems involving the establishment of local level gene, seed, grain and water banks will facilitate both as ever-green farm revolution and sustainable food and nutrition security. Such local level Food Security systems will also help to enlarge the shrinking food basket by including a wide range of millets, legumes and tubers in the diet.

FAO is the flagship of the global resolve to end hunger. The Asia-Pacific Region is the home of the largest number of under-nourished children, women and men. Hunger can be overcome if there is the requisite fusion of professional skill, political will and action, farmers' enthusiasm and above all, people's participation. The FAO Regional office for the Asia-Pacific Region has the unique opportunity for promoting a Food Security Symphony to generate the needed degree of convergence and synergy among the numerous nutrition safety net programmes in operation in our region.

Finally, we should develop and spread climate-resilient cropping and farming systems. Gene Banks for a Warming Planet are necessary [26]. Breeding strategies should give priority to developing varieties of crops, characterised by a high per-day productivity because global warming will lead to a reduction in the duration of crops like wheat and rice under sub-tropical conditions [26]. *A National Climate Management Movement* should include appropriate mitigation and adaptation measures. This is an essential requirement for an ever-green revolution [27].

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