SYSTEM OF RICE INTENSIFICATION

About the Book

System of Rice Intensification explores alternative ways of resource efficient method for paddy cultivation comparing it with the existing resource intensive post Green Revolution conventional method. The book marks a shift from the adoption of scientific and technological practices emanating from a centralized knowledge system and centralized management of input supply to one based on indigenous knowledge systems and local supplies.

There are 15 research papers covering (a) SRI Method, Technology, Resource Use Efficiency and Productivity, (b) Biodiversity and Ecological Security and (c) SRI Future Area Expansion and Policy Concerns. The papers describe evolution of an innovation that is basically farmer centric, reduces water inputs, and challenges high input driven post Green Revolution agricultural practices.

This book shall meet an emergent need to rewrite agricultural policies that are environment friendly, cost efficient and resource efficient.

Studium Press (India) Pvt. Ltd.
4735/22, 2nd Floor Prakash Deep Building (Near PNB),
Ansari Road, Darya Ganj, New Delhi-110002
Phone: +91-11-43240200-15 (15 lines)
Fax: +91-11-43240215
E-mail: studiumpress@gmail.com
Website: http://www.studiumpress.in

ISBN 93-85046-06-3
9 789385 046063

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Technological Options for Rice Farming in India: A Focus on the Eastern Region

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INTRODUCTION

Rice, the main staple in India, occupies 22 per cent of the total cropped area but its share is much higher at 56 per cent in Eastern Region (ER) comprising West Bengal, Orissa and Bihar taken together. Much of the rice is produced by the Northern Region (NR) comprising Punjab, Haryana and Western Uttar Pradesh where water is a scarce resource. Being a water intensive crop it is possible to view any transaction in rice virtually as a transaction in water. A central ingredient of all life forms, the limited reserves of water are in demand for diverse and competing uses. About 97.5 per cent of global water reserves are not available for human use (Hegde, 2012). Agriculture alone claims 83 per cent of the total water use in India. Rice is one of the most water demanding crops in agriculture and 87 per cent of the world's rice area is in Asia and 26 per cent in India.

Within India, 30 per cent of rice area is in the ER where the population is mostly if not mainly rice eating but ER's share in production is less at 27 per cent. In ER 33-61 per cent of the rice area is irrigated, on the other hand, endowed with assured irrigation facilities, almost all rice is irrigated in the NR, where the producers are also privileged with subsidies on farm inputs and energy and open ended procurement by the State. The skewed approach to agricultural development policy turned the northern states into the food basket of the country while with relative neglect and natural limitations, the ER became a net recipient from the national food surplus. It also remained poverty stricken with 33.74 per cent of population in Bihar being poor compared to 5.26 per cent in Punjab. Over time, the northern states also developed their own brand of problems associated with resource degradation. Ecological stress turned public attention turned towards the potentials of the east.

Water is not the only constraint of rice farming. Rice demands nitrogenous fertilizer. About 97 kg fertilizer is used per hectare in Bihar and 211 kg in Punjab (Table 1). Weed proliferation is a dominant influence on the choice of practices. Above all rice farming requires intense labour application for sowing, weeding, transplantation, irrigation and harvest. Done mostly by women workers transplantation requires considerable manual labour involving awkward postures in knee deep water and mud.

The Green Revolution (GR), centered only around the NR, successfully resolved India's problem of food insufficiency. Rice too gained from GR, becoming popular also in NR where wheat had been the staple food. The GR in turn came to be highly critiqued for making agriculture more demanding of water and other inputs. It is little wonder that scientists and other scholars are drawn towards revisiting the conventional ways of rice farming and developing variant technologies which can prove to be more compatible with available water while also meeting food security needs. Research also tended to focus on the problems of Rice-Wheat (RW) rotation in the Indo-Gangetic Plain (IGP) identified more closely with NR than with ER. Public policy on agriculture in India's federation is shifting its focus to the east. The initiative Bringing Green revolution to Eastern India (BGREI) combines various promotional efforts to increase crop yields in ER. This paper undertakes a review and an analysis of rice farming practices under evolution in India with a special attention to the least developed, most vulnerable and food insecure parts of the eastern region.

Scientific Evolution and Innovations

Genetic evidences suggest that rice was first domesticated in China about 10,000 years ago (*https://en.wikipedia.org/wiki/Rice*) to traverse Asia and reach the west through its evolutionary processes. In India, associated with mythological origins, documented cultivation of the grain goes back to 2000 BC in northern India from where it spread across the alluvial plains. Wild varieties grow even today (RKMP, 2011). A vital source of energy (carbohydrates), rice was always associated with prosperity. In 1911, Dr. G.P. Hector initiated planned rice breeding in India as exclusive specialists were appointed in Madras and Bengal. The ICAR was set up in 1929 to conduct research projects in various states and the Central Rice Research Institute of Cuttack was set up in 1946 for screening exotic varieties from available genetic stock. Fertilizer responsive varieties were developed in 1960. By 1950 there were 82 research stations in 14 states.

In the beginning rice breeding was pure-line aimed at increasing resistance to flood, drought and pests but in the 1950s the FAO encouraged inter-racial breeding to bring the two major varieties of the word Indica and Japonica together. With persistent threats of famines in Asia, Ford and Rockefeller Foundations funded an International Rice Research Institute (IRRI) in Manila in the 1960s. IRRI's experiments bore fruit much later when Indian tall varieties were hybridized with Chinese semi-dwarf varieties. The release of IR8 seed marked the advent of the high yielding varieties (HYV) to be flagged by ICAR later in 1966. Extending the ambit of green revolution beyond wheat, IR8 signaled the target of self-sufficiency also in rice (GoB, website).

After several releases in the 1960s, progress slowed down until the end of 1980s, when the programme was intensified again. Public and private sector agencies developed several hybrid varieties in a short span of time in the 1990s, guided by the institution created by the Seed Act, 1966 which mandated a Central Seed Committee to recommend and notify any seed for commercial cultivation. Growth of production began to be driven by varietal innovation. While rain fed agro-eco systems became a fertile ground for their adoption, success depended on the adequate supply of associated inputs, availability of credit, purchasing and marketing power of farmers, natural endowment and hazards. Table 1 clearly shows the relatively poor performance of the east in terms of rice yield and returns despite the greater significance of the crop in economy and diet. There are about 10,000 varieties of rice in the world out of which about 4,000 are grown in India.

Table 1: Comparison of rice farming among northern and eastern states (2011-12)

States	*Rain fall June-Sep*	*Aver-age farm size*	*Land/ Man ratio hectare*	*Ferti-lizer per hectare*	*Rice*			
					Area/ TCA	*Irrig-ation*	*Yield per hectare*	*Retur-ns per hectare*
	Mm	*Hect-are*	*Hect-are*	*Kg.*	*%*	*%*	*Ton-nes*	*Rs. '000*
Punjab	459.2	3.8	0.15	211.4	35.6	99.5	3.74	42.3
Haryana	379.2	2.3	0.14	212.2	19.0	99.9	3.04	34.4
Uttar Pradesh	801.5	0.8	0.08	182.9	22.8	82.1	2.36	18.8
Bihar	1066.7	0.4	0.05	97.4	43.8	61.1	2.15	9.1
Orissa	1100.2	1.0	0.10	82.8	80.7	33.2	1.62	7.2
West Bengal	1455.8	0.8	0.06	148.0	58.1	48.2	2.69	7.4

Source: Ministry of Agriculture

Rice in India: Pre-conditions, Constraints and Contradictions

Rice cultivation demands special conditions so that some of the typical rice growing regions are not ideal for other crops. It is a tropical plant that requires considerable heat, humidity and water. Fairly high mean monthly temperature is essential, the requirement peaking at harvest. Temporally equitable rainfall distribution, where no month should have less than 12 cm of rainfall is also vital though the requirement diminishes at harvest. Rice dominates in areas of over 200 cm annual rainfall but rainfed rice is bound by the 100 cm isohyets (Mondal, website). Irrigation helps rice where annual rainfall is less than 100 cm but agriculture can in principle be diversified to other crops.

All over India, rice is sown in June-July and harvested in September-October broadly as a *kharif* crop with local variations in calendar. The date of arrival of monsoon differs moderately within June but delays in onset are not uncommon. The southwest monsoon brings an average of 1186 mm rainfall in India but the quantum is only 636 mm in the northern state Punjab compared to 1205 mm in eastern state Bihar. Multiple crops (summer, *boro, zayad*) in a year are raised in limited parts of eastern and southern regions enabled by irrigation. In NR, rice is grown as an irrigated kharif crop but it is a highly productive area.

Labour

Globally, areas of dense population that offer large supplies of cheap labour are primarily known for rice cultivation. Most of the work in preparing the seed-bed, broadcasting seeds, transplantation of plants from nurseries to the fields, harvesting and in winnowing is done by human hands in India but evidences suggest that the younger generation is losing interest in farm labour (NSSO, 2005) resulting in migration and increased burden on women who happen to be less mobile owing to natural and social causes. Drudgery of female farm labour is a serious concern in agriculture (Ghosh, 2010, 2013). Mechanization described as mere 'hoe-culture', has not helped rice growing. In NR large scale inflow of farm workers from ER does not appear sustainable especially as public works programmes like MGNREGA are drawing rural people.

Research and Extension

Shaped both by traditions and by agricultural extension, farming practices in different parts of the country are sensitive to the varieties used, farm size, natural conditions as also to the economics involved. Extension which brings research from laboratories to fields was a public function but with its integration with private sector, research and

promotion practices are influenced by real time scientific advances and profit motives of firms. Innovations do not emerge only from laboratories. Practices which are shown to produce encouraging results in actual experiences gained elsewhere are also put under trial by civil societies and different national and international agencies. Agriculture Technology Management Association (ATMA) is a representative unit of participative and holistic extension of current times which guides farmers. Experimental programmes draw risk taking and progressive farmers who inspire others (Yokel, 1979) aiding technology diffusion.

Environmental problems

Rotation of wheat with water guzzling rice in Indo-Gangetic Plains (IGP) creates soil degradation and water depletion. Time constraint between rice harvest and wheat sowing compels practices of waste disposal that are adverse to the environment (Kumar and Kumar, 2010). Thus rice cultivation in the productive north has yielded food security only at high ecological costs. On the other hand, advantages as well as challenges of growing rice in the ER are becoming apparent. Compared to Punjab and Haryana monsoon rainfall is higher in states Bihar and West Bengal where rice occupies 40 to 60 per cent of the total cropped acreage but the productivity is lower by 40 per cent in Bihar.

Contradictions

Public policy seems to be in favour of diverting agriculture in northern states towards high value crops like fruits and vegetables from cereals and of building towns and cities where villages exist. The contradictions of growing rice are growing in size. Concerns about ecology, fiscal prudence, equity and global competition are now impinging on public policy. Contemporaneous perspective presenting a transition in food habits responding to changes in demography and gender role, restructuring of the macro-economy and globalization impel a fresh look at the rice sector. While rice has been losing appeal in food habits even among Asians (Ito *et al.*, 1989) over the decade, as population grows it is still likely to continue to be important in India's food basket in medium future. Rice has historically been eaten not only as cooked staple but also altered as breakfast snacks (puffed, flaked, pooped, *idely* etc.) and potentials of using food technology for processing deserve consideration. The average farm size is small only 0.4 hectare in Bihar (Table 1). Younger people even in these states are not appealed by farm work, preferring to migrate to cities for employment. The returns from growing rice are lower in the three eastern states below Rs. 10,000/- per hectare (Table 1).

Need for Innovation in Practices Now

Rice-based systems are recognized to be especially significant for food security, poverty alleviation, improved livelihood and also women's empowerment. The United Nations General Assembly had declared 2004 as the "International Year of Rice" (IYR) with the theme – "Rice is life". Rice is a primary food in Asia where people obtain 60 to 70 per cent of their calories from rice and its products (FAO, 2004). Some of the typical rice growing regions are not ideal for other crops. Sustainable food security requires improved practices of farming transcending innovations in varieties. Water intensive flooding has been the central feature of innovations in practices.

A large variety of soils can support rice while irrigation can replace natural rainfall in meeting the high moisture demands. Varieties of rice differ based on regional specificities, scientific progress and its adoption rate though the special soil, water requirements make rice dominantly a crop of river valleys, flood plains, deltas and coastal plains. Not surprisingly, the practice of rice farming is varied across India but wet or lowland rice is most dominant. Traditional methods based on transplanting on flooded fields, ranging from wet to deep water rice, is by far the most common practice in Asia and in ER.

Deep fertile clayey or loamy soils are preferable because they can be easily puddled into mud and because they develop cracks on drying. Flooding is an ancient practice but may have evolved due to human intervention, strengthened further by the development of irrigation technology. Several advantages sustained its dominance. Resilience to sudden droughts and hydraulic deluges and control of soil temperature are two of the benefits while nutrient conservation through the action of nitrogen fixing anaerobic organisms (Ghosh, 2004) saves fertilizer use.

However the most clinching rationale of flooding appears to be controlling weeds which would be a challenge if the seedlings are not transplanted to flooded fields which pre-empts growth of many life forms. On the other hand anaerobic fermentation in flooded rice field leads to methane emission contributing to global warming. Late or deficient monsoon also come in the way of flooded rice. Labour scarcity is becoming a most formidable constraint to transplantation. The R-W system concentrated in the IGP (Timsina, 2001) is a more discussed problem because of the contradictions of aerobic and non-aerobic soil management imperatives of rice and wheat respectively and the over-use of water, which along with soil related constraints decelerated the growth of Total Factor Productivity (TFP) (Singh, 2011) in northern India.

Thus even wet rice cultivation practices need to be nuanced to specific conditions. Even while flooding and transplantation absorbing also varietal innovations have sustained the test of time, growing interest in resource conservation and equity demands that the system encounters trials and changes. A summary of some of the variant practices follow.

Zero Tillage (ZT)

Tillage practices govern soil quality. Cropping practices in India are increasingly critiqued for soil degradation, giving way to (Mohanty *et al.*, 2007; Fujisaka *et al.*, 1994; Byerlee and Siddiq, 1994) resource-saving technologies for trial (Gupta *et al.*, 2002, Hobbs and Gupta, 2003a, b). Tillage practices are modulated to protect current profitability aided by a large range of choices in tillage equipment that potentially save labour and fuel.

ZT is a way of growing crops from year to year without disturbing the soil. Not only does it conserve organic matter in soil, by recycling nutrients it also improves soil quality and resilience. It curbs soil erosion and increases the amount of water that infiltrates though the gain in soil biological fertility is the most powerful benefit. The Conservation Technology Information Center of the U.S. distinguishes among sub-practices under ZT like (i) No-till which leaves soil undisturbed except for narrow strips, (ii) Mulch-till which retains 30 per cent or more surface residue cover even while disturbing all of the soil surface with full width tillage, (iii) Conservation tillage which is simply an umbrella term for all the tillage systems which maintain 30 per cent or more residue cover, (iv) Reduced-till that leave 15-30 per cent residue cover, (v) Intensive-till or conventional-till that leave less than 15 per cent residue cover leaving "gray areas" for equipment options and definitions. Additionally implements for one-pass or "no-till" better described as a "till-plant" system result in substantial soil disturbance but with residue burial. At the cost of appearing as a 'contradiction of terms' ZT is actually a wide range of soil disturbance practices.

In India the history of ZT began with the failed efforts of State Agricultural Universities in 1970s but the contradictions of the R-W system (Sharma *et al.*, 2002) revived efforts in the 1990s in which CGIAR, CIMMYT. IRRI, Pantnagar University and equipment manufacturers who spent time with farmers in fields had strong roles while the development of equipment, in particular and the advent of seed drills was important for the change.

ZT is now believed to be the most successful resource conserving policy in IGP (Erenstein *et al.*, 2008) where it is typically applied only to the wheat crop, with the subsequent rice crop still intensively tilled. Usually a tractor drawn seed drill[1] is used to sow wheat on unplowed fields with a single pass over the harvested paddy fields that remain relatively weed-free under prevailing practices. Surface seeding, a manual operation in which wheat seeds are broadcast on saturated soil after or even before rice harvest (Tripathi *et al.*, 2006) is a simple technology for resource-poor farmers. It requires no land preparation or machinery, but its use is still largely confined to low-lying fields that remain too moist for tractors to enter. Haryana pioneered in its rapid spread of adoption in IGP where residue tillage is dominant. In 2004-05 ZT was making inroads also in eastern IGP as corroborated by the sales of drills (Parwez *et al.*, 2004). As adoption spread from middle to eastern Genetic plains, results from Bihar started emerging (Laxmi *et al.*, 2003; Gautam *et al.*, 2002; Prasad *et al.*, 2002; Sinha *et al.*, 2005). Evaluations indicated positive effects on savings of labour, diesel and water, improvement of soil and higher wheat yields coming from timely sowing and enhanced input efficiency (Kumar *et al.*, 2005; Gupta *et al.*, 2002; Hobbs, 2001) but assessments were mostly on wheat and the literature still remains scant on ER.

Direct seeding (DS)

Arguably described as a "new improved" version of no-till planting system correcting for its failures, DS has become accepted around the world and in the US (PNSTEEP, 1999). Compared to ZT, new implements have enabled greater accuracy of response to seedbed conditions. However DS remains different from the traditional ZT as defined, because options of soil disturbances are open to the DS user. Now well tried in India, DS is beginning to replace the more time consuming transplantation process and further improvements are anticipated.

As a traditional and informal technique to save labour, water soaked seeds were sometimes broadcast on standing water in India. However use of drills is making DS more sophisticated in recent times and evaluations show positive results. Primary survey done in Bathinda district in Punjab indicated significant edge enjoyed by DS over the traditionally existing method. At a larger scale, reduction of labour requirement during transplanting is a big relief for the state now facing serious labour shortage (Romana, 2014). Requirement for water was also reduced though cost of weed control and micro-nutrient conservation increased in some varieties. A farm survey of 5 districts in

[1] The typical ZT drill has inverted-T openers and opens a number of narrow slits for placing seed and fertilizers at the correct depth.

Punjab affirmed the interest of farmers in adopting DS which is seen as a profitable practice. Reservations about more labour intensive weeding remained (Kaur *et al.*, 2015).

Alternate wetting and drying (AWD)

AWD defined by periodic drying and re-flooding of rice fields, is a management practice for irrigated low land rice-specific water regimes. The method has been around for decades mostly in China where about 4 per cent of rice farmers practice some forms of water management likened with AWD. Similar practices are also observed in north India and Japan. AWD is identified for its special large potential for reducing methane (greenhouse gas) emission (Ghosh, 2011) from paddy fields. Intermittent irrigation specific soil amendments and fertilizers can further strengthen AWD's ability to reduce methane and nitrous oxide emissions. AWD also promotes effective tillering and enables strong root growth. Organic inputs like rice straw, manure and composts can be used to dry soil. Savings in fuel and labour costs accompany the compromise on irrigation demand. In addition to the ecological benefits, AWD which allows mechanical harvesting improves returns.

Controlled irrigation is however a prerequisite. AWD is ideal only for low land areas where soil can be drained in 5 days interval. Because continuous rainfall prevents drying AWD is less relevant for rainfed rice. It is basically a climate-smart technology effective only with good nutrient management, a proper design of irrigation and efficient coordination among farmers, farmer's associations, irrigation authorities and local governance. Bouman *et al.* (2007) reported AWD treatments resulted in a yield reduction compared with the flooded treatments in 92 per cent of the experiments they reviewed, the yield loss varying from just above 0 per cent to as much as 70 per cent, adjustments of associated agronomic practices being responsible for the variations.

System of Rice Intensification (SRI)

Described as a set of ideas and insights rather than a new technology, SRI is a package in which only a few practices deviate from conventions. The major departure is that only 8-14 days old seedlings, younger than the conventional 4-5 week old seedlings, are transplanted from the nursery. SRI may require added practices and even specific technologies as supplements for adaptability, economics and agronomic success. The seedlings are believed to experience profuse 'tillering' without suffering the shock of transplantation. SRI has evolved through generations of trial and learning.

Genesis of SRI was in Henari de Lanlanie's observation in the 1960s (Uphoff, 2008) in Madagascar that a handful of farmers who transplanted individual seedlings rather than clumps were producing relatively more rice from fewer plants. Not only was the seed cost reduced but water was also saved because the soil was kept moist rather than flooded. Further results on spacing plants, irrigation, age of the seedling being planted, pattern of sowing (square rather than rows), aerating the soil, use of compost and fertilizers and so on flowed from his experimentation with the alternative practices. The central point of departure was in the number and age of the seeding and not so much in the flooding practice which also was part of the modulation.

In 1994 the Cornell International Institute for Food Agriculture and Development (CIIFAD) started promoting SRI. Trials showed that SRI could produce yield several times higher than conventional method and even beyond what scientists consider to be biological maximum (Uphoff, 2008) and the technology was replicated successfully in contrasting agro-ecological situations.

Benefits

Benefits can transcend higher yields. SRI benefits from composting to improve soil organic matter (Uphoff, 2008) and using the rotating hoe to control weeds and aerate soil. With a larger root system in drier conditions SRI plants access varied soil nutrients with less senescence (Kar *et al.*, 1974) and enhance the diversity of soil biota. Unlike the HYV experiment, SRI can save on external inputs. Also unlike GR that transferred to fields readymade packages that originated in research stations and laboratories, SRI is promoted as a civil society innovation with farmers' participation. The SRI experiments have been a lesson that present knowledge and prevailing paradigm should not imprison beliefs. That farming practices should be allowed to develop freely in the regional context verges on philosophy.

Besides being water and seed saving, SRI can become labour saving as well as (Uphoff, 2008) in the longer run. Wide spacing of plants can make farm work much more convenient. Disagreements on labour demand and also over the income effect however remain intense. As an agro-ecological system of practices SRI is still in inception and need further fine-tuning to local environments for replication. Other benefits expected from SRI are incidences of fewer broken grains, better resistance to pests and diseases, better tolerance to drought and storms, shorter crop cycle, reduced lodging.

Skepticism

SRI signifies that more grains can be got from fewer plants. Observations also challenged the widely held belief that rice plant fares best in saturated soil. Controversies therefore surround SRI though record yields, sometimes even over 20 tonnes per hectare, have been reported. Experiments in China, Indonesia and other Asian and African countries generated encouraging results. Critics from the scientific community are vocal about the records of miraculous yields (Rafaralahy, 2002) defying received wisdom. Claims that 7–15 tonnes per hectare are achievable even in soils with low inherent fertility, greatly reduced rates of irrigation and without external inputs (Stoop *et al.*, 2002; Uphoff, 2002; Stoop and Kassam, 2005) are not easily accepted. Some analysts deny any major role of SRI in observed yield enhancement and maintain intensive irrigation and good soil are more cost effective (Dobermann, 2004; Mcdonald, 2006; Sheehy *et al.*, 2004) means for the same. Proponents in turn questioned the assumption underlying modeling of the agro-ecology (Stoop and Kassam, 2005). Even the very novelty of SRI in India[2] (Gujja and Thiyagarajan, 2009) is under doubt.

Promotion and Adoption

SRI first took root in the southern states with the visit of Norman Uphoff in 2002 and the persuasion of Dr. Allapati Satyanarayana, a self proclaimed skeptic. SRI is projected as not only an alternative but also a solution to the green revolution. It suits the capacities of small and marginal farmers and enthuses the proponents of organic farming. A coalition of NGO projects depicted SRI as a method that simultaneously increases rice yields, improves small holders' productivity and reduces water consumption while also curtailing methane emission and nitrogen pollution (Africare, 2010). Methods resembling SRI may have been in use in early 20th century perhaps replaced by the green revolution. Despite lack of unequivocal scientific endorsement and dismissed as Uphoff's 'hobby horse' SRI has quickly spread to many rice growing areas in India attracting diverse stake holders.

SRI is being projected within the frame work of central government's schemes NFSM and ATMA as Central and many State governments are funding the promotion. The M.S. Swaminathan research foundation (MSSRF)'s endorsement has given further credibility to SRI. The

[2] In Tamilnadu a few farmers have a dim recollection of a "single seedling method" applied in previous generation (Gujja and Thya, 2009) and it is not known if GR was responsible for its disappearance.

involvement of civil society organizations and private institutions like Sir Dorab ji Tata trust with a focus on small and marginal farmers has been valuable. National symposiums organized every year by ICRISAT and WWF project publish a newsletter to disseminate new developments. Indian farmers are trained with SRI tools (weeder and markers) and monitored constantly.[3]

Enthusiastic testimonies by rice farmers resulted in growing acceptance but reliable figures on how many of them are actually practicing SRI methods are scant and rigorous impact studies are still awaited. The bio-physical mechanism involved in SRI cultivation and relative cost benefit results are unclear. Yet SRI has gained immense momentum and some key decision makers express impatience with scientists who raise questions.

There are however practical impediments on the spread of the SRI practices. Soil quality and labour shortage can make the weeding process very difficult. Successful development of a suitable of hand held motorized weeder is awaited. Experiments suggest that SRI can increase nutrient use efficiency, but organic manure is not always ample (Ghosh, 2004) though green manure planting such as gliricidia along field bunds and fences can partly compensate this shortage. Also the nutrient management does not translate to exclusion of mineral fertilizers (Sinclair, 2004) because most farmers applied both organic manure and chemicals. Compared to AWD, SRI is a larger process. Randriamiharisoa and Uphoff (2002) maintain there are also profound differences in SRI between flooded and unflooded soil conditions.

In India the ICAR and other organizations under Ministry of Agriculture, the Agriculture Universities, many NGOs, private sectors companies and miller associations, local governing bodies in Tripura, organic farmers Tamil Nadu, Andhra Pradesh farmers association and women SHG cooperated to promote SRI. That the development of SRI is a struggle against odds is implicitly acknowledged by the 'no free lunches' comment of Uphoff (2008) who apprehends that labour demand will add to the cost in the initial learning phase until farmers master the technique. He also states that the method may be impractical under certain conditions.

In Tripura state when a mid-term review found that growth rate of food production was falling short of requirement the local, state and central governments collaboratively began to create large scale

[3]Row planting, using rotary weeder, a component of SRI, is a practice that has been related to the more recent Japanese method by some observers.

demonstration, farmer exposure visits and capacity building as SRI was converted to a tool to improve productivity under the state plan (*www.sri-india.net/html/aboutsri_tripura.html*), stimulating large scale adoption. All sections of society are practicing SRI with women farmers of tribal and Manipuri community being front runners with excellence. Odisha has formed a learning alliance of civil society organizations to share knowledge. In 2000 a research project was initiated in Tamil Nadu which suggested certain modifications in the SRI method. The internationalist commune Auroville in Pondicherry implemented Annapoorna organic farm. The knowledge spread to other farmers *via* networks of organic farmers. The approach is weaker in other state for the lack of strong commitment of both the central and state governments.

In 2008, when SRI reached Bihar, trial started with only one pioneer as farmers were skeptical. Strength grew as word of mouth and government support went around. By 2012, 3035 thousand hectare came under SRI paddy. Women in districts Gaya and Nalanda who had shown little interest in 2007 also grew in numbers. Discussions with the practicing and successful farmers aided while the performances were keenly monitored by researchers and scientists from *Krishi Vigyan Kendra,* Bihar Agriculture University and ATMA, officers from government directorates and politicians including the state chief minister. In 2008-09, ATMA provided a grant to an NGO called PRADAN for applying SRI principles to even crops other than rice. PRADAN has organized workshops and meetings, training programs in the two districts. The practice is described as *Sri Vidhi* in extensions, matching with Sanskrit expression of respect. A world record in rice yield of over 14 tons per hectare was announced in Nalanda surpassing a past record in China largely accepted by the ICAR and the parliament. A great deal of interest surrounded this achievement.

A study of successful practicing farmers found them educated with learning ability trying to best utilize available inputs in agriculture which happened to be was their main occupation. They cultivated on well drained upland and tube well irrigated soil using green manure (*Dhaincha*), varmi compost and also chemical fertilizers and worked closely with ATMA. The sandy soil of the area and inter-cultivation helped the practice in the river bank area where water table was high, and soil was organically rich. Rice was rotated with wheat, maize and pulses. The yield difference from conventional practice could not be attributed to statistical error through field management and field conditions could also be responsible. Fewer labourer were required for transplantation but labour demand for managing water and harvesting larger quantities increased. The average reported yield of 57 farmers surveyed in Nalanda district using different hybrid varieties was 9.34

tonnes per hectare. Total production of paddy in Bihar broke all records in 2012 arguably attributable to the SRI revolution.

Evidences on SRI Along with Technological Innovations

Influential evaluations of SRI included on-station experiments and farm surveys in two main river basins of Tamil Nadu in 2004, a World Bank funded project in Tamil Nadu, on-farm evaluations in Tamil Nadu, Andhra Pradesh, Tripura, Orissa, Jharkhand, Uttarakhand and Punjab by NGOs and ICAR. Evidences suggested that SRI reduced seed rate, nursery area and duration in nursery. Farmers employed less labours than conventional planting due to the drastically reduced number of seedling. Shallow irrigation of SRI can save 50 per cent of water use without any yield loss (Thiyagarajan, 2002; Mahendra Kumar *et al.*, 2007), which also means fuel saving and fewer water conflicts. Grain yield reports ranged from 9.3-68 per cent (ICRISAT-WWF, 2008) but the biggest achievement by a farmer was 4036 kg/hectare and subsequently a record in Bihar.

Flooding practices are justified for weed control which obviously becomes an important operation in SRI. Planting in squares making use of a rope or a popular steel roller marker developed by Andhra Pradesh farmers facilitates the use of a weeder. The weeder disturbs and churns the soil between the rows not only controlling weed growth but also activating microbial processes, incorporating fertilizers earlier applied and reducing leaching losses. It also aerates the soil and recycles the weeds and the nutrients taken up by the weeds. This inter-cultivation significantly increases grain yield compared to hand weeding (Rajendran *et al.*, 2005) at lower cost. Thus SRI involves partial mechanization and a choice to modify the weeder.

Particularly encouraging results came from Purulia a drier district of West Bengal where farmers were monitored thorough during the entire crop cycle (Sinha and Talati, 2007). This influential study found a 32 per cent yield gain and 67 per cent higher returns with labour input lower by 8 per cent even among partial SRI adopters whose management of water, fertilizer, hoeing, drainage, drying and even weeding was poor. Using t-tests, the rice yield was found significantly higher with SRI than conventional despite the incomplete practices. The experiments also offered visual differences in the tillers between the alternative practices. Small farms proved more productive because of higher fertilizer use. Wider spacing made it easier for farmers to move around in the fields for different operations and farmers were found enthusiastic, perceiving SRI to be pro-poor, an answer to their misery and insulation against poor monsoon.

Some studies suggested that combination of modified planting, conventional irrigation, mechanical weed control and green manure application produce largest-yields with water saving compared to conventional irrigation while some results suggest that transplantation still produces the maximum number of tillers (Senthilkumar *et al.*, 2008). There is option of using new technology to facilitate the practices and even modify crop calendars and crop needs. New laser based technology for land leveling has proved successful in reducing water consumption in Punjab where farmers were hesitant to move from R-W system (Singh and Kaur, 2014).

Special Focus: Insights from Koshi Basin Districts in Bihar

Bihar is a highly agrarian state where about 70 per cent of the workforce is engaged in farming and 90 per cent of the farms are less than 1 hectare in size. Bihar ranks 32nd in state per capita GDP and 34 per cent of the population lives in poverty. Although located in IGP Bihar has special geographical and economic features distinguishing it from NR. Food security is a serious issue for the state, especially for its most vulnerable parts. The state has also been a ground for testing the new practices of rice farming as noted in the discussions above.

Comparing the three established rice growing methods; puddled transplanted rice (PTR), SRI and zero tillage direct seeded rice (ZTDSR) recent experimental data collected from Samastipur district's lowland and upland farms by Borlaug Institute of South Asia (BISA) in Pusa show rice yield to be the highest from ZTDSR method in case of lowland farm and from SRI in upland farms. However, net returns in SRI are very low because the total cost of cultivation is also high (Fig. 1). Higher labour intensity at the current state of practice is said to be responsible for the higher cost. Field survey conducted under a programme called 'Cereal System Initiative of South Asia' during 2010 in four districts East Champaran, Samastipur, Begusarai, and Nawada found direct seeded (DS) rice to be superior but only 6 per cent of the sample farmers are aware of the method out of which only few farmers actually adopted it. In contrast, awareness about and adoption of hybrid rice is far more extensive (BISA, 2015).

Bihar has 38 districts of which 16, accounting for a little less than half of the state area and population are identified to comprise Koshi Basin Region (KBR) drained by Koshi, Ganga and their tributaries. Koshi is a trans-boundary river that causes recurrent floods and sedimentation due to heavy rains in upstream in China and Nepal. Despite being fertile alluvial tract and an inland delta KBR is a

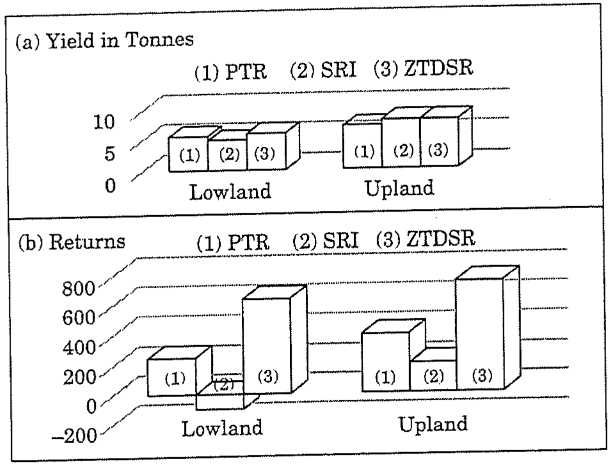

Fig. 1: Comparison of rice yield and returns per hectare by different methods
Source: Borlaug Institute of South Asia (BISA), 2015.

vulnerable zone (Fig. 2) where the fear of flood makes farmers hesitant to grow monsoon rice.

Categorized as a 'backward' region, KBR merits special attention for development planning in Bihar. Government's proactive intervention

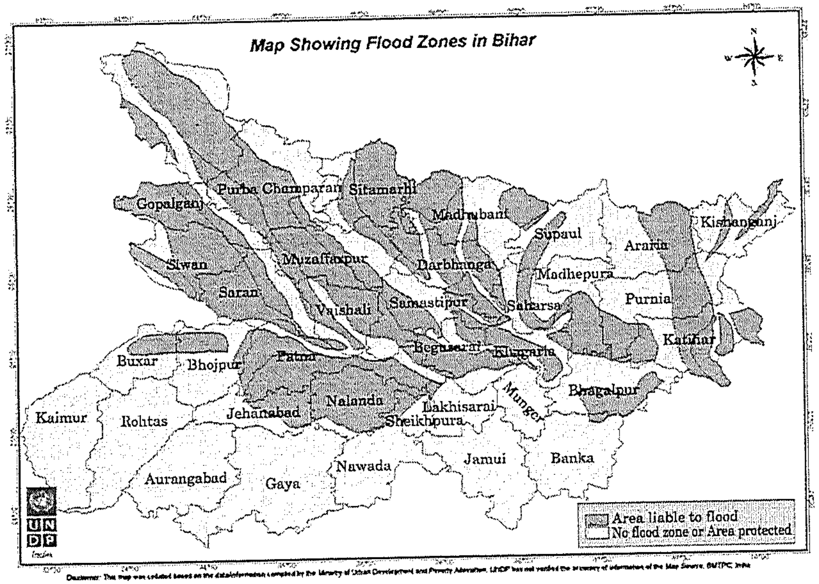

Fig. 2: Flood zone in Bihar: Koshi Basin
Source: Bihar State Disaster Management Authority, Patna.

is important for the region's development. The districts are eligible for special funds from the Centre. In its present status, the public distribution system (PDS) and the recent enactment of the National Food Security Act, 2013 (NFSA) are vital instruments to help people cope with the adversity and derive minimum sustenance. Weather insurance, financial inclusion and cash transfer of subsidies are other tools for poverty mitigation yet to deliver their full potentials. Climate change policies can also be valuable for the region. Commercial farming of maize is encouraged by the promotion of hybrid maize seeds. However, with small sized farms and disaster proneness, food insecurity remains a threat because food supplies will remain to be vulnerable to weather failure and policies in other states, budgetary strains, and public policy of the union government, logistical difficulties and politics. Distress migration from this region has profound implication for socio-economic wellbeing of the region as well as the target urban destinations.

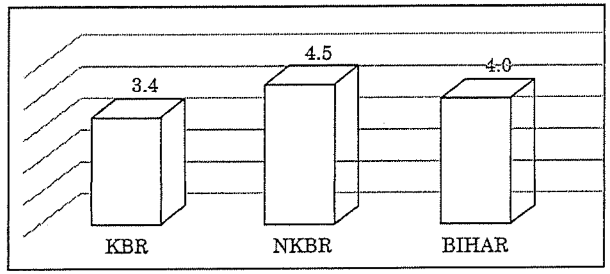

Fig. 3: Average water level below Ground level (In meter)
Source: Centre Ground Water Board http://*gis2.nic.in/cgwb/Gemsdata.aspx*)

KBR receives 1193 millimeter of annual rainfall, concentrated between June and November compared to 1122 in Non Koshi Basin Region (NKBR). The water table is also higher (Fig. 3) indicating greater ground water reserves in KBR. Farm size is smaller in KBR (Table 2). In the Kharif season over 80 per cent of the acreage is devoted to rice in KBR but *kharif* yield is poor at 1.02 tonnes per hectare, low compared to NKBR and also to *rabi* rice yield in KBR. In Bihar rice claims 97 per cent of the *kharif* acreage but its share at 95 per cent is less in KBR where the share of rice in *rabi* acreage is nearly 5 per cent compared to 1.2 per cent in NKBR. KBR claims only 47 per cent of Bihar's total rice area in the kharif season but 78 per cent in the *rabi* season due to flood aversion.

Field visits to a particularly backward and flood prone district in KBR further strengthen the significance of the food security imperative. Khagaria district has been flooded by Koshi in several years including

Table 2: Rice area distribution and yield in Koshi basin region, Bihar

Region	Farm size (hectare)	Seasonal Distribution (%)		Spatial Distribution (%)		Share in total crop area (%)		Yield (Tonnes/ Hectare)	
		Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
KBR	0.38	95.2	4.8	46.8	77.9	82.7	5.1	1.02	1.65
NKBR	0.40	98.8	1.2	53.2	22.1	91.8	1.5	1.49	1.72
Bihar	0.39	97.1	2.9	100	100	88.0	3.0	1.27	1.67

Source: Government of Bihar (Various). Ministry of Agriculture data

2013, and 2014 in recent time though occasional drought is also a problem. Located about 200 Km away from state capital Patna 20 per cent of the people in Khagaria live in poverty. Farming is the primary livelihood but with periodic migration.

From local interaction we found that people have been moving away from rice due to fear of flooding and the cropping pattern is shifting to commercial maize. Despite the risk, *kharif* acreage including even marginal and flood prone lands under lease are devoted to fodder for meeting both household milk needs and cash. Income potential even for maize is low and vulnerable to adverse prices movements. Rice is transplanted as well as broad-cast in flooded fields in crude form DS. Not many farmers are however observed to grow rice even for subsistence and the unmet need is fulfilled by the cheap rice and wheat available in PDS at present. In a random sample of 19 households who grow rice, we found the average rice area is 1.61 hectare with large variance but confined only in *Kharif* season. The BPL card holding poor households who constitute 26 per cent of sample obtain higher rice yield from smaller area probably by intensive cultivation. The households meet 12 per cent of food consumption from PDS, higher at 18 per cent in case of BPL. None of the farmer practices the innovative methods except direct seeding (DS) which is adopted by 80 per cent of APL and 20 per cent of the *ration* cardless farmers. In contrast the neighboring KBR district, Saharsa, SRI is promoted on an experimental basis under an active extension system but ZT was not observed.

CONCLUSION: CHOICES AND CONTRADICTIONS

The green revolution enabled India to become self sufficient in food grains with a 70 per cent rise in paddy yield in 1966-99 but high growth of population, expected to reach 1.6 billion in 2050, provides no ground for complacency. Besides, the incidences of drought years such as 2009, 2012, 2014, water stress, climate change, low investment and competing

Table 3: Statistics on Paddy cultivation by poverty status in Khagaria in Bihar

Type	*No Card*	*APL*	*BPL*	*Total*	*No own land*
Household %	26.30	47.37	26.32	100.00	21.1
Kharif Season %	100	100	100	100	100
PDS (Food consumption %)	3.0	13.0	18.0	12.0	14.0
	(7.0)	(17.0)	(5.0)	(13.0)	(11.0)
Area in Hectare	1.63	1.69	1.45	1.61	1.82
	(1.4)	(1.9)	(1.7)	(1.6)	(1.8)
Yield (Tonnes/Hectare)	4.27	2.07	2.59	2.78	1.65
	(4.9)	(1.2)	(0.8)	(2.6)	(1.2)
Technology Adoption					
Direct Seeding (%)	20.00	80.00	0.00	100.00	5.26
SRI %	0.00	0.00	0.00	0.00	0.00
Zero Tillage %	0.00	0.00	0.00	0.00	0.00

Note: Sample size is 19. Figures in Parenthesis are standard deviations. *Source:* Compute from survey data

demand for land are other sources of duress. Special focus is needed on the poor neglected interest areas of eastern India.

Innovating of rice cultivation beyond varietal novelty is a global interest though India provides a promising ground for trials. Falling per capita production, the leveling of paddy yield, expectations of rising population (Styanarayana, 1999, 2005) and decline in per capita availability in Asia and India are causes of global concern. Several new practices are in trial in India and elsewhere. Evaluations of emerging practices demonstrate promise and relative strengths but the adoption and adaptation to natural, economic and demographic realities require serious deliberation. Innovation of practices in India has focused disproportionately on the problems of IGP in northern India but development policy has shifted in focus to the east which is primarily the rice growing and rice eating zone and poor.

Direct seeding, Zero tillage with variation and SRI are modulating prevalent flooding practices and already finding acceptance among Indian farmers, combined with choices of seed varieties and implements. The myth about the compulsion for continuous puddling of field is broken while technological innovations of micro-irrigation save water. Soil quality is also conserved. SRI is becoming immensely popular aided by state and civil society promotion. It increases labour demand at the initial phase but subsequently will require less labour, seeds and water to produce more grains. All these practices treat water as a central constraint when labour is emerging as critical scarcity. Weeds are a major problem for rice that flooding traditionally mitigated. Any innovation to farming approach must be appropriate for the specific conditions of the growing regions and overall design of national economic development. Rice is the staple food and a dominant crop of ER where both surface and groundwater supplies are copious but poverty is pervasive. Given the array of options all new innovative ideas deserve a chance to allow the emergence of natural selection based results that are likely to be hybrids of practices supplemented by new implements, emerging seed varieties and modulation of crop calendars that can be potentially dovetailed with emerging innovations.

ACKNOWLEDGEMENTS

This paper draws from a study conducted under the Koshi Basin Programme at the International Centre for Integrated Mountain Development (ICIMOD), which is supported by the Australian Government through the Sustainable Development Investment Portfolio for South Asia, as well as core funds of ICIMOD contributed by the governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Switzerland, and the United Kingdom. The authors specially acknowledge Dr. Golam Rasul, Dr. Shahriar Wahid, Dr. Nilhari Neupane for their support. Ms. Rashmi is acknowledged for her contribution in drafting and data management.

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