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Ecological Management of Rice Agriculture in Southern India

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ABSTRACT

As viable alternatives to industrialized commercial agricultural practice, diverse agricultural-practice models such as integrated agriculture, organic agriculture, permaculture, are currently available, which aim at achieving sustainability and environmental security. Because plentiful literature exists on these alternate models, in this paper I will attempt to discuss a few of the agroecological paradigms, which are vital for an effective management of ecosystems, rice ecosystems included, paving the way to sustainable management considering southern India as the intended landscape. One loss of high significance in the rice context of southern India is the rapid disappearance of native-rice varieties of India, because they have been steadily replaced with high-yielding varieties. Disregarding the associated costs of external inputs and germplasm qualities such as loss of non-grain biomass and desirable traits (e.g., tolerance to disease agents and pests, drought, and floods), southern-Indian farmers got blown away by the immediate and bounteous yields offered by the high-yielding varieties. Most importantly, changed management practices have led to extensive deterioration of the soil and landscape. However, the situation does not appear so dismal. Farmers in isolated pockets of southern India still preserve and use native-rice germplasms. Although rice is customarily raised as a monocultural crop, some of the trials indicate that it could be integrated with trees, which, however, need to be fast growing and nitrogen fixing. Rice is presented as a high water-consuming crop, because of spillover and percolation. Impact of rice cultivation on natural resources and water-based ecosystems is twofold: water withdrawal for paddy systems results in diminishing water availability for natural ecosystems (e.g., wetlands); and, rice ecosystems are responsible for the creation of human-made wetland systems. Maintaining biological diversity is the key for productive and sustainable agriculture: rice paddies being no exception. Integrated rice farming is one best practice that ensures how people can live in harmony with and in a respectful manner with Nature. System of Rice Intensification (SRI) is an innovative concept involving a combination of field observations of rice performance and a series of casual trials done over a decade supplemented by an accidental-early planting. Systematic efforts in rice transgenics are being made throughout the rice-growing world. GM technology is being portrayed as the magic bullet for remedying poverty, disease, and hunger; however, concerns prevail with regard to their safety to both environment and humans. We are living in a fast era; at least we think that speed and rapid turnarounds of events are the norms of today. Have we been led to think and talk about sustainability and initiate measures to practice it as much as we can, because our lives and actions are driven by speed? Is speed the root cause of the present malady, which has led us to think of modest slowing down through sustainable practices? Is the slow-design way out? Is sustainable rice agriculture in southern India an exception to this thinking?

Key Words: Agroecological Paradigms; Southern India; Rice Agriculture; Sustainability; Management

INTRODUCTION

Agricultural sustainability is a major contemporary challenge for India despite agricultural production enabling India to go from a net importer of food grains in the 1980s to becoming an important grain exporter by the 1990s. The development of pest-and disease-resistant high-yielding varieties (HYVs) and concomitant agricultural intensifications have enabled this agricultural transformation. Despite these agricultural advancements, India continues to experience staggering income disparities, disturbing unemployment rates, besides severe levels of malnutrition and poverty (Kumar 2011).

Diverse strategies are currently in place to alleviate malnutrition and poverty; for instance, improvement and strengthening of the poultry sector is an important effort made to achieve better nutrition and reduce poverty (Pica–Ciamarra and Otte 2009). Nonetheless, market and institutional weaknesses and failures have constrained resolution of these maladies, which have been awkwardly restricting any laterally thought-out development measure marshalled by the Indian-agricultural R&D sector. Another key downside induced by the indiscriminate use of intensified agricultural practice is the degradation of land and water resources, which manifest themselves in the form of public health issues, loss of biological diversity, loss of resilience in ecosystems, and negative impacts on livelihood security for the poor (Chandrappa and Ravi 2009).

In such a context, the words of Rajendra Singh Paroda (Secretary to Department of Agriculture, Government of India) made in 1999 (p. 117) are worthy of recall: "In future, land use planning on scientific lines will be aimed at sustainable agriculture. … In future, the availability of agricultural land will be restricted and exploitation of water resources for agricultural use will reach its limit. Sustainability will be a major concern. Technological change will thus emerge as a major determinant of sustainable agricultural growth. We will focus on enhancement of productivity through greater adoption of high yielding hybrids and varieties, research on diversification and post-harvest technology and conservation of agro-biodiversity. … We have to further develop integrated pest and nutrient management approaches, agricultural human resources, watersheds for rainfall areas, and implement management reforms. We have to pay attention to resource mobilization through consultancy and contract research, while at the same time selecting research priorities. This will make the goal of sustainable agricultural production a reality".

We are in 2012; nearly a decade has passed since the above statement. I will use this statement as a springboard to analyze the sustainability of contemporary-Indian agriculture, using the rice agroecosystems of southern India as a case study. I will reconstruct the historical and contemporary context for rice production in southern India to examine and address the feasibility of achieving food and environmental security for this important staple crop. Drawing on historical practice and contemporary agroecological paradigms, I will then outline the important missing components that may enable southern India's rice production systems to remain sustainable.

HISTORICAL AGRICULTURAL PRACTICE IN SOUTHERN INDIA

'Since every effort in this world relies on those who plough the soil, the farmer is the lynchpin of the wheels of the chariot — the world.'

—*Tiru-k-kurał*
(a *Tamizh* classic, *c.* 1st century AD); Ch 103, verse 2.

As evident from ancient Indian texts, ancient rulers of southern India were acutely aware that to be politically successful they were not simply to remain obliged to farmers, but to look at them and their land as a core part of their duty and responsibility. That this obligation towards land management was taken seriously is evident from the corroborating texts from southern India's historical trading partners. Descriptions of rural India by Fã-Xiãn (Fã Hien; 377-422 AD) and that of southern India by Xuãn-xãng (Huang Tsang; 602-664 AD) indicate that Indians managed agriculture by aligning it with Nature, its cycles, and its evolutionary dictates. Ninth and 12th century southern-Indian inscriptions reinforce that rice yields were high (Smith 2006). Investments in irrigation are evident in 3rd century southern-Indian inscriptions; they refer to constructed reservoirs (éri-s) and aquifers with their borders secured (Morrison 2010). The Grand Anicut (Kallanai) was built by the Çôla King Karikãla (c. 1st century AD) on the river Kãvéri (Ramaswamy 2008). With particular reference to rice cultivation, a southern-Indian inscription refers to the variety Kãr, which was cultivated during the later-Çôla period for consumption (c. 13th century) (Swamy 1973). Pałłu literature in Tamizh language (13th–16th centuries) lists more than 150 varieties of rice, with specific names given to each of them based on their morphological features and biological performance (Krishnamurthy 2007).

About a century ago, Johannes Augustus Völcker in his *Report on the improvement of Indian agriculture* (1893) indicates that Ŧanjavur district (10° 48' N; 79° 09' E; Tamil Nadu) harvested 12-1800 kg ha^{-1}, Coimbatore district (11° 16' N; 76° 58' E; Tamil Nadu) about 1300 kg ha^{-1}, and South Arcot district (11° 45' N; 79° 45' E; Tamil Nadu), 1500 kg ha^{-1} of rice[1] . An extensive report on agriculture in the Madras Presidency by Thomas Barnard refers to grain production in the 18th

[1] Harvest details and names of districts have been amended to present usage.

century (Prinsep 1885). Thomas Barnard, an engineer, surveyed Çengal-pattu District (12° 42' N; 79° 59' E; Tamil Nadu), which included about 800 villages in the 1770s. Of note is the reference in the Barnard report that the Madras Presidency in the 1770s included 44000 éri-s, large and small. Water abundance in Çengalpattu alone was estimated at nearly one-fifths of its total landscape (140/630 ha) (Sriram 2008), with a significant amount of this water devoted to rice cultivation. Barnard's survey, submitted to the Governor at Fort St. George in Madras on 14 November 1774.

CONTEMPORARY AGRICULTURAL PRACTICE IN SOUTHERN INDIA

By early 1980s, nearly 50% of India's land (180 Mha) had degraded: water logging was affecting 6% of cultivated area and soil alkalinization and acidity were affecting 3% (Government of India 2001). The key contributor to land degradation was soil erosion, accelerated by water and wind erosion, accounting for 70% soil loss; this degradation has been principally due to human activities, and secondarily due to a combination of human activities and natural causes (Government of India 2001). A significantly negative relationship had been established between land degradation and food-grain productivity in the 1980s and 1990s (Chadha et al. 2004).

Water is a critical limitation in southern-Indian agriculture. Irrigated-agricultural practice has been responsible for 80% of the total-water use in India (1990 data; Vyas 2003). Water usage for agricultural purposes rose sharply between 1967 and 1977 (coinciding with the Green Revolution), increasing the net-irrigated area from 31 to 55 Mha. Consequently, groundwater stock was getting rapidly depleted. Rainfed-agricultural states in southern India such as Ãndhra Pradesh and Karnãtakã are presently struggling with the effects of severe groundwater depletion with farmers exploring and extracting ground water from depths of 200 to 300 m.

Modern technology-based agriculture involves extensive water use coupled with indiscriminate use of synthetic fertilizers, pesticides, and planting of HYVs. Application of synthetic fertilizers rose nearly five-fold from about 3.5 million Mg (=megagram or ton) in the 1970s to about 17 million Mg in 2000; pesticide usage has nearly doubled (24 million Mg in 1970–1971; 46 million Mg in 1999–2000) (Agarwal et al. 1999). HYVs have intensified monocultural practice affecting flexibility and reducing farm-biological diversity. Since the first five-year plan period (1951–1956), Government of India has recognized the necessity of conserving and effectively managing resources for agricultural development; yet, the measures initiated have been either inadequate or inappropriate. For instance, the Government of India has only been able to restore 17% of the degraded land (174 Mha) until 2000 (Government of India 2001). Injudicious application of fertilizers and pesticides is another problem of contemporary Indian-farming, which has worsened the state of the soil and watersheds (Alam 2000).

The *New Millennium National Agricultural Policy of India* reinforces that it will seek to promote technically sound, economically viable, environmentally non-degrading, and socially acceptable use of the country's natural resources — land, water and genetic endowments — to encourage and promote sustainable agricultural practice (Government of India 2000). The 2002–2007 Plan derived from this policy emphasizes better natural resource management through rainwater harvesting, groundwater recharging, and regulating groundwater exploitation, watershed development, and restoration of water-inundated areas (Government of India 2002). In the context of synthetic fertilizer and pesticide application, the same Plan refers to injudicious use of nitrogen, phosphorous, and potassium; how that use has induced a dearth of micronutrients; that the reduced levels of soil-organic carbon need to be addressed by adapting a holistic approach stressing on an integrated plant-nutrient management practice. This Plan document also indicates organic farming as a thrust area aiming at sustainable use and management of agricultural resources.

TRANSITION FROM SUBSISTENCE TO COMMERCIAL AGRICULTURE IN SOUTHERN INDIA

Subsistence agriculture (SA) characterized Indian agriculture for ages. This practice involved production of limited quantities of produce in farms that were usually <1 ha and the produce was adequate to sustain the farmer's family. Subsistence farmers utilized either little or no mechanization. In short, a subsistence farmer did not produce to sell the produce; surplus production was rare. SA involves almost no application of fertilizers and pesticides. Nevertheless, SA is labour intensive, because of manual field preparation, weeding, planting, and transplanting. Indian rice cultivation was a subsistence practice until the 1950s. A majority of subsistence farmers leased land. The growing human population, however, led to reduced land size held by families. In spite of the small size of farms, subsistence farmers continued (and still are continuing) to take advantage of the limited land due to the lack of alternative sources of livelihood. Notwithstanding the preceding remark, Chand et al. (2011) indicate that the farms <0.8 ha perform better in terms of production; however, they are weak in terms of generating adequate income and sustaining livelihood (Chand et al. 2011).

In post-1947 India (i.e., since independence from the British rule), a jump from subsistence farming to commercial farming was aggressively promoted by the Government to lift productivity, which resulted in negative environmental and social consequences. For instance, the rising cost of cultivation drove farmers to find agriculture an unviable proposition; desperate farmers even committed suicide (see Deshpandé 2002, on farmer suicides in Karnãtakã in the mid-1980s). Indigenous-farming practices were successfully replaced by mechanization that resulted in unviable and unsustainable farm enterprises. Indian subsistence farming only achieved low levels of productivity when measured by modern economic and development metrics, but when other vital systems variables are factored into the equation, subsistence farming rises on scale to 'moderate' productivity levels, because it ensures sustainability and diverse, ecologically viable and performing agro-ecosystems (Rajendran 2002).

Jawaharlal Nehru's economic policy favoured commercialized agriculture (industrialized agriculture) in post-1947 India; however, commercialized agriculture struck roots in southern India in the mid-16th—late-17th century (Washbrook 1994). Growth of textile production in the northern Coromandel region of peninsular India stimulated a complementary growth of commercially driven rice cultivation. Occupation of the northern Coromandel by the English and the Dutch and their interest in exporting textile materials triggered commercialized rice production. The English exported 4,579,000 yards and the Dutch 4,844,500 yards (1 yard = 0.91 m) of textile materials from the northern Coromandel in 1682 AD (Brenning 1975). The principal crop of the floodplains of Krishna and Godavari rivers was rice. With the rising market influence of cotton, and other fabric-material trade, rice came to be an extensively produced and traded crop − for human consumption − at this time. In addition to evidence of localized short-distance movements of rice, a more complex and extended network of coastal trade emerged. Rice was moved to Masulipatnam (16° 12' N; 81° 18' E; Ãndhrã Pradésh) and nearby small ports from the modern states of Orissa and Bengal to feed the urbanized, cotton and fabric-material trading population; the population of Masulipatnam exceeded 100,000 in the mid-17th century. A part of these rice imports was also distributed in the textile-producing villages along river Krishna (Subrahmanyam 1990). India produced about 40% of world's exportable surplus of rice in 1913–1914.

After 1947, agricultural production tripled through the implementation of different and newly developed technology. Agricultural enterprises emerged based on the principles of co-operative movement propounded by the Welsh social-reformer Robert Owens. Land fragmentation started to reduce gradually, and farmers started using seeds of HYVs. Declining levels of soil fertility were countered with the application of chemical fertilizers and augmented irrigation facilities. With short-duration HYVs, practices such as multiple crop-ping, inter-cropping, and crop rotation were practised to ensure greater crop yields.

The launch of novel-farming strategies by C Subramaniam and MS Swaminathan in 1965 (as part of India's Green Revolution) is a milestone in Indian agriculture, which led India to achieve self-sufficiency in grain production. Notably, periodic famines — recurring events in Indian-agricultural history (Raman 2009) — have not occurred in India after 1965. Planting of HYVs and intense use of synthetic fertilizers and irrigation provided a powerful impetus to grain production pushing India to attain self sufficiency. The powerful role played by All-India Radio, the then singular, government-owned audio medium cannot be gainsaid in promoting new agricultural practices to people. Rice production in India in the post-green revolution period resulted in 99.5 million Mg, which nearly doubled by 2000 AD. The highest mean-annual increase of 6.1% in rice production was achieved in the 1980s: from 110 million Mg (1979-1980) to 171 million Mg (1989-1990); but the annual increase in grain production in the 1990s dropped to 1.5%. Milled-rice export was a modest 0.5 million Mg in 1989 but peaked to 6.7 million Mg in 2001.

POST-1980s INNOVATIONS IN RICE AGRICULTURE IN INDIA

Pests and diseases account for 30% loss in rice produced in India. With every new variety of rice 'generated', new strains of pests and disease agents, endowed with new capabilities, emerged (Lingaraj et al. 2008). For example, a virulent rice-gall midge *Orseolia oryzae* (Diptera: Cecidomyiidae) (popularly referred as RGM) 'biotype 5' emerged close to the heels of the then known, equally virulent, RGM 'biotype 4' soon after the planting of the resistant-rice variety *Abhayã* with the resistance-gene *Gm4t* in Kerala in the late 1980s (Rema Bai et al. 1990; Bentur et al. 1994 2004). A key pathogen was the rice-tungro virus (RTV), the populations of which blew into epidemic proportions in the state of Ãndhra Pradésh and that of the parts of the state of Orissa affecting nearly 183,000 ha in the early 1990s (Azzam and Chancellor 2002). By planting *Nidhi*—an RTV resistant, short-duration variety, the rice crop of following August-January was saved from RTV. Similarly, widening the genetic basis for resistance, enabled the development of cultivars resistant to bacterial leaf-blight disease (*Xanthomonas oryzae* pv. *oryzae* [Xanthomonadales: Xanthomonadaceae]) and white-backed planthopper (*Sogatella furcifera,* Hemiptera: Delphacidae) (Kropff and Struik 2002). Despite these advances, rice cultivation continues to be challenged by a suite of pests, such as the borers (e.g., *Scirpophaga incertulas* [Lepidoptera: Crambidae], *Chilo partellus* [Lepidoptera: Pyralidae]), the leaffolder (*Cnaphalocrocis medinalis* [Lepidoptera, Pyralidae]), and the leaf- and sheath-blight inducing microbial pathogens (*Xanthomonas oryzae* pv. o*ryzae*, *Rhizoctonia solani* [Cantharellales: Ceratobasidiaceae]).

WHAT LIES AHEAD FOR A SUSTAINABLE FUTURE IN THE MANAGEMENT OF RICE AGROECOSYSTEMS?

Although the issue of sustainability has been mentioned extensively in the context of Indian agriculture, its implementation in practice needs to be evaluated within the context of the following key challenges (*sensu* Gomiero et al. 2011):

(1) The multifunctional nature of agriculture that involves the issues of producing commodities and at the same time preserving ecosystems and their health, and looking after the consumers on one hand and the producers of grains on the other.

(2) The multiscale nature of the complex network of relations among ecosystems and socioeconomic systems, which necessitate considering simultaneously different strate-gies and dynamics that function at different hierarchical levels.

The term 'sustainable agriculture' today is variedly understood and interpreted. At least 14 definitions exist, but because these definitions pertain to conditions in industrialized nations, conditions in less-industrialized nations are seldom accommodated under these definitions. The developed-nation context of sustainable-agricultural practices, when transferred to less-developed nations generally do not take the local cultural values that prevail in the less-developed nations and also traditionally valued local-biological resources (e.g., soil arthropods, soil microbes, earthworms) into consideration (Pimentel and Pimentel 2008). Such local-biological resources have a key role in guaranteeing food security. Because industrialized agriculture does not recognize that element, the relevance and usefulness of the local-biological resources are usually relegated to the back burner (Ochatt and Jain 2007).

In the context of sustainable-agricultural practices for the future, the proposed changes need to ensure that the three dimensions of sustainability, viz., production, environment, and society, are matched and synchronized. To do this, a careful evaluation of agroecosystems involving an evaluation of strengths and weaknesses is imperative.

AGROECOLOGICAL PARADIGMS FOR RICE ECOSYSTEM MANAGEMENT IN SOUTHERN INDIA

As viable alternatives to industrialized commercial agricultural practice, diverse agricultural-practice models (e.g., integrated agriculture, organic agriculture, permaculture,) are currently available in different parts of the world, which aim at sustainability and environmental security. Because plentiful literature exists on these alternate models, I will confine my analysis and discussion to some of the agroecological paradigms, which I consider vital for effective management of rice ecosystems in southern India, paving the way to sustainability.

Better Use of Native Germplasm

The rapid disappearance of native-rice varieties of India and their replacement with HYVs is a concern that needs urgent attention. For example, the varieties IR–8 created in IRRI (Manila) and ADT 27 created in

Aduthurai Research Station (Tamil Nãdu) replaced the low-yielding native varieties *Kutiraivãli*, *Kitçili-sambã*, and *Kurangu-sambã* traditionally grown in the Kaveri floodplains of Tamil Nãdu (Arumugasamy et al. 2007); the variety *Çintãmani* (a variety with excellent kernel size, cooking quality, and taste) and *Jénugudu* (a variety with long panicles, each bearing about 300 grains) are no longer cultivated in Uttara Kannada (Bhat and Gowda 2004) (Figure 1). Farmers were won over by the immediate and bountiful yields offered by the HYVs, and the associated costs of external inputs and loss of germplasm qualities such as loss of non-grain biomass, loss of desirable traits (e.g., tolerance to disease agents and pests, drought, and floods) were disregarded. Richharia and Govindasamy (1990) claim that >200,000 native varieties of rice exist in India, although only 6000 of them have been brought under cultivation. The emergence and promotion of genetically modified varieties of rice (both HYVs and those with desirable traits, e.g., β-carotene) raises the risk of further erosion of the diversity of rice under cultivation (Ye et al. 2000, Potrykus 2001)

However, the situation does not seem to be so dismal. Farmers in isolated pockets of India still preserve and use native-rice germplasm, e.g., small-scale farmers in *Çengam* (12° 15' N; 79° 07' E; Ŧiruannamalai Sambuvarayar District, Tamil Nãdu) grow several native varieties for a range of reasons (Vijayalakshmi and Nambi 1997). Soil quality and lack of adequate water are the key reasons for their choice of native varieties as against using HYVs. These farmers have found that use of *Vãdan-sambã* provides the most-preferred outcomes. Vijayalakshmi and Nambi (1997) also refer to *Kałar-pãlai* (*kałar* — saline, referring to the saline soil, here),

Figure 1. 'Rediscovered' traditional rice varieties of southern India. A: *Kouni nel* (grains nutritious to pregnant women and lactating mothers). B: *Mappilai sambã* (grains nutritious to prospective grooms). C: *Ŧanga sambã* (grains fine and long). D: *Ŧuyamalli* (grain clusters resemble jasmine flower clusters and grains when cooked generate a pleasant flavour). (Courtesy: A V Balasubramanian, Centre for Indian Knowledge Systems, *Çennai*, India)

and to the availability of *Sirumani* and *Neelam-sambã*, which are conserved and cultivated by the *Çengam* farmers to enable better health outcomes for lactating women. The variety *Karunkuruvai* is indicated to possess a capacity to cure filariasis, *Kappakar*, a dryland variety, can tolerate extreme dry conditions, and *Sambã-mosãnam* can survive in ill-drained soils. *Sambã-mosanam* is considered an ideal crop to be grown along borders of lakes (Arumugasamy et al. 2007). Native varieties that have evolved naturally adapting to local biotic and abiotic conditions can perform well even under minimum-management practices (Loresto et al. 2000). For instance, the high-yielding, improved varieties *Abhilãś, Intãn, Jayã*, and *Phalgunã* have not been able to completely replace the native rice germ-plasm of Uttara Kannada (Bhat and Gowda 2004).

Use of Perennials as Intercrops

Rice is customarily raised as a monocultural crop. But some of the trials across the rice-growing parts of the world indicate that it could be integrated with trees, which, however need to be fast growing and nitrogen fixing (e.g., species of *Acacia, Albizia, Casuarina, Erythrina, Gliricidia. Inga, Leucaena, Parkinsonia, Pithecellobium, Prosopis* and *Sesbania*) (Barzman and Das 2000). The integration of agroforestry with rice cultivation in central India has resulted in increased crop yield as a result of the effect of residual nitrogen on the yield of rice crop after the removal of 15-year old trees of *Acacia nilotica*. The increased crop yield was nearly equal to the reduced crop yield suffered during the first 15 years of growth of *A. nilotica* (Pandey and Sharma 2003). In the last two decades, upland rice ecosystems in South Asia and South-east Asia intercropped with *Cocos nucifera* (Arecaceae) have yielded not only beneficial ecosystem services such as better pest management, but also better economic returns to the farmer (Gupta and O'Toole 1986; Pabuayon 2008).

Role of Rice Paddies in Wetland Biodiversity Conservation

Maintaining biological diversity is the key for productive and sustainable agriculture: rice paddies are no exception. Rice fields, the largest of human-made wetlands, are complex, diverse, and dynamic (Galbraith et al. 2005). Because bird populations are decreasing in Asia (Wetlands International 2010), rice paddies can play an effective role as habitats in building their populations. In such a context, I value the argument that many of the drivers for habitat loss and degradation induced by different human actions and activities, including agriculture, need to be addressed regionally. Biological diversity of rice paddies in Laos and Thailand are articulated in Heckman (1974, 1979). Of course, practice of rice farming varies from region to region: rice farming (deepwater cultivation) in Bangladesh is different to that practiced in the states of Kéralã and *Assãm* in India. However, the role of the rice paddy in water cycle is complex. Birds, either resident or migratory, are supported by rice paddies, but, in practice, farmers often perceive them as pests affecting their yield. Nonetheless, the potential for habitat restoration and approaches that would integrate wetland conservation with improved agricultural performance also need to be factored. The rice paddies are biologically relevant because they provide habitats for reptiles, amphibians, fish, crustaceans, insects, and molluscs, besides migratory birds. The benefits from well-managed rice paddies, when seen as wetlands, in fact, stretch beyond the realm of biological diversity and its conservation. Some benefits to in terms of groundwater recharge, climate moderation, flood and erosion control, landslide prevention especially in upland-rice agroecosystems, supply of plant and animal food sources, and plants of medicinal value have been alluded to (*vide* Resolution X.31, *Enhancing biodiversity in rice paddies as wetland systems*, RAMSAR Changwon 2008). Examples of rice ecosystems from Népal (Bhandari 2011) offer insights into how this ecosystem functions enabling diverse ecosystem services, besides serving as a vital source of nutrition to people and as a major source of income and employment.

Integrated rice farming is one best practice that ensures how people can live in harmony with and in a respectful manner with Nature. The integrated-rice farming in Thailand involving practices of rice-fish culture, rice-fish-duck culture, rice–bean-poultry-livestock culture, rice–fish–orchard–vegetable culture, rich–fish–agroforestry culture based on the *New Theory* and *Philosophy of Sufficiency Economy* proposed by His Majesty Bhumibol Adulyadej, the King of Thailand (Government of Thailand, no date) deserves recognition.

System of Rice Intensification

System of Rice Intensification (SRI), the innovative proposal developed by the French Jesuit Henri de Laulanié in Madagascar in 1983, combines field observations of rice performance and a series of casual trials done over a decade supplemented by an accidental-early planting. This trial offered a substantially better growing environment for rice, evoking productive phenotypes from all the rice germplasms trialled. Noteworthy is that this innovation occurred outside a formal research system. SRI is a system of growing rice that involves principles that are at times radically different from traditional ways of growing rice. It involves the transplantation of single young seedlings instead of the conventional method using clusters of mature seedlings from the nursery. SRI spaces rice plants more widely and most importantly does not suggest continuous flooding of rice fields, involves the use of fewer seed and chemical inputs, and promotes soil biotic activities in, on, and around plant roots. The activities are enhanced through liberal application of compost, removal of weeds done with a rotating hoe that aerates the soil.

Rice has been cultivated as a water-intensive and high-chemical input requiring crop throughout rice-growing parts of the world. With intense support from governments (e.g., reallocating national-water resources, subsidizing chemicals, price support mechanisms) rice has become a preferred crop for farmers who have access to copious water. With such intensive support, intensity of rice cultivation has even spread to areas with scarce water resources and is held responsible for the ever increasing water crisis. Rice industry is also a large consumer of fertilizers and pesticides. Increasing investments into external inputs and either digging new water bores or deepening the existing ones forces rice farmers into severe debt. On the other hand, with greater volumes of chemicals used, food grains are accumulating toxic chemicals (e.g., Natural Health Cure 2011). The Watershed Support Services and Activities Network (WASSAN) and the Centre for Sustainable Agriculture (CSA) launched a trial to create awareness and encourage practice of SRI in the state of Ãndhra Pradesh in 2005 involving 1000 farmers (WASSAN—CSA 2005), which was a grand success as measured in 2010. Many Indian-rice farmers have adopted SRI today, because it gives either similar or greater yield relative to more conventional rice-cultivation practice. Moreover, SRI uses less water, fewer seeds, and less chemical inputs. The net effect is a significant reduction in external inputs. However, greater human labour for removing weeds and cultivation in saline lands are unresolved weaknesses in SRI. For an extensive list of benefits of SRI refer to Uphoff (2003).

The Green Revolution accomplished higher productivity involving (1) genetic changes in crops to make them suitable to accepting and responding to external inputs and (2) increased inputs of water and agrochemicals including pesticides and weedicides. SRI involves neither of these. It enhances growth and health of roots and mobilizes the ecosystem services (soil biota); in essence, SRI builds on the mutualism between soil organisms and plant performance (Uphoff 2006). The following remarks by Uphoff (2006: p. 8) are worthy of remembering: "The emerging paradigm for post-modern agriculture differs from its namesake in the arts and humanities in that it embraces modern science, rather than being hostile to it. Indeed post-modern agriculture is the most modern agriculture because it builds upon cutting-edge research in microbiology and ecology."

SRI can play an important role in safeguarding ecosystems and also maximize the resultant ecosystem services; in doing so it can enable the achievement of important strategic goals identified in the Convention on Biological Diversity Strategic Plan 2010—2020 (Pattnaik 2011).

Transgenic Technology

One of the early efforts of creating a rice transgenic was to incorporate the insecticidal-crystal protein [ICP]-characterizing gene of *Bacillus thuringiensis* (*Bt*) (e.g., *cry1Ab*, *cry1Ac*) into *indica* rice to resist *Scirpophaga incertulas*. Trials on the binding properties of ICP to brush-border membrane receptors in the midgut of the larvae of *S. incertulas* indicated that *cry1Ab* and *cry1Ac* are two individually suitable candidate genes for developing resistance to this insect (Nayak et al. 1997). A recent breakthrough in India is the cloning and characterization of *Allium-sativum* leaf agglutinin (*asal*) gene and its expression in elite *indica* variety. The stable transgenic *indica* lines, expressing ASAL, showed explicit resistance against major sap-sucking insects of rice such as *Nilaparvata lugens* (Hemiptera: Delphacidae), *Siphanta acuta* (Hemiptera: Cicadellidae), and *Sogatella furcifera* (Hemiptera: Delphacidae) (Yarasi et al. 2008). The prototypic *asal* transgenic rice lines are considered promising for direct commercial cultivation, besides serving as a potential genetic resource in recombination breeding.

Systematic efforts in rice transgenics are being made throughout the rice-growing world. Nonetheless, unintended spread of commercially interesting transgenic crops *via* pollination and seed dispersal is a matter of concern. Therefore, a study in China (Lin et al. 2008) trialled tagging rice gene(s) of interest to an RNA interference suite, which has the specific capacity to suppress the expression of the bentazon-detoxification enzyme *CYP81A6* (bentazon is a herbicide used in rice ecosystems), thus rendering the transgenic rice sensitive to bentazon. Their tests verified that the terminable transgenic rice created in their study showed no difference in growth, development, and yield, when compared with its non-transgenic control. This study has opened a window of opportunity in the creation of rice sensitive to bentazon to control weeds in a rice ecosystem. Therefore, any possible hybrids outside of the field could be controlled by spraying bentazon during the conventional rice weed control process, even if transgene introgression were to occur in rice weedy relatives either within or near the agronomic field.

Notwithstanding the above, GM technology is being portrayed as the magic bullet for remedying poverty, disease, and hunger (Kwit et al. 2011). Concerns continue to exist with regard to their safety to both environment and humans (Royal Society of London et al. 2000, National Academy of Agricultural Sciences, India [NAASI] 2003). For example, a 2011 Canadian study reveals that pesticides associated with GM crops have been engineered to tolerate either herbicides such as glyphosate and gluphosinate or insecticides such as the δ-endotoxin produced b*y Bacillus thuringiensis* leave imprints in pregnant women and fœtuses (Aris and Leblanc 2011). According to the NAASI (2003) policy paper "Deployment of GM rice in major rice growing areas of Asia merits a comprehensive evaluation in view of the fact the these regions happen to the centres of diversity for rice. The merit and demits of not using GM technology in developing new crop cultivars need to be weighted against any possible risks associated with it". Recommendation # 6 in this policy paper refers to a non-transgenic agroecological practice of utilizing refugia in non-transgenic rice ecosystems.

CONCLUSIONS

In this paper, I have raised more questions than have provided answers. I have not referred to themes of contemporary interest such as climate change and sustainability of rice ecosystems. We need to identify the right questions and seek answers to them in the most appropriate manner, to solve our problems and resolve our issues.

It would be impertinent if I do not refer to what Mohandas Karamchand Gandhi thought of and said about sustainability, although in his times this term sustainability never had the same connotation and usage as we have today. Mohandas's principal concern was to alleviate poverty in India; he was, undeniably, a human-centred person. He was deeply concerned about the poverty-stricken Indian living in the remotest village. Yet while thinking of worthwhile paradigms to improve the lot of that Indian, he drew abundantly from Nature, which to him was plentiful and bountiful. In 1909, Gandhi envisioned the insatiable and unending pursuit of wealth accruing and its derivative of material pleasure in the Western society as a threat to the earth and natural materials. With clairvoyance he warned the ill-effects of such an imprudent lifestyle may bring about, and sought India not be trapped by material gains. His thoughts on simple living, a rural-centred human existence based on freedom and self reliance, emphasis on physical effort, and decrying of exploitative relationships have deep environmental underpinnings (Jones 2000). Even his remarks on gender did not alienate his connectivity with Nature, but to manipulate within it and provide a respectable space for women. Not surprising that he inspired many environmental thinkers worldwide, E F Schumacher and Arne Naess, for example, and those who could empathetically connect their thoughts with concerns for the struggling humans (Moolakattu 2010). He has shown us a viable pathway of organizing our affairs holistically, so as to leave a lighter footprint on this earth; he has offered us useful directives how we, humans, can live harmoniously with Nature. No wonder, we repeatedly quote his inspirational words 'That the earth has enough for everyone's need, but not for anyone's greed'.

We are in a fast era; at least we think that speed and rapid turnarounds of events are the norms of today. Have we been led to think and talk about sustainability and initiate measures to practice it as much as we can, because our lives and actions are driven by speed and fastness? Are speed and fastness the root cause of the present malady, which has led us to think of sustainability? Can we slow down in our actions? For example, from 'fast foods', can we think of 'slow foods'? Small vibrations have started to occur across the world today considering of viable options keeping slowing down as the key denominator (refer to the website of the *World Institute of Slowness*). Slow-design outcomes encourage a reduction in economic, industrial, and urban metabolisms, and thus influence consumption; slow–design services the basic human needs by creating moments to savour to and to enabling enjoying life; it creates spaces to think, react, dream, and muse; it keeps humans and other organisms first; it balances local context with global context and social elements with environmental elements; it demystifies and democratizes by re-awakening an individual's personal design potential; it catalyzes social transformation towards a less materialistic way of living (Fuad-Luke 2002). Is sustainable agriculture an exception to this thinking? We need to think further.

India is one of those countries in the world that can proudly boast of long-term wisdom constructed through knowledge built on trials and errors (Balasubramanian 2010). Several models linking Indian traditional wisdom and scientifically valid agroecological paradigms are currently available, which cite viable, performing, and sustainable examples (Ramakrishnan 1998; Sinha 1998). Is this not the ripe time that we reflect and take stock of our strengths and weaknesses? Is this not the ripe time for us to build on strengths and mitigate weaknesses? We have a major responsibility ahead of us: we need to see that we sustain a plentiful and bountiful India, which will not only be the fountainhead of sustainable actions and sustainable performance.

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