9 Increasing Agricultural Productivity of Farming Systems in Parts of Central India – Sir Ratan Tata Trust Initiative

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Abstract
Soil health mapping was adopted as entry point activity in the initiative supported by Sir Ratan Tata Trust in Jharkhand and Madhya Pradesh states of India which emphasized on developing soil test-based fertilizer recommendations at block level. In Jharkhand, yield benefit with balanced nutrition was 27–44% in paddy, groundnut and maize with benefit–cost (BC) ratio varying from 7.36 to 12.0. In Madhya Pradesh, balanced nutrition increased crop productivity by 11–57% in crops like soybean, paddy, green gram, black gram and groundnut with BC ratio of 1.97 to 9.35. Water harvesting through farm ponds (~500) helped in supplemental irrigation during critical crop stages besides serving as reservoir for fish cultivation. Efforts were made to promote off-season cultivation of vegetables, crop intensification, vermicompost units (~200) and seed bank in pilot villages and capacity development was carried out for ~15,000 farmers through direct demonstrations and around 2–3 times more through field days.

9.1 Background

With the growing population, achieving food security in the 21st century has become a daunting challenge due to increase in water scarcity and land degradation, and extreme variation in weather, which is further expected to aggravate due to impact of climate change. In this scenario, to meet the Millennium Development Goal (MDG) of halving the number of food-insecure poor people could not be met by India. In order to meet the food demand and reduce poverty, there is an urgent need to unlock the potential of rainfed agriculture by enhancing soil productivity, and resource use efficiency through integrated approach. During the past six decades, agricultural research emphasized mainly on component and commodity-based research involving development of crop varieties, animal breed, farm implements, machinery, fertilizer use, and other production and protection technologies. These technologies were mostly conducted in isolation and at the institute level which enabled the farmers to grow more but at the same time

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over-exploited the resources. It resulted in decreasing factor productivity and resource-use efficiency and ultimately less farm productivity and profitability. The greatest challenge for Indian agriculture is to increase the production in agriculture and allied sectors, while minimizing environmental impact. This necessitates conservation and protection of quality of the present resources that determine the performance of agriculture like land, water and air.

Reduction in yield, although determined by many factors, may be partially a consequence of land and water exploitation. Land degradation and water scarcity are among the major constraints for Indian agriculture and are largely responsible for the reduction in crop yield (Chadha *et al.*, 2004). By the early 1980s approximately 173.6 million ha (53%) of India's geographical area had been considerably degraded either by human or natural causes (due to water and wind erosion) (GoI, 2001); 15% is degraded cultivable wasteland (NRSA, 2000); waterlogging affected about 6% of the cultivated area, while alkaline and acidic soils both affected about 3%. It is further complicated by national problems such as environmental degradation, groundwater contamination and entry of toxic substances into the food chain (Gill *et al.*, 2009).

Thus, because of the ever-increasing population and decline in per capita availability of land, there is practically no scope for horizontal expansion of land for agriculture. Only vertical expansion is possible by integrating farming components requiring lesser space and time and ensuring reasonable returns to farm families (Kuruvilla and Mathew, 2009). The declining size of landholdings without any alternative income augmenting opportunity is resulting in a decrease in total farm income and causing agrarian distress, whereas a large number of smallholders have to move to non-farm activities to augment their income.

9.1.1 Sir Ratan Tata Trust Initiative

For harnessing the potential of dryland agriculture through available scientific technologies and approaches for improving rural livelihoods on a sustainable basis, Sir Ratan Tata Trust (SRTT) supported the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India through an impact-oriented development project in Central India. ICRISAT was invited for technical backstopping and empowerment of all the stakeholders to improve their livelihoods through increased agricultural productivity and livelihood opportunities by sustainable use of natural resources.

9.1.2 Project locations

The target districts were Gumla and Saraikela districts in Jharkhand and Jhabua and Mandla in Madhya Pradesh, India (Fig. 9.1). These districts in general are dominated by an agrarian economy. Soil fertility degradation is one of the major factors holding back the realization of large potential yields in these regions (Wani *et al.*, 2003; Sahrawat *et al.*, 2007; Chander *et al.*, 2013a,b, 2014). Rice fallow (practice of keeping extensive tract of lands fallow after rainy season crops) is another important issue and presents considerable scope for crop intensification and increasing farmers' incomes. Hence, for achieving high productivity and profitability, a farming system approach was adopted which helped to integrate farm as a unit targeted for adoption of modern management practices pertaining to seeds, water, labour, capital or credit, fertilizers and pesticides usage and its further linking with other agriculture allied activities for efficient resource management and enhancing system's profitability.

9.1.3 Project goal and objectives

The overall objective of this project was to increase the impact of the development projects in Central India through technical backstopping and empowerment of stakeholders to improve livelihoods through increased agricultural productivity and livelihood opportunities by sustainable use of natural resources.

The specific objectives of this technical assistance programme were as follows.

- To establish a holistic participatory integrated genetic and natural resource management (IGNRM) model for the convergence of activities in four nucleus clusters (five

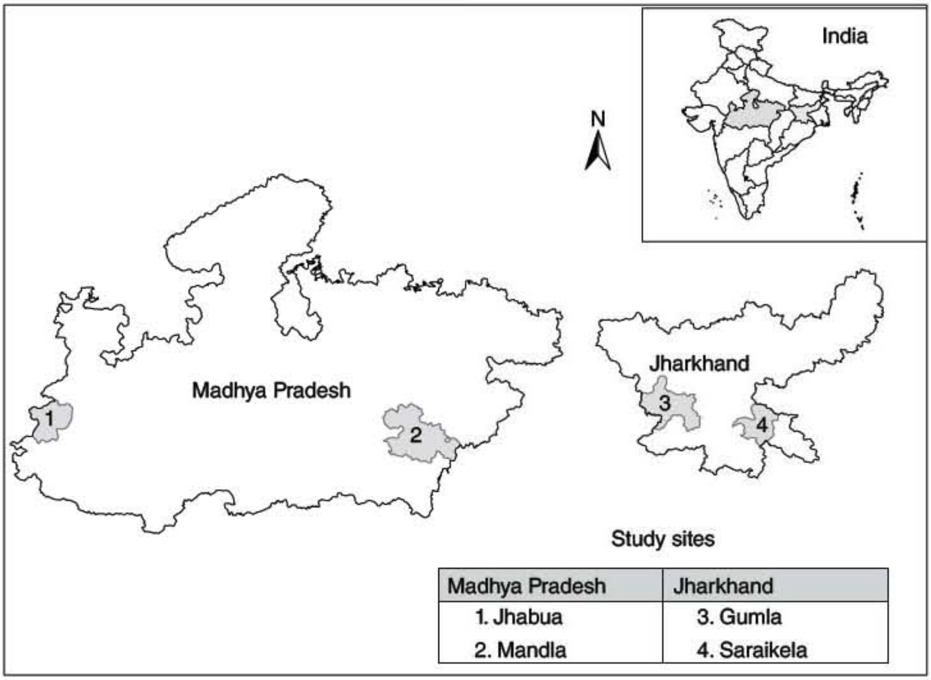

Fig. 9.1. Study sites in Madhya Pradesh and Jharkhand states of India.

villages in each cluster) encompassing suitable technical, institutional, gender equity and policy options for enhanced agricultural productivity and crop-livestock management systems to alleviate poverty.

- To provide technical know-how to farmers, landless rural people in the target districts and partner nongovernment organizations (NGOs) supported by SRTT in the region through empowerment by bringing together learnings from the national and international experience.

9.2 Methodology

9.2.1 Yield gap analysis for increasing system productivity in project location

Globally rainfed areas are hot spots of poverty, malnutrition and degradation of natural resources. Modern agriculture begins on the research station, where researchers have access to all requirements, i.e. fertilizers, pesticides and labour at appropriate time. But when the package is extended to farmers, even the best performing farms cannot match the yields obtained by researchers. Similarly, Barman *et al.* (2003) reported that the partial factor productivity of the crops for fertilizers and manures, irrigation and pesticides has been declining over the past decade and there is good scope to introduce better management practices using holistic farm management approach to increase the production by reducing yield gaps (attainable yield minus actual yield), namely 48, 30, 35 and 52% for rice, wheat, maize and mustard respectively.

Studies undertaken by many researchers revealed that the crop yields in dryland areas of Central India are quite low (1–1.5 t/ha) which are lower by two- to fivefold of the achievable potential yield (Fig. 9.2) largely due to low (35–45%) rainwater as well as resource use efficiency (Rockström *et al.*, 2007; Singh *et al.*, 2009; Wani *et al.*, 2009; Jha *et al.*, 2011). ICRISAT and its partners have demonstrated that large yield gap exists for different dryland crops in different parts of the country as well as in the region. The current farmers' yields of rainfed crops are lower by two- to fourfold than the yield from researcher-managed or commercial plots.

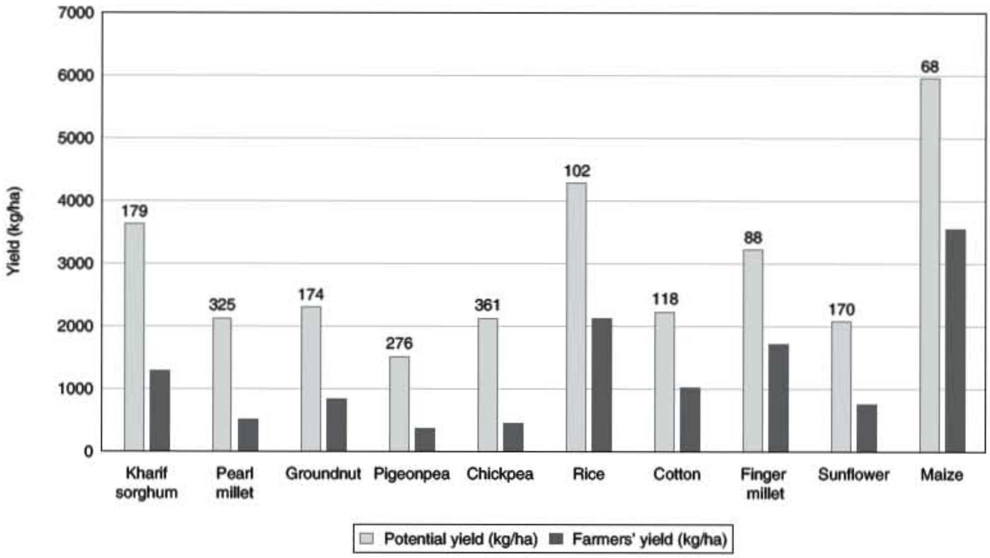

Fig. 9.2. Crop yields in farmers' fields in Central India compared with the potential yield.

9.2.2 Assessing the challenges for increasing system productivity

In the project area of Madhya Pradesh, in addition to the problem of soil erosion and waterlogging, particularly in lowland, Vertisols and associated soils, a large tract of land is kept fallow during the rainy season. The rainy season fallow area is about 16,400 ha in the two target districts of Madhya Pradesh despite relatively fertile soils and assured rainfall. Similarly, an extensive tract of land in Jharkhand is kept fallow after harvest of the rainy season crop, although sufficient stored moisture remains in the soil for growing a post-rainy season crop. However, nutrient depletion is a common problem across these rainfed areas. Thus, the potential for double cropping in these areas remains untapped due to the lack of availability of proper technology for soil, water, nutrient and crop management, and improved crop cultivars.

9.2.3 Soil health mapping as an entry point activity

Soil and water are vital natural resources for human survival. The burgeoning world population and increased standard of living are placing tremendous pressure on these resources. Because the soil and water resources are finite, their optimal management without adverse environmental consequences is necessary, if human survival is to be assured and development is to be sustained. In India, severe soil infertility problems in the rainfed systems (Rego *et al.*, 2007; Bekunda *et al.*, 2010; Sahrawat *et al.*, 2010b) and managing water stress alone cannot sustainably enhance the productivity of rainfed systems; hence for achieving sustainable gains in rainfed productivity both water shortage and soil fertility problems need to be simultaneously addressed through effective natural resource management practices (Wani *et al.*, 2009; Sahrawat *et al.*, 2010a).

Indian soils show deficiency of not only primary nutrients (nitrogen (N), phosphorus (P) and potassium (K)) but also secondary nutrients (sulfur (S), calcium and magnesium) and micronutrients (boron (B), zinc (Zn), copper and iron) in most parts of the country. Field studies carried out by different researchers clearly indicate that integrated nutrient management comprising soil test-based nutrient management approach can be an important entry point activity and also a mechanism to diagnose and manage soil fertility in practical agriculture (Wani, 2008). Research at ICRISAT and several on-farm benchmark watersheds demonstrated that soil testing is a useful tool for diagnosing the nutrient deficiencies in farmers' fields (Sahrawat *et al.*, 2010a). Therefore soil sampling and its chemical analysis assumes greater importance for developing soil test-based fertilizer recommendation more precisely at micro level.

Thus, soil health mapping was adopted as entry point activity under the SRTT initiative to strengthen the soil resource base. Farmers' fields in target regions were found seriously mined of S, B and Zn. In Jharkhand, 69–100% farms were low in S, 93–98% in B and 71–73% in Zn (Table 9.1). Similarly in Madhya Pradesh, 43–95% farms were low in S, 69–91% farms in B and 5–19% farms in Zn. Some farmers' fields also showed low levels of soil organic carbon (C), available P and K; however, in general, the majority of fields had their normal levels. Saraikela district, by contrast, had a majority of farms with low levels of P (80%) and K (58%). The results revealed relatively serious land degradation in Jharkhand as compared with Madhya Pradesh.

9.2.4 Institutional arrangement

To reach out to a large number of farmers for developing sites of learning and scaling-out best practices, ICRISAT entered into agreements with local NGOs such as Tata Rural Development Trust, Jamshedpur and PRADHAN, Gumla in Jharkhand and Gramin Vikas Trust, Jhabhua and Foundation for Ecological Security, Mandla in Madhya Pradesh. In addition to the NGO partners, other important partners collaborated for collective action, such as integrated watershed management programmes in target states, state agricultural universities (SAUs) (Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur; Birsa Agricultural University, Ranchi), national research institutes (Indian Institute of Soil Science, Bhopal; and National Research Centre for Soybean, Indore), All India Coordinated Research Project for Dryland Areas and Jain Irrigation Ltd, Jalgaon.

9.2.5 Capacity building

Training assessment

In the SRTT project, efforts were made to understand the variability of different factors affecting crop productivity, its sustainability and thereby livelihood of the farmers, and accordingly training modules were designed for capacity building of all the stakeholders. The first and foremost aspect targeted at the beginning of the project was to assess the need for training and conduct training programmes. To provide quality training, efforts were placed on developing training material and content, and delivery of a programme and targeting the right stakeholder for the particular training.

Capacity building under the initiative

Capacity building of various stakeholders and farmers has been an important component of the SRTT project. For the successful technology transfer to grassroot level, capacity building is very important as without it no technology can percolate down to grassroot level. Thus farmers were oriented towards better crop production technology and their capacity was built by organizing various types of training on new technology and better farming practices. Some of the major interventions were technical training conducted in villages, planning exercises carried out, self-help groups (SHGs) trained for management of seed banks, field exposure visits and farmers' days. Apart from this, training was provided on soil sampling (Fig. 9.3), use of multipurpose bullock-drawn toolbar – tropicultor; planting of *Gliricidia* on bunds, balanced nutrient management including secondary and micronutrients, seed priming, vermicomposting, nursery raising and seed bank development. Various capacity-building activities were taken up for effective implementation of productivity enhancement through sustainable management of natural resources in Jharkhand and Madhya Pradesh. Along with this initiative, ICRISAT conducted capacity-building courses on integrated watershed management and best practice management options for senior policy makers from the states as well as from the NGO Central India Initiatives (CINI) and other NGO staff. Lectures on methodology of designing and delivery mechanisms were followed by demonstration and hands-on training and skills development, which resulted in increased adoption of the technologies with high degree of success. The primary stakeholders were marginal and small farmers from the project districts. During the project period, annual workshops, training during crop seasons and field days were conducted with targeted activities. During the project period, around 5371 farmers were trained on different agro-techniques

Table 9.1. Soil fertility status of farmers' fields in target districts in Jharkhand and Madhya Pradesh states of India. From: Chander *et al.* (2012).

State	District	pH	% deficiency[a] (Range of available contents[b])					
			OC	P	K	S	B	Zn
Jharkhand	Gumla	5.0–7.1	33 (0.28–1.13)	23 (1.4–72.4)	27 (29–247)	100 (2.0–9.6)	93 (0.06–0.80)	73 (0.30–2.90)
	Saraikela	4.5–7.4	45 (0.19–0.99)	80 (0.0–18.2)	58 (8–194)	69 (1.3–50.0)	98 (0.06–0.80)	71 (0.24–2.50)
Madhya Pradesh	Jhabua	6.4–7.4	0 (0.58–1.53)	45 (0.2–42.2)	0 (88–506)	95 (2.7–28.2)	91 (0.26–0.76)	5 (0.66–3.18)
	Mandla	5.9–7.4	3 (0.45–2.62)	32 (1.0–147.5)	0 (82–1846)	43 (2.0–74.2)	69 (0.06–1.02)	19 (0.40–5.50)

[a]Critical values adopted for delineating % deficiency are 0.5% for OC, 5 mg/kg for P, 50 mg/kg for K, 10 mg/kg for S, 0.58 mg/kg for B and 0.75 mg/kg for Zn.
[b]Figures in parentheses indicate the range of available contents (% for OC and mg/kg for P, K, S, B and Zn).

Fig. 9.3. Soil sampling training to farmers of: (a) Jojo village of Saraikela district, Jharkand; (b) Katangsivani village of Nivas block of Mandla district of Madhya Pradesh.

directly by ICRISAT and partners whereas capacities of more than 20,000 farmers were improved through indirect measures, namely field exposure visits, results of demonstrations and field days during the cropping season.

9.2.6 Dissemination

The learnings from the project were disseminated and spread in the neighbourhood cluster of villages. For disseminating the results of the interventions, field exposure visits of nearby villagers were targeted as an important activity under this initiative. This helped in training as well as straightforward transfer of technology, knowledge transfer and skills development to different stakeholders. Thus, there was no intermediary and this helped farmers to learn directly from the live demonstrations and knowledge providers (scientists, field staff, NGOs, ICRISAT, SAU partners, etc.). The project partner NGOs were active in their respective areas and conducted field-level training, field days, field exposure visits and farmers' days with active help and guidance from ICRISAT scientific staff.

9.3 Integrated Approach for Livelihood Improvement

An integrated livelihoods framework is essential for increasing agricultural productivity, income and sustainable use of natural resources by adopting the participatory and holistic farming system approach. In order to bridge the yield gap, ICRISAT and its partners have adopted integrated genetic natural resource management (IGNRM) guided by an inclusive market-oriented development strategy, linking farmers with markets and reaping the benefits of productivity enhancement initiative. The aim is to bridge the gap between the 'desired' and 'achieved' and to bring quantitative as well as qualitative improvement in fulfilling the food needs in parts of Central India, so as to sustain the agricultural resource base and to provide livelihood security to millions of rural citizens.

9.3.1 Soil test-based balanced nutrient management

Balanced nutrient management is the timely application of all essential plant nutrients (which include primary, secondary and micronutrients) in readily available form, in optimum quantities and in the right proportion, through the correct method, suitable for specific soil/crop conditions. It includes judicious use of chemical fertilizers based on deficient soil nutrients as established by soil testing in conjunction with other sources of plant nutrients such as organic manures and bio-fertilizers. Use of soil amendments for acidic/alkaline soils also need to be promoted to improve soil health and its fertility thereby ensuring adequate availability of nutrients in soils to meet the requirement of plants at critical stages of growth and thus ensuring adequate soil humus to improve physico-chemical and biological properties of the soil. Researchers have reported that soils below the critical limits of the nutrients evaluated responded to the application of nutrients although the overall crop response was regulated by the rainfall received during the cropping season (Rego *et al.*, 2007; Sahrawat *et al.*, 2007, 2010b).

Thus, based on analysis of results, fertilizer recommendations were designed for a cluster of villages called a block, a lower administrative unit in a district and promoted in the pilot sites. In Jharkhand, the yield benefit with soil test-based fertilization was 27–44% in crops such as paddy, groundnut and maize as compared to that under farmers' standard practice (Table 9.2). The benefit–cost (BC) ratio of adopting balanced nutrition (BN) was 11.5–12.0 for paddy, 7.36–12.0 for maize and 9.92 for groundnut. Similarly, in Madhya Pradesh, BN increased crop productivity when compared with farmers' practice by 11–57% in crops like soybean, paddy, green gram, black gram and groundnut. The BC ratio of adopting BN in Madhya Pradesh varied between 1.97 and 9.35, a profitable proposition to promote BN.

9.3.2 Weather monitoring

A rain gauge with a dual recording system (manual and using a data logger) was installed in all the pilot sites for recording rainfall, minimum

Table 9.2. Crop yield improvement with balanced nutrition (BN) in Gumla district, Jharkhand and Jhabua district, Madhya Pradesh, India during the rainy season 2009–13.[a]

	Yield (kg/ha)		
Crop	FP	BN	BC ratio
Gumla			
Paddy	3442.5	4762.5	11.75
Groundnut	1997.5	2950	10.66
Maize	3785	4995	9.68
Jhabua			
Soybean	1495	1705	2.205
Paddy	2435	3230	5.215
Green gram	907.5	1292.5	7.135
Black gram	560	662.5	3.36

[a]FP = farmers' practice; BC = benefit–cost.

and maximum temperatures, and relative humidity (Fig. 9.4). The data was recorded daily for all the above parameters by the villagers, who were trained by ICRISAT on the working of the rain gauge and maintenance of the data set.

Rainfall data was recorded by farmers from the rain gauges installed at Teleya village for Gumla district and at Sherbida village for Saraikela district. Rainfall received in Gumla district was higher than normal during 2008 and 2011 (101.3% and 108.6% of normal rainfall respectively), whereas during 2009, 2010, 2012, 2013 and 2014, the rainfall ranged from 49.4 to 80.3% of normal rainfall (Fig. 9.5). Thus, except in 2008 and 2011, paddy as well as other crops suffered due to deficit rainfall and thereby recorded reduction in crop productivity. In Saraikela district, rainfall during 2008 was 97.5%, but during 2009 to 2014 there was only 36.3–85.4% of normal rainfall, which clearly affected the crop productivity in these areas. However, ICRISAT promoted a diversified cropping pattern in the pilot areas with the introduction of crops, namely maize, black gram and chickpea, which could be grown with less rainfall.

The rainfall deficit affected paddy cultivation, meaning that farmers incurred huge losses on raising paddy seedlings, as transplanting was not possible in many places. The rainfall information shared with the farmers helped them with better planning of growing upland crops and vegetables. Due to the variability in rainfall, coupled with its irregular distribution, farmers were advised to plant more upland crops which require less water than paddy, and they realized the usefulness of this change over monocropping of paddy. Thus, the farmers obtained considerable yield from the change in cropping pattern, promoted through both vertical and horizontal integration, and thereby obtained sufficient nutritional food security besides ensuring economic stability.

9.3.3 Water conservation and harvesting

In the target districts, the productivity enhancement practices available through integrated water resource management are used with participatory research and development approach for enhancing the overall productivity of farming

Fig. 9.4. Dual-purpose manual and recording type rain gauge with data logger installed at (a) Sherbida in Jharkand and (b) Hateyadeli in Madhya Pradesh.

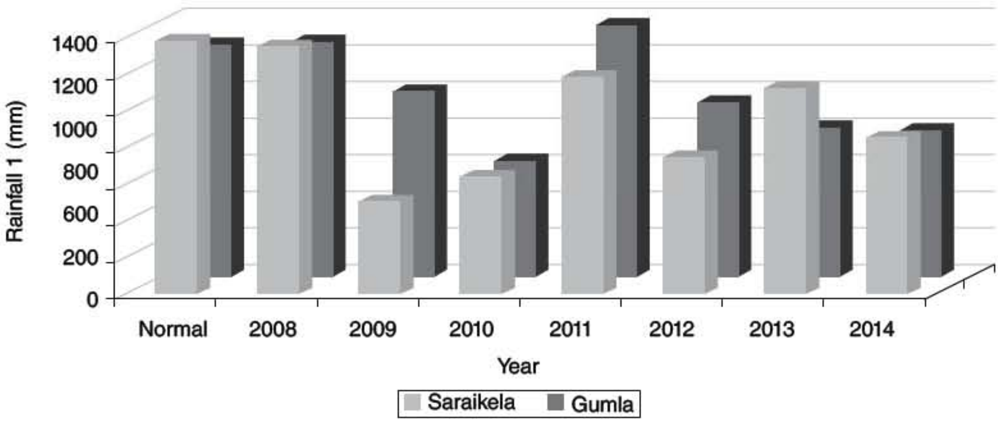

Fig. 9.5. Rainfall during 2008–14 in Gumla and Saraikela districts of Jharkhand.

systems. Water-shortage-related plant stress is the primary constraint to potential crop production and productivity in the rainfed systems in the semi-arid tropics (SAT), and consequently the importance of water shortage has been rightly emphasized globally (Wani *et al.*, 2002; Molden, 2007; Pathak *et al.*, 2009). In rainfed agriculture, demand for rainwater can be met through efficient rainwater conservation and management. For this both *in situ* and *ex situ* rainwater management play crucial roles in increasing and sustaining the crop productivity. The comprehensive assessment of water management in agriculture (Molden, 2007) describes a large untapped potential for upgrading rainfed agriculture and calls for increased water investments in the sector.

Water harvesting through the construction of farm ponds comprising small dugout structures with a capacity of 300–400 m^3 and having a catchment area of around 1 acre was promoted in the project area (Fig. 9.6). These ponds were constructed on the land of farmers who had a landholding of 0.75–2 acre and with the active contribution from beneficiary farmers in kind. The construction cost was ₹10,000 per farm pond. Farm ponds supported supplemental irrigation during the critical crop growth stage besides serving as a reservoir for fish cultivation. Thus, 256 farm ponds in Gumla district (Fig. 9.7) and 30 farm ponds in Saraikela district were constructed with the farmers' contribution. In 2012–13 season, 500 g of fish seeds were released in each farm pond and each pond contributed

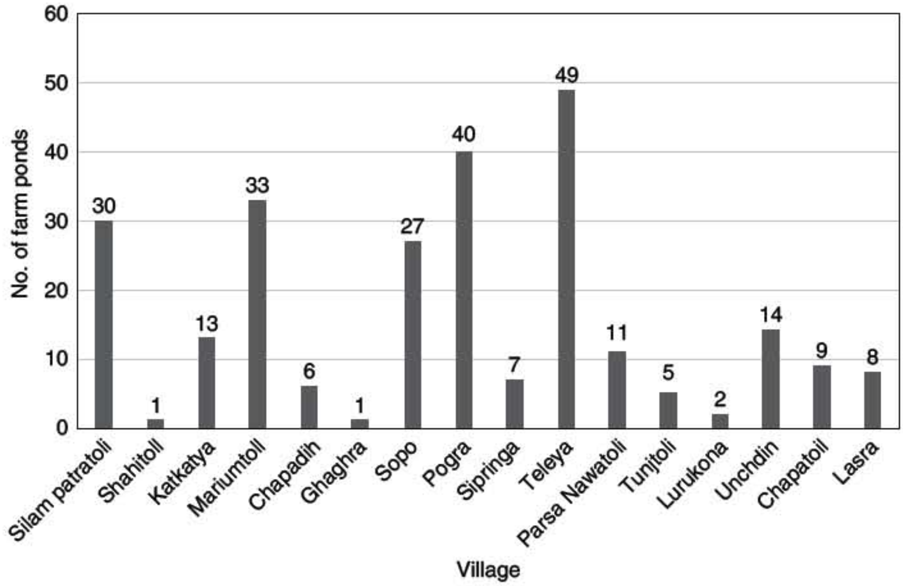

Fig. 9.6. Farm ponds constructed in villages in Raideh block, Gumla district, Jharkhand during 2010–14.

Fig. 9.7. Farm pond at Sipringa village in Gumla district, Jharkhand.

profit of ₹6000–7000 to beneficiary farmers. During 2013–14, the government also supported this activity by giving fish seeds and feed as a subsidy to farmers, who thus gained increased monetary benefits up to ₹10,000 from each pond. These farm ponds also provided drinking water for cattle and provided water for washing clothes.

9.3.4 Crop intensification

Rainy season fallow management

Vertisols and associated soils which occupy large areas globally (approximately 257 million ha) (Dudal, 1965) are traditionally cultivated during the post-rainy season on stored soil moisture. Due to poor infiltration rates and waterlogging, farmers were facing difficulties to cultivate during the rainy season. It is perceived that the practice of fallowing Vertisols and associated soils in Madhya Pradesh have decreased after the introduction of soybean. However, 2.02 million ha of cultivable land is still kept fallow in Central India, during *kharif* (rainy season) (Wani *et al.*, 2002; Dwivedi *et al.*, 2003). Therefore efforts were made to intensify the *kharif* fallow areas with suitable landform management options along with required change in cultivar selection. Accordingly, ICRISAT conducted on-farm soybean trials involving improved land configuration (broad-bed and furrow system) and short-duration soybean varieties during *kharif* and growing of chickpea with minimum tillage in *rabi* (post-rainy season), which had practically enhanced the cropping intensity in Guna, Vidisha and Indore districts of Madhya Pradesh. The results revealed that there was an increase in crop yields of 40–200% while income increased up to 100% with landform treatment, new varieties and other best practice management options (Wani, 2008) through crop intensification.

Rice fallow management for crop intensification

To feed the burgeoning population, vertical expansion in dryland agriculture is being targeted by many stakeholders with the aim of increasing productivity. However, the other potential areas, particularly rice fallows in eastern and southern India (Jharkhand, Bihar, Chhattisgarh, Andhra Pradesh, Odisha and Assam) offer great scope for horizontal expansion of area by inclusion of a suitable pulse crop in the system and thereby enhancing cropping intensity and systems productivity. About 14.29 million ha (30% of the rice-growing area) rice fallows are available in the Indo-Gangetic Plains spread in Bangladesh, Nepal, Pakistan and India, of which 11.4 million ha (82%) are in the Indian states of Bihar, Madhya Pradesh, Chhattisgarh, Jharkhand, West Bengal, Odisha and Assam (Subbarao *et al.*, 2001). ICRISAT analysed rice fallows in pilot sites along with identification of various bottlenecks associated with effective and sustainable utilization of rice fallows (Subbarao *et al.*, 2001) and it was estimated that considerable amount of green water is available after the monsoon, especially in the rice fallow systems, which could be easily utilized by introducing a short-duration legume crop with simple seed priming and micronutrient amendments (Kumar Rao *et al.*, 2008; Wani *et al.*, 2009; Singh *et al.*, 2010). Taking advantage of the sufficiently available soil moisture after harvesting the rice crop, growing of early-maturing chickpea during the winter season in rice fallow areas with best management practices provides an opportunity for intensification (Harris *et al.*, 1999; Kumar Rao *et al.*, 2008).

Therefore efforts were targeted towards introducing appropriate legumes into rice fallows to have significant impact on the national economies through improved quality of nutrition for humans and animals, poverty alleviation, employment generation and contribution to the sustainability of the cereal-based production systems. ICRISAT adopted the strategy to develop a sustainable farmers' participatory seed production system for pulses by promoting improved agronomic (e.g. seed priming, soil test-based balanced fertilizer including micro- and secondary nutrients, biofertilizers, integrated management, etc.) and water conservation practices (e.g. zero/minimum tillage, relay planting) for better crop establishment in rice fallows. Similarly, suitable rice cultivars with appropriate crop duration were identified to help make use of residual moisture to promote short-duration pulses during *rabi*. This intensification combined early-maturing varieties of rice to best fit chickpea in sequence as there is time to sow a chickpea crop to take advantage of the residual moisture in the soil.

Earlier, the rice varieties cultivated were late maturing and were sown late, thereby increasing more area left as fallow. However, with ICRISAT intervention, the farmers started growing an extra crop on residual soil moisture. On-farm research in farmers' fields have clearly showed that short-duration pulses are suitable for cultivation in rice fallows and good yields can be obtained, provided suitable varieties and technologies including mechanization for crop establishment in rainfed rice fallows are made available. Participatory trials to demonstrate and evaluate chickpea cultivars (JG 11, JGK 9218 and KAK 2) in post-rainy fallow regions showed a yield of 1710–1900 kg/ha with KAK 2 and 1608–1728 kg/ha with JG 11 in Jharkhand (Table 9.3). Results clearly demonstrated that chickpea is a suitable crop to grow after rice in otherwise fallow regions and that is bringing dividends for the farmers through additional income as well as by enhancing rainwater use efficiency.

An economic analysis for the project sites revealed that growing legumes in rice fallows is profitable for farmers with BC ratio exceeding 3 for many legumes. In addition, utilizing rice fallows for growing legumes resulted in the generation of employment to the farmers, besides helping in tackling issues of nutrient deficiencies due to inclusion of pulses in the diet.

9.3.5 Farmer participatory varietal evaluation

Balancing productivity, profitability and environmental health is a key challenge for today's agriculture for ensuring long-term sustainability (Robertson and Swinton, 2005; Foley *et al.*, 2011). However, most crop production systems in the world are characterized by low species and management diversity, high use of fossil energy and agrochemicals, and large negative impacts on the environment. Therefore, there is urgent need to focus attention on the development of crop production systems with improved resource use efficiencies and more benign effects on the environment (Tilman *et al.*, 2002; Foley *et al.*, 2011). Cropping system design provides an excellent framework for developing and applying integrated approaches to management because it allows for new and creative ways of meeting the challenge of sustaining the agricultural productivity.

Table 9.3. Evaluation of chickpea cultivars in rice fallows in Jharkhand during post-rainy season.

District	Block	Variety	Yield (kg/ha)
Gumla	Raideh	KAK 2	1900
		JG 11	1610
Saraikela	Saraikela	KAK 2	1710
		JG 11	1730

The main issue with the existing cropping system in the targeted districts was the recurrence in usage of low-yielding cultivars year after year, which was accompanied by low seed replacement rate, largely contributing to decrease in factor productivity and in turn low crop production. So efforts were made to focus on farmer participatory varietal evaluation programme in these pilot districts to test the suitability of new high-yielding climate smart crops and cultivars to prevailing climatic situations. The farmer participatory varietal evaluation programme works towards increasing farm productivity by facilitating the delivery of high-yielding, profitable varieties that are well adapted to a wide range of soil types, environments and farming systems. This is achieved by providing accredited, unbiased information to farmers on better adapted crop varieties, or new and better cultivars, at the earliest opportunity. In all targeted districts of Madhya Pradesh and Jharkhand, farmers were able to choose improved varieties of preferred dryland crops from the list of varieties provided to farmers' groups.

ICRISAT and SAUs released improved cultivars and proprietary hybrids of crops were evaluated in this mission programme with an objective to select cultivars having suitable traits for better adaptation to biotic and abiotic stresses to enhance or sustain productivity and further scaling-up the spread of these varieties to satellite taluks. Each demonstration was laid approximately on 0.5–1 acre of farmer's field. Best management practice included application of 70 kg diammonium phosphate, 100 kg urea, 5 kg borax, 50 kg zinc sulphate and 200 kg gypsum per ha for cereal crops and for legumes a reduction in urea application from 100 to 40 kg/ha. The layout of varietal trial was designed to assess the performance of local variety with traditional practice of input management. In this trial, there were two treatments: (i) farmers' practice with local/traditional cultivar + farmers' inputs; (ii) Improved cultivar + best practice inputs.

With these trials, farmers were exposed to several improved varieties of each crop grown in their villages and had the option of evaluating the performance of each variety more or less in the same climatic and soil conditions with different levels of input management. Participatory varietal selection trials were confined to two or three main rainfed cropping systems of the district/region during the crop season. During the rainy and post-rainy seasons, crops evaluated included cereals (sorghum and pearl millet), pulses (pigeonpea, chickpea and cluster bean) and oilseeds (groundnut, soybean and castor). The programme collects and delivers the data which not only assists farmers with their choice of suitable varieties but also facilitates the registration and commercialization of new cultivars by plant breeders. The experimental protocol has been established to evaluate the performance of improved varieties under BN against a common set of traditional varieties to characterize their yield, quality, disease resistance/tolerance and agronomic characteristics. The information on yield performance of the improved cultivars was collected through crop-cutting experiments by ICRISAT, NGOs and lead farmers in presence of agriculture department staff/officials.

9.3.6 Crop diversification

In Madhya Pradesh and Jharkhand, the agriculture sector is the important source of livelihood for over 65% of the total population that is dominated by small and marginal farmers. After independence, there was yield advantage in these regions due to irrigation expansion and Green Revolution technologies well supported with government policies. However during the course, especially in Jharkhand and partially in Madhya Pradesh, there was a tendency towards cereal specialization without inclusion of pulses and oilseeds in the cropping system, which in turn resulted in decline in factor productivity often coupled with more probability of crop failures. So attempts were made to come out of subsistence agriculture having dependence on single crop and move towards diversified crops that have a larger potential for returns from land. For crop diversification in targeted sites, information was obtained on the potential benefits of diversifying cropping systems through efficient crop rotation as a means of controlling decrease in crop productivity while simultaneously enhancing other desirable agroecosystem processes (Karlen and Stott, 1994). The aim in diversifying the cropping system in these states, particularly in rainfed ecology, was to reduce the risk factor of crop failures due to drought or less rains or decline in market value. This process was triggered by inclusion of suitable pulses (namely pigeonpea, green gram, black gram, cowpea, etc.) and oilseeds (namely soybean and groundnut) to the existing cropping system either as vertical or horizontal integration which proved to be one of the safest cultivation practices to overcome the climate change effect. ICRISAT witnessed similar experiences from these states and also from Southeast Asian countries, which clearly revealed that diversification toward high-yielding cultivars leads to the development of innovative supply chains and opens new vistas for augmenting income, generating employment and promoting exports. Thus, if carried out appropriately, diversification can be used as a tool to augment farm income, generate employment, alleviate poverty and conserve precious soil and water resources.

Major driving forces for crop diversification were increasing income on small farm holdings, mitigating effects of increasing climate variability, balancing food demand, improving fodder for livestock, conservation of natural resources, minimizing environmental pollution, reducing dependence on off-farm inputs, decreasing insect pests, diseases and weed problems, and increasing community food security. Based on these aspects, pigeonpea was pilot-tested and evaluated at SRTT sites and results proved that it could be a potential crop for these regions (Table 9.4). The yield of important varieties was 760–880 kg/ha in Hazaribagh district whereas in Deoghar district, it ranged between 2050 and 2290 kg/ha.

9.4 Livelihood Improvement

Apart from targeting productivity enhancement interventions, efforts were also concentrated on

Table 9.4. Evaluation of pigeonpea varieties in Jharkhand, post-rainy season 2009–13.

District	Block	Variety	Yield (kg/ha)
Hazaribagh	Mandu	Asha (ICPL 87119)	790
		Laxmi (ICPL 85063)	880
		Puskar (ICPH 2671)	760
Deoghar	Palajor	Asha (ICPL 87119)	2050
		Laxmi (ICPL 85063)	2290

improving livelihood of resource-poor farmers in pilot districts of Jharkhand and Madhya Pradesh. Emphasis was especially given to empowering women through certain targeted activities, namely vermicomposting, kitchen gardening, raising nurseries for vegetable seedlings as well as for biological N-fixing trees, producing quality seed and establishing a village seed bank, etc. All these activities were promoted through women as well as youth clubs collectively as the SHGs with a focus on increasing the income to their family.

9.4.1 Vermicomposting

Vermicomposting activity was started in all the districts with demonstration of model units constructed at all locations. Training was provided to farmers for the preparation of vermicompost using crop and field organic waste and dung and earthworms. In Teleya village of Gumla district, 22 units were constructed in 2009 by active involvement of farmers. After realization of benefit of increased yield in vermicompost applied field of vegetables and agricultural crops, there was huge demand generated at local level. Therefore, vermicomposting was successfully promoted to each farmer in the pilot sites in Gumla district and many farmers' fields in other pilot districts (Fig. 9.8). Villagers in the surrounding areas also learnt this process and more than 50 units were established by farmers themselves by taking advice and guidance from the locally trained lead farmers from the pilot sites. The strategy was worked out with support from Government of Jharkhand and SRTT team so that in this initiative, the cost of material for tank construction was borne by the team whereas farmers invested in the shed. The cost of each unit was around ₹3000 and each unit had 2 or 4 chambers and comprised internal walls with holes for the movement of earthworms from one chamber to the other.

With the project direct interventions, altogether 87 units were established in Gumla district in four villages, viz. Teleya, Sipringa, Tunjutoli and Parsa Novatoli and 27 units were established in Sherbida and Jojo villages of Saraikela district which are producing higher quantity of good-quality compost. In order to make better use of this activity, extensive training was given to the farmers on the approach, methodology and maintenance of vermicomposting units using crop and field organic waste with dung and earthworms. Each unit produces about 800–1000 kg of good quality of vermicompost. Similarly, farmers were encouraged to use the vermicompost for cultivation of vegetables, as it helps in improving the quality of produce besides obtaining increased productivity. The results clearly revealed that farmers cultivated vegetables such as cauliflower, tomato and pea using vermicompost and obtained 20–80% increase in quality produce compared to their general cultivation practices. Even after withdrawal of ICRISAT from the project in 2004, all the farmers are still active in vermicompost preparation and harvest 800–1000 kg of produce three times a year.

9.4.2 Vegetable cultivation

The farm ponds have sufficient water to support a considerable area, particularly in providing supplemental irrigation to crops both during the *kharif* and *rabi* seasons. With the additional water, farmers started cultivating vegetables like tomato, cauliflower, cabbage, brinjal, okra, peas, potato and other leafy vegetables during winter and summer. In order to use the available water efficiently, drip irrigation was promoted for vegetable cultivation in Teleya village in Gumla district with support from ICRISAT and team. The efforts towards off-season cultivation of these vegetables has enabled considerable economic gain to the farmers as they earn net profit of ₹8000 to ₹10,000/*bigha* land (1 *bigha* = 0.2 acre). After reaping such huge benefits, this watershed model now was extended to many villages in Gumla and Saraikela districts, where

Fig. 9.8. Vermicompost units at farmer's field in Gumla district, Jharkhand.

farmers are constructing farm ponds on their own land with the support from Government of Jharkhand, and technical guidance from ICRISAT and NGO partners involved in this project.

9.4.3 Biomass generation for soil fertility management

Considering the poor soil health due to indiscriminate use of fertilizers, efforts were concentrated on promoting green manuring activities in the project area. Accordingly, *Gliricidia* seeds were distributed to farmers who were then trained on raising the seedlings in nurseries and plantation on field bunds and boundaries. Farmers were encouraged to plant 3–4-month-old plants from the nursery or cuttings of tender branches of *Gliricidia* at 50 cm apart on field bunds. *Gliricidia* plants produce green leaf and succulent green branches abundantly, which are rich in N. The *Gliricidia* plants grown on bunds not only strengthen the bunds while preventing soil erosion but also provide N-rich green biomass, fodder and fuel. *Gliricidia* can be harvested 2–3 times in a year and applied before sowing of rainy and post-rainy season crops. A study conducted at ICRISAT Center indicated that adding the N-rich green biomass from *Gliricidia* plants planted on bunds at a spacing of 0.5 m apart for a length of 700 m could provide about 30–45 kg N per ha per year. From the first year itself, farmers harvested the green leaf and loppings, leaving 1-m-high plants, and applied it to the top soil for enriching organic C and nutrients in the soil.

During 2008–14, 5–10 kg of *Gliricidia* seeds were supplied by ICRISAT to women SHGs and youth clubs to raise the seedlings at all the project locations. Seeds were treated with acid for removing dormancy and planted in polythene bags (supplied by ICRISAT) by adding soil mixed with fertilizer and vermicompost (Fig. 9.9). Women SHG and youth club members raised about 15,000–35,000 seedlings per year in

Fig. 9.9. *Gliricidia* seedlings raised in a nursery for transplantation into the main field at Teleya village, Jharkand.

Gumla district and 7000–15,000 seedlings per year in Saraikela district since 2008 and sold these seedlings to fellow farmers for planting on main field bunds at low price. Seedlings were planted during the rainy season as hedges on field bunds (Fig. 9.10) and inside the fence of mango orchards. Farmers also planted these seedlings on bunds as fences for vegetable fields. Loppings were placed in paddy and vegetable fields and around mango plants, which resulted in good crop yields besides a reduction in cost of fertilizer use. Apart from these project locations, about 1–2 kg seeds were supplied to different NGOs associated with project partners for promoting *Gliricidia* planting in different locations, namely Kunti, Keonjar, Mandu, Hazaribagh, Deoghar, Pravah Deoghar and RDA Ghatsila.

9.4.4 Seed bank

Considering the lack of quality seed available to farmers, efforts were targeted towards producing quality seed at farmer level and its preservation by SHGs at village level. Thus the concept of the seed bank was established in the pilot villages in Jharkhand and Madhya Pradesh. In Gumla, Jharkhand and Jhabua, Madhya Pradesh seed banks were successfully established where in seeds of pigeonpea (Asha, Maruti variety) black gram (TAU 1, T 9 variety), chickpea (JG 11, JAKI 9218 variety) were established. Lead farmers were taking care of seed bank management and necessary precautions and care were taken by them to protect seeds from any pest damage. ICRISAT gave these farmers hands-on training in seed storage and its protection. The farmers were trained in seed production of crops such as black gram, chickpea and pigeonpea and also their grading and storage aspects. The seed bank concept helped farmers to earn a good profit by selling the stored seed at a premium price to fellow farmers.

9.4.5 Kitchen gardening

For this activity, the women farmers were guided and supported to grow vegetables in a small area (0.1 to 0.2 *bigha*) or as kitchen garden to improve family nutrition and capture the market-led opportunities. The demand-driven seeds of vegetables such as brinjal, tomato, okra, cabbage and cauliflower were provided during the initiative by ICRISAT along with required capacity building and other inputs like soil test-based nutrients.

Fig. 9.10. *Gliricidia* planted by farmers on farm bunds as a living fence in Sherbida village, Saraikela district, Jharkhand.

Vegetables were grown by around 100 women farmers every year and they obtained good yields and income.

9.5 Sustainability

In the project sites, a common practice of open grazing of animals prevails after the harvest of the paddy crop. Thus, concerted efforts were targeted on training and awareness building of stakeholders (including farmers and development agencies), strengthening formal and informal seed systems and increasing access to other inputs for enhancing adoption of improved cultivars and technologies. Along with technology demonstrations, for bringing awareness to stakeholders and policy makers, social engineering was focused to intensify crop production in these fallows. For effective implementation and scaling-up of interventions, a sustainable approach with efficient monitoring and evaluation system was followed. It was aimed to target and demonstrate crop intensification as well as other technologies on a pilot basis and further scale-out to a large number of farmers' fields in a phased manner. This initiative helped in strengthening various environmental benefits/ecosystem services such as improved land- and water-use efficiency and a more resilient rice-based cropping system with balanced fertilizer input and improved soil fertility. Apart from the increased income and livelihood, the project helped the community to address the issues of nutritional deficiency with increased domestic availability of chickpea and other pulses.

9.6 The Way Forward

The initiative supported by SRTT has demonstrated several agrotechniques for adoption by resource-poor farmers. The soil health status clearly reflected that there are widespread deficiencies of S, B and Zn in Jharkhand and Madhya Pradesh, which farmers should consider and include in their fertilizer management strategies. The on-farm evaluation results in pilot sites suggest the need to promote the use of vermicompost in vegetable production for higher productivity and net returns. Almost all farmers from Gumla district, and many farmers from other pilot districts, constructed vermicompost units in their fields and are judiciously utilizing them in vegetable as well as food grain production. Crop intensification with chickpea, black gram and short-duration pigeonpea has helped in horizontal expansion of cropping intensity in the area with additional net profit of ₹8000–15,000 per ha. Varietal replacement and increased livelihood opportunities like village seed banks, fodder promotion for livestock productivity and nutri-kitchen gardens are notable interventions for improving the incomes of farmers. The smallholders in the rainfed SAT of India are unaware of the issues and available technologies and are not in a position to implement the science-led strategy on their own. So, there is a strong need for desired policy orientation by the respective governments to promote capacity strengthening and soil test-based integrated and balanced nutrient management strategies through appropriate incentives for poor smallholders in the SAT of India.

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