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OPPORTUNITIES AND CONSTRAINTS IN ORGANIC FARMING: AN INDIAN PERSPECTIVE

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Abstract

Organic farming follows the principle of circular causation and has emerged in response to questions on health, environment and sustainability issues. In this review, we assess the status, opportunities and C- sequestration potentials of OF in India. We identify constraints that impede adoption of OF especially for small farm holders who constitute over 70% of farming community in India. With large land area and climate diversity, India has a considerable potential to contribute to C-sequestration. The soil organic carbon (SOC) in cultivated soils is less than 5 mg g^{-1} compared to 15-20 mg g^{-1} in uncultivated soils. This available potential of 10-15 mg g^{-1} soil–C sink could balance net emission from fossil fuel combustion. Although India occupies second position in terms of number of certified organic farms (44,926), it is 13th in terms of area under OF representing only 0.3 % of total agricultural lands. This scenario appears poor compared to many other countries. Farmers apprehension towards OF in India is rooted in non-availability of sufficient organic supplements, bio fertilizers and local market for organic produce and poor access to guidelines, certification and input costs. Capital-driven regulation by contracting firms further discourages small farm holders. An integrated effort is needed from government and non-government agencies to encourage farmers to adopt OF as a solution to climate change, health and sustainability issue.

Keywords: Organic farming, Climate change, Cost-benefit analysis, Indian farmers.

Introduction

India is mainly an agricultural country, where agriculture contributes to about 14.6 percent in gross domestic product (GDP) and support over 58 percent of nation's population for livelihood (GOI, 2010). The recent economic and trade liberalization are exerting heavy pressure on India's land resource partitioning in sectors such as forestry, agriculture, pasture lands, human settlements and industries. Thus, the coupled effect of meeting food demand under limited arable area and toxin-free agricultural produce have become an important forcing factor for countries like ours to explore possibilities for opting 'conventional agriculture', the dominant farming approach promoted by most government and agribusiness groups throughout the world or 'organic agriculture' a holistic production management system which is supportive to environment, health and sustainability. Organic farming system emphasis on the use of organic matter for enhancing soil properties, minimizing food chain associated health hazards and attaining closed nutrient cycles, the key factors for sustainable agriculture (Cardelli *et al*., 2004). According to the International Federation of Organic Agriculture Movement (Willer *et al*., 2008) the major objectives of organic farming include: (1) production of high quality food in sufficient quantity in harmony with natural systems and cycles, (2) enhancing biological cycles within the farming system involving microorganisms, soil flora and fauna, plants and animals, (3) maintaining long-term soil fertility and genetic diversity of the production system and its surroundings including plant and wildlife, (4) promoting healthy use with proper care of water resources and all life therein, (5) creating harmonious balance between crop production and animal husbandry, and (6) minimizing all forms of pollution.

Organic farms although yield on an average 10-15% less than conventional farms, the lower yields are balanced by lower input costs and higher margins. Its annual growth rate has been about 20% for the last decade (Lotter, 2003), accounting for over 31 million hectares of area and generating over 26 billion US dollars in annual trade worldwide (Escobar and Hue, 2007). Organic agriculture is now being practiced in more than 130 countries with a total area of 30.4 million hectare, about 0.65% of total agricultural land of the world (Willer *et al*., 2008). With respect to the area under organic agriculture, Australia occupies the prime position followed by China, Argentina, USA, Italy and many other countries (Willer *et al*., 2008). India, although comes at second place with respect to total number of certified organic farms (44,926), occupies 13th position as far as the area under organic agriculture concerns. In India, about 528,171 hectare area is under organic agriculture (including certified and area under organic conversion) accounting for about 0.3% of total agricultural land.

Despite the economic boom our country is witnessing from last few decades, there remain three important and interrelated issues that need serious concern for agriculture sector: (i) although the cereal production increased over 4.5 folds during last 60 yrs (Lal, 2004), our country need to meet the expected food demand of 300 million tons of cereals by 2050 from continuously shrinking land resources, (ii) there is rapid degradation of water and land resources leading to reduction of use efficiency of fertilizer, irrigation, tillage etc, along with rising emission of pollutants and green house gases, and (iii) agricultural release of toxic chemicals, contamination of food stuffs and associated health problems. The cropland areas represent over 60% of the total land area in the country although a major portion of land is divided in small farm holders (Lal, 2004). The country is undergoing rapid industrialization and urban growth and consequently minimizing the possibility of expansion of cropland area. Furthermore, the urgency of meeting demand of agricultural produce and by implication, the increased fertility mining practices such as residue removal, imbalance application of plant nutrients, uncontrolled and excessive grazing are exacerbating the soil degradation.

Organic farming emerged as a potential alternative for meeting food demand, maintaining soil fertility and increasing soil carbon pool. However, Indian organic farming industry is almost entirely export oriented, running as contract farming under financial agreement with contracting firms, and as per the latest report (Ramesh *et al*., 2010), about 585,970 tones of organic products worth US$ 6.8 million are being exported from India. Most of the farmers are opting organic farming due to price margins which may shift motive of the commercial farmers towards economic vantage rather than for safe agricultural produce to competitively discourage small farm holders. Additionally, limitations regarding bulk availability of organic supplements further constrain organic farming in India. Despite these issues, the increasing market demand and institutional support coupled with growing inclination of farmers to go organic have resulted in rapid growth in certified organic area during last 2-3 years. The objective of this review is to assess the status and potential of organic farming and the constraints therein impeding the adoption of this sustainable agricultural practice in India.

The Paradigm Shifts

Traditional farming practices prior to the 20th century were generally regarded as 'organic' but the introduction of synthetic farm inputs such as urea and DDT to increase crop yield overshadowed those approaches. Organic food attained a separate identity during 1960s but the steps towards identification of sources, standardization of methodology and its application in agricultural field received serious concern only after a long gap. The British botanist Sir Albert Howard who is often referred to as the father of modern organic agriculture documented traditional Indian farming practices as superior to the conventional agriculture. In the 1st quarter of 20th century, Rudolf Steiner's (Germany) approaches to biodynamic agriculture was probably the first comprehensive document on organic farming system. In 1909, American agronomist F.H. King after visiting China, Korea, and Japan for studying traditional fertilization, tillage, and general farming practices, published "*Permanent Agriculture: Farmers of Forty Centuries*". In the later years his book became an important reference for the introduction of new and improved methods (Paull, 2006).

Lady Eve Balfour launched the Haughley experiment in 1939 in England and her publication *The Living Soil*, led to the formation of the Soil Association, a key international organic advocacy group. Japanese microbiologist, Masanobu Fukuoka, devoted his 60 years towards developing a radical no-till organic method for growing grain and other crops, now known as nature farming or Fukuoka farming. The international campaign of Green Revolution launched in Mexico in 1944 with private funding from the US encouraged the development and use of hybrid plants, chemical controls, large-scale irrigation, and heavy mechanization in agriculture around the world. Rachel Carson's *Silent Spring*, which appeared in 1942, chronicling the effects of DDT and other pesticides on the environment (Paull, 2007) is considered to be a key driver in the US government's banning of DDT. The International Federation of Organic Agriculture Movements (IFOAM) was founded in 1972 at Versailles, France, to exchange information on the principles and practices of organic agriculture across national and linguistic boundaries. Fukuoka’s first book, *The One-Straw Revolution*, appeared in 1975 advocates for a meticulous balance of local farming system and minimum human interference. In the 1980s, various farming and consumer groups all over the world began pressuring for government regulation of organic production. This led to legislation and certification standards being enacted through the 1990s and to date. The retail market for organic farming in developed economies is now growing by about 20% (Narayanan, 2005).

Indian is one of the oldest civilizations as far as domestication of animals concern. Human adaptation and migration in response to severe climate changes are known from palaeorecords. Climatic amelioration and the fact that more energy is required for hunting and gathering than for agricultural practices to obtain same calories of food energy (Li and Rutger, 2000) coupled with intrinsic dynamics of human populations, led a turn in the purpose of animal domestication from hunting to agricultural use and associated shift in food habits and lifestyle. Since tropics provide enough moisture for growth of plants for food and feed, South and Central Asia became the centres of earliest domestication of plants and animals in the early half of the Holocene that led to the beginning of agricultural practices (Gupta *et al*., 2006). Domestication of animals and plants began around 10000 – 7000 cal years BP in the northwestrn part of India in the region watered by Indus River and its tributaris (Allchin and Allchin, 1997). The first evidence of agriculture and domestication of animals for agriculture in our country, found at Mehrgarh (now in Pakistan) and surrounding areas (Allchin and Allchin, 1997) indicates expansion of wheat and barley cultivation (Rabi crops) and domestication of cattle, sheep and goat was favoured by excess rain and longer monsoon season in early Holocene. Heavy rains however, probably could not allow early farmers of Indus region to grow rainy season crops (Kharif crops) such as maize, millet and lentils. With rise in aridity since ~ 5000-4000 cal yrs BP, populaton shifted towards east Gangatic plain (Saraswat, 1993) and cultivation of millet, lentils, horse gram, green gram, field peas and chickpeas became the part of later agricultural practices (Allchin and Allchin, 1997).

Traditional Indian agriculture witnessed the use of basic organic techniques, where fertilizers, pesticides, etc, were obtained from plant and animal sources. During 1950s and 1960s, due to rapidly growing population and natural calamities took a turn to drastically increase food production. The Green Revolution marked with expansion of agricultural land, use of hybrid seeds, chemical fertilizers and pesticides drove our country in 1990 to again become an exporter of food grains. In due course of time however, the lands started losing fertility and demanding larger fertilizers use. Pests became immune requiring stronger pesticides. Realizing such side effects of conventional agricultural practices, the Ministry of Commerce launched the National Organic Programme in April 2000 and since then the Agricultural and Processed Food Products Export Development Authority (APEDA) is implementing the National Programme for

Organic Production (NPOP) (Bhattacharyya and Chakraborty, 2005). Due to increased cost of farming couples with environmental and health issues, farmers in India are gradually shifting back to organic farming. Consumers are now willing to pay higher premium for the healthy organic food. According to the International Fund for Agriculture and Development (IFAD), there are over 44,926 certified organic farms in our country making it one of the most important exporters of organic food to the developed nations.

THE SUSTAINABILITY ISSUES

Ecological Perspective

Most of the conventional farm practices are ecologically unsustainable for natural resources and soil fertility enhancing erosion and greenhouse forcing. Sustainable agricultural practices are intricately linked with ecological sustainability in terms of: (1) improved soil fertility, (2) increased ability of top soil to retain organic matter, nutrients and water, (3) increased diversity of crops, microbes and other plants and animals in and around the field, (4) reduced use of hazardous chemicals including pesticides; (5) minimized soil erosion, landslides and improved green cover to conserve soil, (6) increased carbon sequestration and, (7) reduced energy demand.

***Economic sustainability*:** Agriculture can be sustainable only if it has a long-term economic viability. Conventional agriculture, which follows the principle of diminishing return, may pose long-term economic risks than its sustainable counterpart. The issues that need concern are:

1. *Export vs. local orientation:* From economic perspective, an export-oriented production system is considered more important than those that supply domestic demands. The Indian organic produce market is mainly export oriented. Focusing on export alone involves hidden costs including transport and risks to local food security. Policies considering domestic demands particularly food security as equally important are needed for a rationale balance of trade.

2. *Debt:* The green revolution raised India's grain production by multifold. At the same time, a large number of small-scale farmers trapped into debt. They took loans to raise production and on failure in re-paying, about 40,000 desperate farmers committed suicide.

3. *Market risk:* Concentrating on specific commodities although promises high economic returns, is vulnerable to market risks. Market fluctuates quickly and a disproportional sweep of low priced international agricultural produce into the national market, may lead Indian farmers at risk. As a WTO signatory, the Indian government is under pressure to open its economy to the global market and hence unable to protect farmer's interest especially those of small farm holders.

4. *Employment:* Agriculture is the main source of employment for rural people. Specialized and mechanized practices reduce rural employment. Sustainable agriculture, as witnessed through organic farming system, being labor-intensive helps overcome such problems.

***Social sustainability*:** The social sustainability of farming techniques focuses on social acceptability and justice. Ignoring these issues may lead to loss of valuable local knowledge and provoke political unrest. This needs serious attention as our country has a large share of traditional knowledge and culture. The issues that need serious concern include:

1. *Inclusiveness:* Development is a process of organized and dimensional growth driven by negative feed backs. It cannot be sustainable unless it is inclusive reducing poverty for the broad masses of people. This has particular concern for countries like ours having very large gap between rich and poor. The government needs to explore ways to enable rural poor to get benefit from agricultural development.

2. *Political unrest:* Rising gaps between rich and poor feed social injustice driving poor masses to feel neglected and excluded from developmental opportunities. The result is the political unrest, violence, and economic unstability.

3. *Local acceptance:* Many new technologies fail for being based on practices followed outside. Sustainable agricultural practices consider local social customs, traditions, norms and taboos. Thus, the local acceptance enhances harmony, fulfill needs and promote sustained growth and yield.

4. *Indigenous knowledge:* India is among the leading countries regarding its climatic, biotic and cultural diversities. Our country has a vast treasure of tribal diversity and traditional knowledge. Sustainable agriculture often focuses on the use of traditional knowledge and local innovation. Locally adapted breeds and crop varieties coupled with their social structures to manage and conserve common resources, can support strengthen stability in agriculture. A balance use of indigenous knowledge with appropriate information added from outside would drive sustainable agricultural to enrich itself.

5. *Gender:* In our traditional agriculture, women bear the heaviest load in terms of labor. In modern conventional farming men often benefit the most by controlling what to grow and how to spend the resulting income. Sustainable agriculture ensures that the loads and benefits to be shared more equitably between men and women.

6. *Food security:* Modern farming approaches in India consider few crops only and fail to provide variety and a balanced diet. Sustainable agriculture ensures food

security by improving the quality and nutritional value of food with greater range of crop varieties and edible produce.

7. *Participation:* Traditional society in India is driven by wealth and caste distinctions. Conventional farming innovations often exacerbate these gaps. Sustainable agriculture consciously targets the less well-off people as well. From social point of view, sustainable agriculture involves full participation of vibrant rural communities to ensure safe and sustained food supply for everyone.

Soil Fertility Stability

In agriculture, soil fertility declines over time due to continuous extraction of nutrients with crop harvest, soil acidification and compaction and when the replenishment with fresh nutrients is inadequate, over application is inevitable. Global fertilizer use increased from 27.4 million tons in 1959/60 to 143 million tons in 1989/90 which is anticipated to reach to 208.0 million tons by 2020 (Byrnes and Bumb, 1998). However, despite use of new and improved crop varieties and chemical fertilizers, crop yield began to slow down in the latter part of the 20^{th} century. The world's annual cereal yield growth rate has declined from an average of 2.2 percent in the 1970s to 1.1 percent in the 1990s (Gruhn *et al*., 2000). In many parts of the developing world sufficient availability of inorganic fertilizers is an important constrain for food production and farm income (Henao and Baanante, 1999).

Further, in a comparative analysis of soil organic amendments using broilter litter leaf compost (BLLC); dairy manure leaf compost (DMLC); raw dairy manure (RDM) and conventional mineral fertilizer (CNV) application, the respective ratios of N input to N leached were found to be 87, 63, 34, 25 with clover cover and 20, 7, 8, 7 with hairy vetch cover (Hepperly *et al*., 2009).Thus, nutrient management through organic farming helps stabilizing soil fertility via improving nitrogen fixation and reducing nutrient leaching.

Soil microbes are among the most important components to regulate soil organic matter decomposition and nutrient cycling. An acre of living topsoil contains approximately 900 pounds of earthworms, 2,400 pounds of fungi, 1,500 pounds of bacteria, 133 pounds of protozoa, 890 pounds of arthropods and algae, and even small mammals in some cases (Pimentel *et al*., 2005). Microbial biomass (C_{mic}) in natural soils ranges between 90 and 2300 µg per gram of dry soil. However, active microbial biomass in agricultural soils range between 75 and 272 µg per gram of dry soil indicating that much of soil microbial biomass may be present in a dormant state (Bae *et al*., 2002). A balanced ratio of microbial biomass and activity is needed to consistently release nutrients for plant and microbial growth. Organic supplements are easily colonized by microbes and increase other soil properties maintaining fertility stability. XU *et al*., (2008) reported that in red soil of tea garden in China, soil amendments with straw mulching + 100% organic manure; straw mulching + 75% organic manure + 25% fertilizer; straw mulching + 50% organic manure + 50% fertilizer; straw mulching + 25%

organic manure + 75% fertilizer; 100% fertilizer, and intercropping with white clover, increased the microbial biomass by 17.05%, 32.38%, 32.05%, 24.30% 26.23% and 24.63% respectively.

OPPORTUNITIES

Carbon Sequestration

Anthropogenic activities such as fossil fuel combustion, fertilizer production and land-use changes have dramatically increased the global CO_2 concentration which is expected to reach 600 ppm before the middle of this century (Wuebbles and Jain, 2001). Increasing concentration of greenhouse gases (GHG), particularly CO_2 in the atmosphere could lead to a rise in average earth surface temperature by 0.17^0C per decade (IPCC, 2001) and 0.5 – 1% of precipitation per decade in most of the Northern Hemisphere and 0.3 % in tropics and sub-tropics (Wang *et al*., 2010). These activities negatively affect land productivity, biomass accumulation, and biodiversity. Fossil fuel combustion is the prime cause of rising CO_2 level followed by changes in land-use pattern. Deforestation accounts for an annual release of carbon between 0.9×10^{12} and 2.5×10^{12} kg, about one third of which comes from oxidation of soil carbon in the tropics mainly linked with changes in land-use pattern (Lal, 2010). A substantial amount of global CO_2 comes from soil through decomposition, mineralization and soil respiration (Jabro *et al*., 2008). Conventional agricultural practices that most often accelerate these processes can substantially influence atmospheric C balance on global scale.

Knowledge of relative C-storage and flux characteristics of converted ecosystems (such as agro-ecosystems) are essential for predictive global geosphere-biosphere modeling and for the amelioration of increased atmospheric CO_2 levels through C-sequestration. The mechanism and potential of C-sequestration in converted ecosystems are still not well understood and probably for this reason, predictions made for global carbon balance remain uncertain (Idso *et al*., 2011). The soil C pool reflects a balance between the input and output and if the carbon flux is low relative to storage it leads sequestration in soil but a higher flux cause C loss. As per IPCC (2007) report, soil carbon sequestration holds the greatest global C mitigation potential. Most agricultural soils have lost 30% to 70% of their antecedent SOC pool (Lal *et al*., 2007). Soil carbon sequestration is cost effective and may contribute to about 89% of total C mitigation (Smith *et al*., 2007). FAO has prepared a Global Carbon Gap Map that identifies areas of high carbon sequestration potentials (FAO, 2008). India, representing almost all major climatic zones and wide range of land use systems, has vast opportunities for soil carbon sequestration.

Conversion of natural to agricultural ecosystems causes depletion of SOC pool by as high as 60% in soils of temperate regions and over 75% in cultivated soils of the tropics (Lal, 2010). Since the soil C can have a stable and long residence time, even hundreds to thousands of years under many circumstances (Lal, 1998b), the conversion of plant sequestered C to soil organic C could play a crucial role. Soil is an ideal reservoir of organic C, however land degradation could lead to loss of 30-40 Megagram C ha^{-1} in crop land and 40- 60 Megagram C ha^{-1} in degraded soils (Wang *et al*., 2010). Carbon sequestration can offset fossil fuel emissions by 0.4 to 1.2 Gt of carbon per year, or 5 to 15% of the global fossil fuel-linked emissions (Lal, 2010). In addition, compared to C passively stored in a forest, the SOC in agricultural soils actively benefit food production and improve agricultural sustainability (Hutchinson, 2007). For instance, an increase of 1 ton of soil carbon pool of degraded cropland soils may increase crop yield by 20 to 40 kg/ha of wheat, 10 to 20 kg/ha of maize, and 0.5 to 1 kg/ha of cowpeas (Lal, 2010) indicating direct link between carbon sequestration and crop production.

Soil constitutes the largest carbon pool of approximately 2500 gigatons (including 1550 Gt of soil organic carbon (SOC) and 950 Gt of soil inorganic carbon, SIC), which is almost 4.5 magnitude greater than that stored in the biotic pool (560 Gt) and almost 3.3 times the size of atmospheric pool (760 Gt) (Bernoux, 2006). Among the major determinants regulating C-flux or storage in soil include climate (especially temperature), soil moisture, microbial biomass and quantity and the quality of natural and added organic inputs (Trumper *et al*., 2008). Although the major goal of any agricultural practice is to enhance crop yield, recent global attention has focused serious attention to link agricultural management strategies with C–sequestration and sustainability of agro-ecosystems (Smith *et al*., 2007). Accordingly, soil organic amendments (crop residues, farm yard manure, green manure, compost etc) are used for enhancing agronomic yield and soil fertility stability (Pandey *et al*., 2008) while increasing the soil C pool.

Sequestration of C may be in the forms of soil organic carbon (SOC) and soil inorganic carbon (SIC). The rate of SIC sequestration as secondary carbonates is low (5 to 150 kg C/ha/yr) and is accentuated by biogenic processes and leaching of carbonates into the groundwater (Nordt *et al*., 2000), especially in soils irrigated with water containing low carbonates. Upon dissolution, CO_2 in soil air forms carbonic acid that precipitates as carbonate of Ca^{+2} or Mg^{+2}. Cations such as Ca^{+2}, Mg^{+2}, K^+ and Na^+ supplied from outside the ecosystem enhance SIC sequestration (Nordt *et al*., 2000). Some external sources of cations include eolian dust, Ca^{+2} dissolved in rainwater, sea salts and sprays, application of biosolids and amendments.

There are two major compartments of organic C in plants; the smaller size, with rapid turnover is termed labile and the larger and, inert counterpart with slow turnover is termed recalcitrant (MacLauchlan and Hobbie, 2004). Chemical recalcitrance is conferred by high molecular weight, irregular structure and aromatic structures (Krull *et al*., 2003). Physical fractionation relies on differences in either particle density or size of labile and recalcitrant fractions. The light fraction is considered to be labile whereas the heavy fraction is assumed to be stabilized onto surfaces of clay particles making it more resistant to microbial degradation. The active organic C consists of decomposable organic - C, resistant organic - C, microbial biomass - C, and humified organic C (Janik *et al*., 2002). Under anaerobic condition, as happens in rice cultivation, most of the C entering the soil is labile and therefore respired back to the atmosphere. About 1 percent of that entering the soil (55 Pg/year) accumulates in stable fractions (0.4 Pg/year) with long residence times (WSR, Report 2004). Recalcitrant SOM are considered more resistant to tillage, although it is also sensitive to other soil management practices (Ding *et al*., 2002).

With a large geographical land area and diversity of eco-regions, India has a considerable potential of terrestrial carbon sequestration. Soil organic carbon (SOC) in most of the cultivated soils in India is less than 5 mg g^{-1}. This amount is less than one third of SOC (15-20 mg g^{-1}) in uncultivated soil (Nambiar, 1994). Conventional agricultural practices such as plowing, removal of crop residues, soil fertility mining and accelerated soil erosion are mainly responsible for low SOC in cultivated soils. Soil erosion alone leads to a soil C loss of 4.3 to 7.3 Tg C y^{-1} (Lal, 2004). In addition, monocropping pattern, also as being followed in many parts of the country, accelerate soil C and N losses (Drinkwater *et al*., 1998). After USA (75-208 Tg C y^{-1}), China (105-198 Tg C y^{-1}) and European Union (90-120 Tg C y^{-1}), India occupies fourth position (39-49 Tg C y^{-1}) in potential rate of C sequestration in cropland (Wang *et al*., 2010). Of the total potential of average soil C sequestration of 44 Tg C y^{-1} in India, an average of 8.5 Tg C y^{-1} can be sequestered by restoration of degraded soils and ecosystems, 6 Tg C y^{-1} by erosion control, 6.5 Tg C y^{-1} by adoption of RMPs on agricultural soil and 24 Tg C y^{-1} as secondary carbonates (Lal, 2004). Among the eco-regions, semiarid and sub-humid regions have the strongest potential of C-sequestration (Nordt *et al*., 2000). Thus, a rational shift in agricultural practices alone may contribute massive carbon sequestration at scale of year and help mitigating global atmospheric C balance. Common recommended management practices (RMPs) include mulch farming, conservation tillage, agro-forestry, diverse and intercropping systems, crop rotation, cover crops, and integrated nutrient management including the use of manure, compost, biosolids, improved grazing, and forest management (Wang *et al*., 2010).

Further, many agricultural activities enhance GHG emissions (Flessa *et al*., 2002). Since soil C sequestration refers to the balance of C in soil which remains after deducting total C emission from total C input from all sources at a given time in unit area, agricultural activities-linked GHG emission bears significance (Lal, 1999). Rice is an important crop in India constituting over 42.5 % of the area under cereal cultivation (Ramanjaneyulu and Kuruganti, 2009). Rice is cultivated under flooded condition and the anaerobic condition created during rice cultivation leads to emission of CH_4 and N_2O (Pathak *et al*., 2005). More importantly, the input such as synthetic fertilizers, pesticide and high frequency of irrigation which are massively used in India for enhancing agronomic yield, substantiate to this hidden cost. For a vast agricultural land of India, total emission of GHG could be a massive amount. A recent study conducted in Punjab indicated that organic amendment can significantly reduce methane emission from rice field (Khosa *et al*., 2010). Thus, adoption of RMPs on agricultural land would sizably reduce this environmental cost. Looking into the vast potential of C sequestration and GHG emission mitigation, the government needs to encourage farmers at all levels towards adoption of recommended management practices. Such practices, if properly implemented, not only will provide a cost-effective opportunity to climate change mitigation but also help sustain food security in India.

Cost-benefit Issues

Agriculture is the base of economic policies and is the ultimate driver of national economic growth and poverty alleviation in many developing countries including India. The industrial agriculture however, that increased grain production and farmers profit by a large margin, is being driven by significant externalities with long standing hidden cost such as loss of natural resources, effects on human health and on agriculture itself (Subba Rao, 1999). Organic farming has now been tagged not only for minimizing externalities but also for its cost effectiveness. Model estimates indicate that organic methods have potential to produce enough food to sustain current human population and an even a larger population without increasing the agricultural land area while reducing the detrimental effects of conventional agriculture (Badgley *et al*., 2007). Some government programs in Sweden, Canada, and Indonesia have demonstrated that organic farming can reduce pesticide use by 50% to 65% without sacrificing crop yields and quality along with 50% lower expenditure on fertilizer and energy use (Pimentel *et al*., 2005).

The increasing demand for organic produce has created new export opportunities and many developing countries have started to tap lucrative export markets for organic produce. Export of tropical fruits and African cotton to the European food industry, Zimbabwe herbs to South Africa, and Chinese tea to the Netherlands and soybeans to Japan are classical examples of organic food export market. Indian organic farming industry is almost entirely export oriented, running as contract farming under financial agreement with contracting firms. Further, the majority of farmers in India are opting this practice motivated by attractive market and price margins (Sharma, 2001). Thus, the capital driven policies coupled with lack of open local market for sale of organic produce may negatively influence the bottom-up response on organic farming discouraging small farm holders who have currently no access to organic agricultural technology and certification.

Cost-benefit analysis (CBA), sometimes called benefit-cost analysis (BCA), is an economic decision-making approach used particularly in government and business sectors. It compares the total expected costs of each option against the total expected benefits, to asses if the benefits outweigh the costs and with what margin. The benefit-cost-ratio (BCR), the ratio of net value of crop produce (minus cost of inputs) to cost of input that depicts total financial return for each rupee invested in this production system (IGNOU, 2007), is an important tool to assess economics of farming. The production system is considered viable if the ratio is more than one. For agriculture sector, the component of cost estimate includes fixed costs, variable cost and other costs. Fixed cost includes land, land revenue, depreciation of farm implements and interest on fixed capital. Variable cost includes cost of planting materials, organic inputs, pesticides, irrigation, bullock, tractor and cost of labor and irrigation and other costs include cost of marketing, power consumption, storage and packing.

A study, based on 120 farmers of six villages of Shimoga and Bhadravati Talukas of Karnataka State of India, compared the cost-benefit components of organic rice production (Suresh and Kunnal, 2004). The study indicated that in organic farm, although the average cost of cultivation per acre of paddy was lower only marginally, the net return increased by over 40% suggesting that a properly planed organic farming is beneficial not only from environmental point of view but also from economic margin. Another study undertaken by Central Institute for Cotton Research, Nagpur India indicated that the cost of cultivation under organic farm was about 21 % lower than that under conventional farm mainly due to no use of chemical fertilizers and insecticides (IGNOU, 2007). An increase in price margin subject to market demand of organic produce status further substantiates total benefits.

Similarly, the benefit cost ratios estimated for per acre organic and inorganic wheat and carrot were found to be 1: 1.08; 1: 1.01 and 1: 1.52; 1: 1.44 respectively (Mehmood *et al*., 2011). In particular, for rain-fed systems organic agriculture out-performs its conventional counterpart (Ramesh *et al*., 2005). A survey of 208 projects in developing countries, in which contemporary organic practices have been introduced, revealed average yield increases of only 5–10% in irrigated crops and 50–100% in rainfed crops (Ptetty and Hine, 2001). In another study, it was observed that, despite reduction in crop productivity by 9.2%, organic agricultural produce provided a 22.0% higher net profit to farmers due to coupled effect of 11.7% reduction in cost of production and 20-40% greater premium price of certified organic produce (Ramesh *et al*., 2010). The successive improvement in soil quality in organic farming constitutes an important hidden benefit as it helps reducing cost of future fertilizer needs (Escobar and Hue, 2007).

Employment Opportunities

One of the major issues of developing countries is the problem of unemployment especially for a large sector of less skilled group. Organic farming requires over 15% more labor than traditional farming and therefore provides rural job opportunities (Pimental *et al*., 2005). Some of the commonly used organic farming techniques such as strip farming, non-chemical weeding, and production, collection and transportation of organic supplements all requires significant labor. The labor scarcity and cost involved therein, may constrain adoption of organic farming in developed countries and also for cash-poor farmers in developing countries. However, for countries like India, labor as well as the cost involved therein is not a constraint. Instead, organic farming can generate employment opportunity for a vast section of rural communities. In India, women constitute an important component of labor work force in agriculture.

Thus, the variations in nature of works and in planting and harvesting schedules may provide more work opportunities for rural women and a more evenly distributed and stabilized employment opportunity for male agricultural labor. It makes farmers and farm labors busy throughout the year with crops such as wheat, hairy vetch cover, rice and summer crops and mechanical weed control. In conventional farming more labors are required during spring and fall, providing only part-time job opportunity. Thus, the organic farming addresses the concept of cost-effectiveness also.

CONSTRAINTS

Environmental Constraints

Soil quality**:** Of the total reported geographical area of India (304.89 m ha), about 80% (264.5 m ha) is under agriculture, forestry, pasture and biomass production (Lal, 2004). Our country supports approximately 16% of the world's human population and 20% of the world's live stock population on merely 2.5% of the world's geographical area. The steady growth of human population coupled with fastened developmental activities exerts heavy pressure on India's limited land resource and cause severe land degradation. Despite overuse of synthetic fertilizer and pesticides, the agricultural productivity in our country reduced from 234.5 million tons in 2008-09 to 218.2 million tons in 2009-10 due to soil quality degradation and nutrient mining (NCAER, 2011). According to latest estimates (SOE Report, 2001), about 184.8 m ha of Land (57% of total land area) has been degraded due to the following one or other reasons:

1. About, 111.7 m ha lands in India are degraded due to soil erosion and desertification, 15.5 m ha due to salinity and water logging and 3.2 m ha by nutrients depletion (Lal, 2004). Soil erosion by water is a serious problem in the Himalayan region and other sloping lands where removal of vegetation cover and tillage make soils more susceptible to erosion. Wind erosion and desertification are common in dry regions. Salinization, caused by excessive irrigation and lack of adequate drainage, is a problem in regions irrigated by canal water. Ground water depletion occurs in regions intensively irrigated by tube wells (FAO, 1994).

2. The rate of loss of soil organic carbon (SOC) and total nitrogen (TN) in surface soil horizon decreases with time in cultivation. For instance, An *et al*., (2008), observed that, in 0-20 cm surface soil horizon, the initial rates of decrease during 0-4 yrs were 1.54 g kg^{-1} yr^{-1} and 0.10 g kg^{-1} yr^{-1} for SOC and TN, respectively. These high rates dropped to 0.62 g kg^{-1} yr^{-1} and 0.06 g kg^{-1} yr^{-1} respectively, for yrs 4-9 and so on.

3. Over 10.9 m ha of permanent pasture contains 42 animals per hectare for grazing against the threshold level of 5 animals per hectare (Sahay, 2000). Overgrazing and massive extraction of fodder increase compaction and reduces infiltration and ultimately changes the soil quality.

4. Most parts around metropolish and industrial areas are witnessing massive release of solid and liquid waste. In addition, India is witnessing opencast mining in many of its geographical regions with consequent increases in soil pH, Mg: Ca ratio, bulk density, clay dispersibility, total magnesium and calcium carbonate and decreases in soil porosity and available phosphorous (Sha-Sha, 2011).

***Water quality*:** According to the National Water Quality Inventor report, compared to the point sources, agricultural nonpoint sources (NPS) are the leading contributor to water quality degradation of rivers and lakes. Agricultural activities as non-point source of pollution include the following:

1. *Sedimentation:* Agricultural activities, deforestation and overgrazing expose soil and make it prone to erosion. Runoff water carries soil particles and dumps them into nearby lakes and streams. High frequency of flooding in major rivers of India is due to rapidly rising sediment deposits and reducing channel depths (Sridhar, 2007).

2. *Nutrients:* Agricultural release of nutrients especially phosphorus and nitrogen are accelerating eutrophication and fish kill in surface waters. Excess application of N also lead to ammonia volatilization and N deposition at remote locations (Pandey and Pandey, 2009a). In addition, farmers and ranchers often feed and maintain livestock in small areas which slowly become major source of animal waste. Direct release or runoffs from poorly managed facilities lead water quality problems.

3. *Irrigation:* In arid areas, where rainwater does not carry minerals deep into the soil, evaporation of irrigation water can concentrate salts which along with nutrients, pesticides and heavy metals are added to downstream lakes and rivers through runoff. It also causes selenium buildup that, when reach to downstream water, harms waterfowl.

Further, the quantity of fertilizer use, type of farming practices and crop species also affect the ground water quality. Zhao *et al*. (2007) have reported that the average groundwater nitrate concentration of seven Northern provinces of China reached to 11.9 mg L^{-1}, about 34.1% exceeding the WHO standard for drinking water. According to Lian-feng *et al*. (2011), nitrate in groundwater under vegetable field was 13.8 mg L^{-1}, 2.8 magnitudes higher than that under croplands and, under orchards it was 9.3 mg L^{-1}, 1.9 magnitudes higher than that of croplands. Between 1950 and 1995, about 6×10^8 tons of phosphorus was applied to the croplands globally (Carpenter *et al*., 1998). In high yielding farmlands, nutrient input continuously exceed production requirements and farming methods increase land vulnerability to run-off and erosion. From organic farm lands, nutrient loss to runoff is considerably low. Goulding *et al*. (2000) reported that N loss from organic farms (52 kg ha^{-1} yr^{-1}) was about 34 % less than those from conventional farms (78 kg ha^{-1} yr^{-1}).

Additionally, green manures help crops to out-compete to weeds, and prevent soil erosion. Ryegrass sown as a cover crop has been shown to reduce nitrate leaching from spring barley up to 35 kg N/ha (Thomsen & Christensen, 1999). Similarly, the average leaching loss from bare soils following cereals has been shown to reduced up to 25 kg N/ha by sowing an overwinter catch crop (Shepherd, 1999).

Health issues: Recent studies indicate, in addition to soil and water-borne sources, air-borne toxicant also contaminate crops and vegetables even in areas away from emission sources. By developing appropriate measures, agricultural land may be refrained from irrigation–linked contamination or from wastes release to farmlands. However, protections of crops from air-borne toxic materials need more serious concern for being transported to long distances downwind. Atmospheric deposition of heavy metals increases their concentration in soil and consequently in dietary component of agricultural produces with long term health risks (Pandey and Pandey, 2009b).

Recent researches in our country have shown elevated levels of Cu, Zn, Pb, Ni and Cd exceeding permissible limits in crops and dietary vegetables grown in and around urban industrial areas (Singh *et al*., 2009; Suruchi and Khanna, 2011). Such reports are also available for countries like China, (Zhuang *et al*. 2009), Iran, (Bigdeli and Seilsepour, 2008), and Nigeria, (Eriyamremu *et al*. 2005). Pandey *et al*. (2009) observed that the concentrations of heavy metal in vegetables vary with species as well as with plant parts and leafy vegetables with large surface area exposed to air environment bear more significance as far as dietary contamination-linked human health concerns. Rupert *et al*. (2004) mapped hazard index (HI) around junctions of major roads, railways and canals and identified hot spots with potential health risk. Smuc (2010) analyzed contamination factor around Zletovska river and found very high concentrations of Ag, As, Cd, Cu, Mo, Ni, Pb, Sb and Zn in Kocani paddy fields. The bioavailability of heavy metals varies depending upon soil types and fertilizer application and organic amendments most often reduce metal bioavailability (Angelova *et al*., 2010).

Pesticide application also contaminates agricultural produce. In India, average dietary intake of pesticide residue is 32.5 mg per day per person for vegetarians and 356.5 mg per day per person for non-vegetarians (Ghosh *et al*., 2004). These problems are more acute in high yielding farmlands of Punjab (Nagarajan, 2003a). Among the organophosphorous pesticides, methyl parathion and ethyl-chlorpyrifos have been shown to cause more sever health risks than those caused by chlorpyrifos and malathion (Bhanti and Taneja, 2007). Similarly, mercaptothion, permethrin and chlorpyrifos also found as most frequently detected pesticides in cereal-based food (Dalvie and London, 2009). At present, India is the largest producer of pesticides in Asia and ranks twelfth in the world for the use of pesticides with an annual production of 90,000 tons. A vast majority of population in India (56.7 percent) is engaged in agriculture and is therefore exposed to pesticides used in agriculture which results in acute and chronic health problems. Organic farming practices that minimize the use of such chemicals may reduce pesticide exposure to environment in general and man in particular.

Irrigation: Industrial and municipal wastewaters containing toxic metals such as Zn, Cu, Pb, Mn, Ni, Cr, Cd are increasingly being used for irrigating crops especially in urban and peri-urban areas of developing countries due to easy availability, disposal problems and scarcity of unpolluted fresh waters. Regular irrigation of crop land with sewage and industrial wastewater may cause heavy metal accumulation in soil (Zhang *et al*., 2008) and vegetables (Singh *et al*., 2010) and degrades soil quality (Muchuweti *et al*., 2006). In a study at Rajasthan, conducted by Arora *et al.* (2008), plants irrigated with wastewater accumulated 116–378 mg/kg Fe, 12–69 mg/kg Mn, 5.2–16.8 mg/kg Cu and 22–46 mg/kg Zn. In a study at Varanasi, continuous application of treated waste water was found to cause accumulation of Cd (1.55 - 13.80 $\mu g\ g^{-1}$), Pb and Ni (10.45 - 39.25 $\mu g\ g^{-1}$) exceeding their safe limits (Singh *et al*., 2010). Pandey *et al*. (2009 a, b) have reported heavy metal contamination of Ganges, the major river system of North India, and suggested that regular irrigation could lead long standing health risk to consumers. Similarly, in a study in China, concentrations of Cu and Ni in sewage-irrigated top soils were beyond Chinese, agricultural soil environmental quality criteria (Zhao *et al*., 2010). In addition to toxic metals, long term application of sludge or sewage effluents for irrigation results in accumulation of chlorides and sulphates and gradual building up of salinity. The overall effect is reduced crop growth and risks to human health.

***Atmospheric deposition*:** Atmospheric deposition of pollutant aerosols is rising in many parts of the world including India (Singh and Pandey, 2010). Agriculture around Dabaoshan mine area of South China (Zhuang *et al*., 2009) showed exceedance of maximum allowable concentrations of Cu, Zn, Pb and Cd in paddy and garden soils and high dietary intake of Cd and Pb through rice and vegetables under atmospheric influences. The potential risk to local inhabitants around mining areas has also been reported by other workers (Pruvot *et al*., 2006). High atmospheric depositions of heavy metals and increased accumulation in crops and vegetables have also been reported in India (Sharma *et al*., 2009). Atmospheric deposition of toxic metals could affect human health and plant performance directly or through soil and food chain associated routes (Pandey and Pandey 2009c).

Pandey and Pandey (2009c) reported that deposition of heavy metals not only leads to multifold accumulation in tomato, egg plant, spinach, amaranthus, carrot and radish but also cause significant damage to soil microbial activity in organically amended soil. Thus, deposition of heavy metals may compromise organic farming's ability of stabilizing soil fertility and providing toxin-free produce. Water-borne contamination to organic agriculture may be avoided by appropriate alternatives. However, atmospheric deposition may contaminate areas far from sources of emission and, is difficult to control. Despite all efforts to raise safe and hazard-free agricultural produce, rising atmospheric input of toxic metals in agricultural systems if continued, will have a long standing concern for the success of organic agriculture.

***Resource need*:** Livestock resources have played multifaceted roles strengthening indigenous agricultural practices and generating income and livelihoods for large masses of rural dwellers in India. However, with the advent of technology in agriculture, livestock population in our country is rapidly declining. From 1997 to 2003 indigenous cattle population declined by 10.23% and for mules, donkey and camels the decline was 20.36, 26.30 and 30.70% respectively. Advent of technology in agriculture coupled with inadequate feed supply are the major determinants reducing attraction of common people towards livestock production, and thus the availability of manure, even to small farm holders. Natural pastures, crop residues and kitchen waste are the major feed components in India. The area under natural pasture in India is rapidly declining as a result of expanding urban and agricultural areas. In particular, high frequency of drought often leads acute shortage of feed and most often exacerbate the cattle death in many areas of western states of the country. In the wetter regions, feed supply could be adequate, but the problem is that the area under natural pasture and range land is continuously declining. FAO strongly advocates that improved pasture and range land management practices are essential not only for supporting livestock production but also for restoring carbon pool, nutrient cycling and soil quality. Further, the type of dietary intake by animals strongly influences the amount of essential nutrients in their excreta (IAEA, 2008). Since organic supplements are required in bulk, their production, collection, transportation, storage and application all may be further be impeded by constrained labor and transport facilities for areas away from the site of production/collection. Traditionally, ox - drawn carts or trailers were used in many parts of our country. Corralling animals on cultivation fields during night has been used as an important option to minimize problems of transportation. A concerted effort is needed to increase the quantity and quality of feedstock and area under pasture and increasingly adopting livestock from agricultural sustainability perspective.

A major part of rural population in India is poor and use animal manure for domestic fuel. This further limits availability of animal manure for soil amendment. In a typical rural household in India about 1500-2000 kg (dry weight basis) of cattle manure is used as domestic fuel annually. The solution to this ‘competitive’ constrain requires a comparative evaluation of usefulness of manure for different purposes and search for alternative energy source or technology such as agro-forestry systems to maximize the availability of manure for soil fertility. For maintaining soil fertility and meeting crop nutrient demands, large quantity of these organic supplements are needed and accordingly, appropriate farm-scale management strategies considering cultural and socio-economic environment of farm holders are required. In particular, lack of sufficient amount of vermicompost and non-availability of biofertilizers in local market further constrain organic producers (Gill *et al*., 2000). Further, non-availability of appropriate amount of biopesticides sometime leads organic producers in India at high risk (Nirmala, 2003). Another major constrain in adopting conservation tillage and mulch farming in India is the least availability of crop residues returning to the soil. Use of crop residues and manure not only enhance soil organic matter content but also strongly support soil biodiversity, especially earthworm activity to increase soil quality and C sequestration (Lal, 2004). In India, most of the crop residues are removed from the fields for use as fodder and fuel. A decrease in area under natural pasture creates tremendous pressure on crop residue to be used as fodder. This together with rising use of crop residues as fuel in rural sectors led large scale use of mulch farming technique to a failure.

Thus, adoption of mulch farming technique as a potential tool to conserve soil organic matter content to sustain biomass/agronomic yield is possible if cost effective alternate sources of fodder and fuel are identified and made available at large scale.

***Certification*:** Access to certification, cost involved therein and a time lag of three years (conversion stage) often constrain farmers especially small land holders in India from adopting organic farming. Organic produce needs certification to ensure that all synthetic inputs are prohibited and soil building approaches are followed. Certification authenticates organic produce for consumers and validate price margin of the product in the market. The certification process aims at converting the growing area to comply with requirements of standard within a period of 3 years. For this reason, farmers who adopt organic management need to wait for up to three years under certification procedures that requires purging of chemical residues.

In India, the Director General of Foreign Trade, New Delhi, permits the export of organic produce provided that these are produced, processed and packed under a valid organic certificate issued by a certification agency accredited by an accreditation agency designated by the Government of India. The Government of India has recognized Tamil Nadu Organic Certification Department, Agricultural and Processed Food Products Export Development Authority (APEDA), Spice Board, Ministry of Commerce and Industry, Coffee Board and Tea Board for the purpose. However, lack of knowledge, rationale capital and access to certification discourage small farm holders in developing countries including India. Over overcome these constraints the government of India is providing extension services, training and institutional demonstration, fiscal incentives to encourage organic farm sector to strengthen nation's economy and sustainability.

***Social acceptance*:** Indian agriculture system is under a transition stage. The increasing demand for organic produce has created new opportunities and a small sector of farm holders are aspiring economic boom with lucrative export markets. On the other hand, majority of small farm holders are still dependent on government incentives to meet the cost of input and are striving for a rationale profit margin for their produce in indigenous market. Small farm holders in India therefore, are apprehensive in adopting this agricultural practice. Major issues that constrains farmer's acceptance in India include: cost benefit anomalies, access to certification, non - availability of organic supplements and lack of appropriate knowledge to RMPs. Our country lack indigenous lucrative market for locally grown organic produce. Further, under conversion stage, economic viability depends on the status of the farm. Yield declines during first year of conversion and steadily increases in subsequent crop cycle. Once the farm is established organic, the yield enhances and the cost of production declines. Accordingly, there may be a deficit in net income under organic farming compared to conventional one up to third year. As input cost declines, the net income increases progressively fourth year onward (IGNOU, 2007). However, the three initial year deficit coupled with certification associated constraints often make small farm holders apprehensive. Major issues that need to be considered to resolve farmers' apprehension in India include: to distinguish the benefit-cost ratio of different crops in organic and chemical farming practice, to understand the difference of production cost under organic and chemical farming, to assess whether net profits are higher in organic farming system and with what margin for considering conversion of conventional land to organic land and, to enhance appropriate government incentives and extension services to support farmers capital input and knowledge base and to ease certification access. These issues may be furthered using relevant variables to address the benefits associated with improved health and reduced externalities.

Conclusions

The historical overview shows that India is among the pioneer civilizations witnessing ancient agriculture and domestication of animals. Indian agriculture evolved principally as an ecologically sustainable approach using natural inputs for enhancing crop yield. Modern innovations and technology diffusion to agriculture coupled with massive demand of food grains by burgeoning human population transformed the agriculture from a circular causation mode to a linear flow model with complete dependence on external inputs of synthetic fertilizers and pesticides. Massive use of these materials although increased agricultural yield by many folds, significantly contributed to environmental degradation including green house forcing. The modern concept of organic farming (OF) emerged in response to the questions raised on health, environment and sustainability issues.

With a large land area and diversity of eco-regions, there is a considerable potential of soil C sequestration in India. The SOC in cultivated soils is less than one third to one fourth compared to those in uncultivated soils. This gap in soil C pool could balance net emission from fossil fuel combustion of Indian sub-continent. In addition, OF has vast opportunity for rural employment and livelihood security. Despite these issues, the growth of OF in India is relatively slower. An overview of this paper shows that there are a number of constraints impeding Indian farmers, especially small farm holders from adopting OF. Farmers' apprehension lies in non-availability of sufficient amount of organic supplements, bio-fertilizers and local market for organic produce. Additionally, lack of access to guidelines, certification and input cost coupled with capital-driven regulation by contracting firms strongly discourage small farm holders who constitute over 70% of farming community in India. There is a need for a comprehensive framework that integrates OF with bottom up responses, technology diffusion with reciprocal knowledge flow from farmers' institution and their local resources and innovation. This will help generating large-scale farmers' acceptance to solve ecological crisis in context to climate change and to address the health and livelihood security of large rural masses of India.

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