Food Security

Environmental Concerns and Remedies

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Annual food grain production in India increased from about 50 million tons in 1950 to almost 220 million tons in 2007. Despite these impressive gains, the expected food grain demand for medium dietary requirement will be 253 million tons by 2011, 308 million tons by 2021, and 338 million tons by 2025. The food demand is driven by increase in population and possible change in diet because of increase in the earning power. India's population of 1,103 million in 2005 is projected to be 1,183 million in 2010, 1,260 million in 2015, 1,332 million in 2020, 1,396 million in 2025, 1,449 million in 2030 and is expected to stabilize at around 1,593 million in 2050. Therefore, an important question in the context is: How can India achieve food security while improving the environment and meeting the energy needs for a rapidly industrializing economy? While the quantum leap in food production ushered in during the Green Revolution of the 1960s and the 1970s is a success story to be proud of, there are several environmental concerns which needs immediate attention. Impressive gains in agricultural production through adoption of Green Revolution technology were achieved by growing input-responsive varieties on irrigated soils along with high utilization of chemical fertilizers and pesticides. It was precisely the application of these technologies that raised environmental concerns because expanded agricultural productivity resulted in soil degradation and nutrient depletion. With increased use of chemicals came environmental pollution; increased irrigation brought about depletion of the ground water in tubewell irrigation and salinity and waterlogging in canal irrigation; while intensification of the rice-wheat system invited decline in biodiversity. The problem of soil degradation is exacerbated by drastic depletion of soil organic matter content caused by extractive farming practices including removal of crop residues for use as animal feed and other purposes, use of animal dung as residential/cooking fuel and uncontrolled grazing that denudes the soil of any biomass return.

State of the soil and water resources

India is endowed with vast and ecologically diverse soil and water resources and a wide range of climates. Agricultural land areas comprise 160 million hectares (Mha) of arable land and 11 Mha of permanent pastures. However, the increase in population is decreasing the per capita cropland area, which was 0.158 ha in 2000 and 0.147 ha in 2005. Assuming that there is neither additional soil degradation nor conversion to urbanization and industrial uses, the per capita cropland area as estimated, will be 0.137 ha in 2010, 0.121 ha in 2020, 0.112 ha in 2030 and 0.102 ha in 2050. There has also been a rapid increase in the irrigated land area in India. The irrigated cropland area was 33.7 Mha in 1975, 41.8 Mha in 1985, 50.1 Mha in 1995, 54.8 Mha in 1998, and 55.8 Mha in 2003. Per capita irrigated land area was 0.05 ha in 2003. Ironically, both soil degradation and urban encroachment are serious issues and likely to worsen over time. The land area prone to degradation processes is conservatively estimated at 32.8 Mha by water erosion, 10.8 Mha by wind erosion, 3.2 Mha by fertility decline, 3.1 Mha by waterlogging, and 4.1 Mha by salinization. In some densely populated regions, top 1m of soil from as much as 0.7% of cropland, is mined annually for brick making, whereas large areas are being converted to urban and industrial uses. Therefore, all basic needs (e.g., food, feed, fiber and fuel) must be met through the judicious management of the per capita land area of 0.1 ha or less. Similar to cropland, the per capita renewable fresh water resources in India is projected to decrease from 2244 m^3/person/yr in 1995 to 1360 m^3/person/yr in 2050. In addition to decline in the quantity, pollution, contamination and eutrophication of water resources are also serious constraints.

Energy demand and carbon emission

The energy demand in India will be an important issue during the coming decades. Measured in Quads (1 Quad = 10^{15} BTU), energy demand was 4.2 Q in 1980, 8.0 Q in 1990, 13.5 Q in 2000 and 14.0 Q in 2003. About one-sixth (17%) of the world population relies on only 3.5% of the world's energy consumption, which is a reflection of extreme poverty and low standard of living. However, the demand for energy and the attendant CO_2-C emissions have been increasing rapidly. The gaseous emission of CO_2-C (in terragram or Tg = 10^{12} g = 1 million metric ton) in India was 18 in 1950, 33 in 1960, 53 in 1970, 95 in 1980, 185 in 1990, 316 in 2000, and 333 in 2003. In comparison, CO_2-C emissions in the US, with a population of 300 million, is about 1800 Tg. With rapid industrialization and economic growth of about 10% per annum, both energy demand and gaseous emission in India are increasing rapidly.

Causes of soil, water and environmental degradation

Land misuse and soil mismanagement, driven by poverty and helplessness of the resource-poor farmers, and myopic policies of the government, have been the chief causes of soil degradation. Extractive farming practices, removal of crop residues and minimal/no input of animal manure along with low rate and unbalanced application of fertilizers (subsidizing nitrogenous fertilizers but not P and K) have caused depletion of soil organic matter and mining of soil fertility. Free or cheap irrigation water caused excessive irrigation with the attendant increase in salinization and water imbalance. Use of traditional biofuels (crop residues, dung) is one of the principal causes of soil degradation with severe adverse impact on health of women and children. On an average, India annually uses 260 Tg C as fuel wood, 72 Tg C as cattle dung, 43 Tg C as crop residue, or a total of 374 Tg C as traditional biofuels. Annual energy produced from agricultural biosolids in India is estimated at 200 million tons of oil equivalent. Use of these vast quantities of biomass as fuel, rather than as soil amendment, exacerbates the problem of soil erosion, decline in soil organic matter content, reduction in soil biodiversity and increase in nonpoint source pollution. Soil degradation is an indication of the degree of the societal care of the land, but unfortunately it shows that the Indian population and policy-makers are least bothered.

Potential of increasing agronomic yields and achieving food security

Crop yields in India increased impressively during the last four decades of the 20^{th} century. Grain yield increase between 1975 and 2005 was from 1.9 t/ha to 3.0 t/ha in rice and 1.4 t/ha to 2.7 t/ha in wheat. Cereal production in India, between 1960 and 2003 was linearly correlated with fertilizer use (Y (million tons/yr) = 9x + 86.8, R^2 = 0.98 where x is fertilizer use in million tons), and irrigated land area (Y (million tons/yr) = 4.8x + 36, R^2 = 0.99, where x is irrigated land area in Maharashtra). There was lesser increase in the yield of rainfed crops (e.g., sorghum, millet, pulses). Increase in grain yield of other crops between 1960 and 2004 was from 960 kg/ha to 2,075 kg/ha for maize, 500 kg/ha to 635 kg/ha for pulses, 150 kg/ha to 275 kg/ha for oil crops, and 500 kg/ha to 1,115 kg/ha for coarse grains. Because of the drought stress, fertilizer use is considerably less in rainfed crops.

Crop yields in India are much lower than the world average and the average yields in China and countries in Southeast Asia. Technically, it is possible to increase crop yields in India by a factor of 2 or 3 over the next 2-3 decades. The question, however, is how to double or triple food production without affecting the already degraded soil and water resources and without polluting the environment which is already under great stress.

Stewardship of soil and water resources

It is important to follow the words of wisdom in ancient scriptures. The *Vedas* vividly state that "Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel and our shelter and surround us with beauty. Abuse it, and it will collapse and die, taking humanity along with it." The entire population in general and the policy-makers in particular must take this warning very seriously, and not take soils for granted. In this regard, the following actions and policy interventions are necessary:

- Ban making of bricks from cropland soils and develop alternate sources of construction materials;
- Discourage using animal dung for household fuel and provide clean cooking fuel for rural communities;

- Minimize and discourage communal grazing;
- Charge market price for canal water and electricity for pumping tubewell water;
- Promote restoration of degraded soils via afforestation;
- Regulate discharge of urban wastes and industrial effluents in rivers;
- Facilitate trading of carbon sequestered in soils and trees and generate another income stream for farmers;
- Advocate value addition of farm produce by establishing agro-based industries (food production);
- Establish energy plantations at village levels; and
- Encourage water harvesting, recycling and conservation at both farm and village level.

Using nanotechnology, biodiversity and Information Technology

India has the human capital to 'leap frog' technological adoption. Several weaknesses and constraints of Indian agricultural system, notably low fertilizer use efficiency and excessive use of irrigation, can be alleviated through appropriate application of modern technology. Examples of such technological innovations include the following:

i. **Conservation tillage with crop residue mulch and use of cover crops/forages in the rotation cycle:** Erosion control, water conservation, increase in use efficiency of energy and water and improvements in soil quality can be achieved through adoption of conservation tillage or no-tillage. In addition to sowing of wheat in untilled field, following the harvest of rice, use of conservation tillage and mulch farming can be especially beneficial to crops grown under rainfed conditions. Combination of no-till/conservation tillage, with Genetically Modified (GM) and herbicide-resistant crops and judicious use of fertilizers can bring about a quantum jump in food production.

ii. **Drip irrigation:** Alleviating drought stress while improving water use efficiency is important in improving crop yields in semi-arid and sub-humid regions. Sub-surface drip irrigation can be used for perennials and annuals at a low-cost of less than $10/acre and it can last for up to five years. Drip irrigation, combined with fertilizer (fertigation) can save nutrients and water and improve crop yields.

iii. **Waste water reuse:** Scarcity of water in India is likely to be exacerbated by rapid melting of the Himalayan glaciers because of the projected global warming. Availability of water in the Indo-Gangetic Plains will be most adversely affected. It is thus important to reuse waste/urban water, following appropriate treatment, for irrigation.

iv. **Nanofertilizers:** There will be an increase in fertilizer demand to meet the need of increasing agronomic production. The future fertilizers must be C-neutral (produced from solar/wind/nuclear energy) and delivered directly to plant roots in a form, quantity and during the most critical stages of crop growth. Nanocapsulation of fertilizers, containing the essential elements, can be delivered to plant roots with minimal losses by leaching or volatilization. Combination of nanotechnology with biotechnology can drastically improve productivity.

Use of zeolites and hydrogels can enhance water and nutrient use efficiency. Zeolites have numerous applications in phytoremediation of soils, purification of irrigation and waste water and as an amendment in improving fertilizer use efficiency.

v. **Biotechnology:** Adoption of Bt cotton is a success story in India, with increase in production from 16 million bales in 2002 to 27 million bales in 2006. There is a tremendous scope of adopting roundup-ready (herbicide resistant) wheat, soybean and other crops which can then be successfully grown with no-tillage or conservation tillage. Biotechnology innovations can improve edaphic conditions with regard to both biotic and abiotic stresses (e.g., drought stress, tolerance to high temperature, and resistant to pests).

There are several applications of biotechnology to efficient use of input and sustainable management of soil and water resources. Biotechnology and gene manipulation can be used to build into plant mechanics so that plants emit specific molecular signals in response to specific environmental stresses (e.g., drought, nutrient deficiency, disease and pests). Biotechnology can be used to connect molecules internally to the physiology of the plant so that plants emit signal before anything detrimental occurs. This is the linkage of biological/physical interphase. Molecules given off under stress signals can be used as markers. Genetic manipulations are also needed to improve production of recalcitrant compounds, root-shoot ratio, and the harvest index under a range of edaphic environments.

vi. **Aerobic rice:** Flooded rice, grown under puddled conditions, is a water-intensive practice. Being a scarce resource, it is important that specific rice varieties are developed which can be grown under upland/irrigated conditions. In addition to water conservation, weed management needs to be prudently addressed through chemical and mechanical measures under non-flooded/aerobic conditions.

vii. **Trading carbon credits:** Resource-poor small farmers can benefit financially through another income stream created by the trading of C credits. Carbon sequestered in soils, by adopting no-till farming, using crop residue mulch, applying compost and other biogenic amendments, is a tradeable commodity and can be bought and sold. Similar to the soil, C pool that sequestered in trees can also be traded. Provisions must be made to develop

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market infrastructure for trading C credits.

viii. **Information Technology:** This is an important facet that can improve farm income and reduce risks. For example, there are 7,500 grain markets in India. The price information from these markets must be made available to farmers in 600,000 villages throughout the country. Use of IT can improve forecast of monsoons and incidence of disease and pests. There is a tremendous scope for using bioinformatics to enhance technology adoption.

ix. **Ecosystem monitoring:** Remote sensing techniques can be used to monitor microclimate and soil conditions in otherwise remote and inaccessible areas. Sensors can be dropped by airplanes which emit signals with regard to soil moisture and temperature regimes.

x. **Plastics and screenhouse agriculture:** Use of plastic mulch for water conservation and weed control, and production of vegetables and horticultural crops in plastic/ screenhouses are important land and water saving technologies. These techniques of agricultural intensification are extremely relevant to urban and peri-urban agriculture.

Policy interventions

Application of science and technology alone cannot solve all problems. There are several issues related to social, cultural and political realms which must also be addressed. Technological miracles can happen only under the most conducive political and social environments. A relevant example is the adoption of the Green Revolution technology in western versus eastern India. Soil, water and climate resources in Bihar are superior to those in Punjab, Haryana and western UP. Yet, the Green Revolution far outperformed Bihar and eastern India because of vital conducive factors as social, cultural and political conditions there. Therefore, creation of a favorable political, social and economic environment is essential for the adoption of recommended technology by farmers and land managers. Appropriate governance is as crucial as development of yield-enhancing technology.

The role of biofuels

An example of good governance and use of policy interventions to improve the standard of living and restore the environment would be making clean cooking fuel available to rural households in 600,000 villages across India. Clean cooking fuel may involve fuel wood from tree plantations (e.g., acacia, mesquite, leucaena, eucalyptus, neem, dalbergia, etc.) It may also involve modern biofuels such as methane gas from biodigesters (using animal dung and other residues), bio-ethanol from ligno-cellulosic materials grown on energy plantations (karnal grass, elephant grass, switch grass, and guinea grass), or biodiesel produced from non-edible oils (jatropha). A clear policy that encourages production of clean cooking fuels at the village level has numerous ancillary benefits. Important among these are improvement in air quality and better health of women and children. In addition, animal dung and crop residues spared from burning would be available for use as soil amendment.

Benefits of improved technology can only be realized with proper governance and creation of a conducive social, cultural and political environment.

Conclusion

Impressive gains in agricultural production were made during the second half of the 20th century when food grain production quadrupled between 1950 and 2000 from 50 million tons to 200 million tons. However, even greater challenges lie ahead because production will need to be increased by 50-60% by 2025 to meet the demands of growing population and rising standards of living. The strategy is to increase food production while restoring soil, improving water quality and mitigating climate change.

Assess to food and clean living environment are the two basic human rights which must be respected for each and every individual. They can be achieved through adoption of modern innovative technology. As has been the case in the past, those holding neo-malthusian views will again be proved wrong through the adoption of modern scientific technology. These technologies have the potential to enhance production, while ameliorating soil, improving water and restoring the environment.

The objective is to increase yield/ha/crop on existing land by increasing cropping intensity, replacing low-yielding with high-yielding varieties and farming systems. The strategy is to adopt land saving technologies, and deliver water and nutrients directly to plant roots at the required rate at the critical time.

Important innovative technology includes no-till farming with crop residue mulch used in conjunction with roundup ready crops (wheat, soybean, corn, sorghum, and millet), sub-surface drip irrigation, precision farming, nano-fertilizers, hydrogels, zeolites and use of GM crops which emit molecules under stress that can be detected prior to severe adverse impacts on crops. Replacement of traditional residential fuels with modern biofuels is important in improving human health, restoring soil quality and enhancing the environment.

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