Chapter 4
Scaling-Up Land and Crop Management Solutions for Farmers Through Participatory Integrated Demonstrations "*Seeing is Believing*" Approach

Suhas P. Wani, Raghvendra Sudi, and G. Pardhasardhi

Abstract Farmers' distress is noted across the country and it can get worse with the impacts of climate change as the small farm-holders in tropical regions are most vulnerable to impacts of climate change. At present farmers' yields are lower by two to five folds than the achievable potential yields. Further, farmers receive only 30–40% of the price what consumers pay as the current value chains are inefficient and long. As a result, farmers' incomes are almost half as that of city households (Rs 40,925 rural vs. Rs 98,435 urban per capita). Given the choice, large number of farmers would like to come out of agriculture and youths are shying away from agriculture (National Sample Survey Organization (NSSO), Situation assessment survey of agriculture households in India (70th Round: July 2012–June 2013). Ministry of Statistics and Program Implementation, New Delhi, 2013). To achieve the sustainable development goal of no poverty (SDG 1) zero hunger (SDG 2) and good health and wellbeing (SDG 3) there is an urgent need to transform agriculture in India as well as in other developing countries in Asia and Africa. For scaling-up technologies such as improved cultivars, soil, water and nutrient management technologies, income-generating micro-enterprises particularly undertaken by women and youths to benefit farmers for increasing productivity and incomes "*Seeing is believing* "principle is a well-tested and proven tool to build the capacity of the

S. P. Wani (✉)
Former Director, Research Program Asia & ICRISAT Development Centre, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India

International Consultant, Asian Development Bank, Manila, The Philippines

R. Sudi
Watersheds, ICRISAT Development Centre, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India

G. Pardhasardhi
CRAL, ICRISAT Development Centre, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India

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farmers. Results from various scaling-up initiatives benefitting >10 million farmers in India, China, Thailand, and Vietnam are discussed and drivers of success are identified and way forward for scaling-up is discussed in this chapter.

Keywords Food security · Seeing is believing · Participatory demonstrations · Scaling-up solutions · Science-led technologies

4.1 Introduction

The greatest challenge of twenty-first century for the humankind is to achieve food, nutrition and income security through sustainable development (SDG 1, 2 & 3) with growing water scarcity and shortages, increasing land degradation and decreasing per capita land and water availability due to ever-growing population estimated to reach 9.1 billion globally and 1.6 billion in India by 2050 (Wani et al. 2003a; Sahrawat et al. 2010; Chander et al. 2013). Achieving the sustainable development goal of no poverty (SDG 1), zero hunger (SDG 2) and good health and wellbeing (SDG 3) with the already experienced impacts of climate change due to global warming is a challenge which is surmountable but it calls for innovative approaches, technology driven solutions to be taken at the door step of farmers through building partnerships and achieving convergence and collective action of millions of small farm-holders (500 million globally and 125 million in India) who cultivate <2 ha and produce 70% of food globally (World Bank 2016; Graueb et al. 2016).

4.1.1 Why Small Farm-Holders Are Distressed and Want to Quit Agriculture

Farmers in India have enabled the country to be self-sufficient in food production and the country has transformed from "*Ship to Mouth*" stage in 1967 to overflowing buffer stocks in the country which are almost three-folds higher than needed in 2020. The transformation was achieved through "Green revolution" by increasing total food production around 300 million tonnes in 2020 as compared to 50 million tonnes in 1950. The production during 2019–20 is higher by 25.89 million tonnes than the previous five years' (2014–15 to 2018–19) average production of food grain (GoI 2020; Financial Express 2020). Out of 295. 67 million tonnes food production 225 million tonnes production is of rice and wheat, which is becoming a point of concern for farmers' distress. As far as food production is concerned farmers are doing well, however, as per their incomes they are in stress as the per capita rural incomes are almost half that of urban incomes (for details refer Chap. 1 in this volume Wani 2021). Due to financial losses/crop failures, thousands of farmers committed suicides (11,772 in 2013, 12,360 in 2014, 12,602 in 2015 and 11,379 in 2016) in different states. Suicides in the farm sector have steadily declined by 10%

over four years (2016–2019), according to the latest data released by the National Crime Records Bureau (NCRB).With two successive years of drought, the year 2015 had seen a sharp jump in suicides among cultivators (Indian Express 2020) indicating drought/water scarcity (failure of bore well) as the main cause for distress amongst the farmers as 52% of agriculture is rain-fed. Another causes reported for farmers' suicides are increasing cost of inputs, low crop yields, crop failures, low price realisation for farm produce due to lack of market access, debt, losses in non-agricultural activities, and high post-harvest losses of major agricultural produce. In 2018, post-harvest loss was estimated at Rs. 92,651 crores ($ 13 billion) (Ministry of Food Processing) per year largely due to storage, logistic, and financing infrastructure inadequacies in India. As it is generally stated that farmers distress in India is largely due to 3 Ms-monsoon, middlemen and markets.

In spite of bumper harvest of food grains, in 2019, India's food security position globally was 72nd as compared to 3rd position for the United States of America, and 35th position for China. Affordability, quality, safety, and availability are the key factors considered for comparing the food security levels among the countries (Global Food Security Index 2019). Food security is very critical for the internal security concerns as well as at international level too for "*Atmanirbhar* India" (Singh and Wani 2020). In addition to food security agriculture is a major sector employing 44.2% workforce in the country with 65% rural population, however, it's contribution to the national gross domestic product (GDP) value is 16.5% in 2019–20 (NSO 2019) and transformation of agriculture sector is a must.

4.2 Urgent Need to Build the Confidence of our *Annadatas* by Adopting the Principle of "Seeing is Believing"

As small farm-holders are the backbone of India's food, nutrition and economic development, as they are the ones who largely feed the 1.3 billion people. Considering internal and external security concerns associated with food security as well as national commitment to meet the targets of sustainable development goals (SDG 1, 2, and 3) there is an urgent need to build the confidence amongst small farm-holders and ensure that agriculture becomes a respectable business proposition as against the subsistence agriculture at present. Outmigration of farmers and educated youths from rural areas to urban areas in search of better livelihood opportunities has to be minimised by providing urban facilities in rural areas (PURA) as envisaged by former late President Dr. Abdul Kalam. For transforming agriculture in to a business proposition empowerment of small farm-holders as well as developing needed infrastructure in rural areas is a must so that medium small and micro enterprises (MSMEs) doing value addition and processing can be established in rural areas for providing employment. Building trust is a continuous process and takes time but there is no other option to ensure that small farm-holders benefit through increased adoption of knowledge-driven technologies/products developed by the researchers/

scientists. As indicated in Chap. 1 of this volume (Wani 2021, Chap. 1) to build the trust between researchers and farmers, change of mind-set of researchers to work in partnership with small farm-holders is must. *The CERES 2030* Team has also highlighted that poverty is not reduced as researchers work in isolation and do not involve small farm-holders (Nature Food 2020). In this chapter we deliberate in detail the participatory on-farm demonstrations as an effective scaling-up tool to provide integrated and holistic solutions to the farmers. The principle of "*Seeing is believing*" has been perfected and successfully employed based on several scaling-up initiatives which have benefitted >ten million small farm-holders in Asia.

*4.2.1 Basic Principles of "***Seeing is Believing***" Participatory Holistic on-Farm Demonstrations*

As discussed in Chap. 3 of this volume (Bhattacharyya et al. 2021, Chap. 3) empowering farmers is a challenging task largely due to big number (145 million) and non-functional agricultural extension system (AES) in the country. As revealed by the national sample survey- 2013, 51% of farmers in the country are not getting any extension support (NSSO 2013).

(a) **Needs assessment.** In Chaps. 1 and 3 of this volume, following principles are discussed in detail (Wani 2021; Bhattacharyya et al. 2021) starting with farmers' needs assessment to provide demand driven solutions rather than supply driven solutions for increasing the productivity and profitability of farming through enhanced efficiency of inputs.
(b) **Identifying partners and consortium formation.** Once the needs assessment is undertaken then identifying the right stakeholders/partners needed to deliver the holistic solutions is critical. As discussed in Chap. 3 of this volume (Bhattacharyya et al. 2021) formation of consortium and empowerment of partners through capacity building workshops for bringing all partners on the same page about goal, objectives and approaches as well as standard operating processes (SOPs)is critical. To transform the agriculture across the country there is an urgent need for rejuvenating extension systems with innovations and use of new technologies such as information technology (IT), internet of things (IoT), linking knowledge- generating institutions with knowledge-transforming institutions, remote sensing (RS), geographical information system (GIS), simulation modelling, etc. (Wani et al. 2003a, b, d; Wani 2020). We adopted well developed, validated and scaled-up successfully, an integrated holistic approach with 4 ISECs as indicated below

Innovate	**S**ustainable	**E**conomic gain	**C**onsortium
Inclusive	**S**ocially acceptable	**E**quity	**C**ollective
Intensive	**S**calable	**E**fficiency	**C**apacity Building
Integrated	**S**ynergistic	**E**nvironment	**C**onvergence Protection

For each scaling-up initiative separate consortium of right partners including concerned state department of agriculture as well as needed private companies/corporate was formed. For example, in *Bhoochetana* in order to ensure availability of recommended fertilisers at right time based on soil test-based recommendations to balance widespread deficiencies of secondary and micro-nutrients (Wani et al. 2011), DoA identified suppliers and provision was made to store the fertilisers at village level before the season starts. To enhance the awareness about micronutrients, they were bundled with seeds for the farmers at *Raitu samparka kendras (RSKs).*

(c) **Changing mind-set of all actors for strengthening science of delivery.** Main reason for poor AES in India is the mind-set of researchers as well as other actors who consider extension as low rung academic/research activity. They think that trickledown effect will be there and new knowledge/products will be automatically disseminated amongst the farmers. Through team building workshops and delivering messages from top policy makers/heads of the partner institutions that achieving good impacts on large scale is must which helps in changing the mind-set of all the partners. Lack of awareness and access to the technologies are responsible for large yield gaps in farmers' fields across the world and more so in developing countries in Asia and Africa (Rockström and Falkenmark 2000; Wani et al. 2003a, b, d; Rockström et al. 2010; FAO and WEP 2020). Further, lack of synergy amongst the actors and deficiencies in technology delivery systems due to compartmental approach adopted without considering farmers' requirements for providing the solutions results in *"Death Valley" of impacts* (Wani and Raju 2018a, 2020). Ingraining the importance of science of delivery in minds of the partners is very critical and a game changer intervention which can be achieved by the good team leader with the help of policy makers and heads of institutions during the team building workshops. Finalising the strategy and plan development collectively with all consortium partners with clear roles and responsibilities of each partner along with financial provisions were done for all the initiatives (for more details refer 1.3.3 section in Chap. 1 in this volume, Wani 2021).

(d) **Institutionalisation of transparent monitoring, evaluation and learning (MEL) system.** For achieving desired impacts through consortium it is critical to have institutionalised MEL system in place. For example, in *Bhoochetana* and *Bhoosamruddhi* in Karnataka weekly videoconferencing with all the 30 district officials, chaired by Additional Chief Secretary (ACS) was institutionalised (Raju and Wani 2016). For *Rythu kosam* in Andhra Pradesh Chief Minister participated in state-level meetings as well as chaired and reviewed the progress throughout the day with all partners, concerned ministers and district officials (ICRISAT 2017; Raju et al. 2017). For *Yamnag Lupa* in Philippines Director, of Agriculture chaired the MEL and reviewed periodically in addition to internal departmental reviews.

(e) **Identifying knowledge-based entry point activity (EPA) to build trust with farmers by ensuring tangible economic benefits.** As indicated equity, economic benefits ensure participation by the small farm-holders and to achieve this suitable knowledge-based EPA for building rapport with the community played critical role in a community- based programme rural development (Wani et al. 2003a). During our watershed work over three decades, through participatory rural appraisal (PRA) we learnt that in Adarsha Watershed Kothapally farmers loose nearly 40–50% pigeon pea plants during flowering due to wilting once the moisture stress sets in. Introduction of developed wilt-tolerant pigeon pea cultivars as an EPA will benefit the farmers immensely. Following points while selecting an appropriate EPA for integrated community watershed management were considered as suggested by Wani et al. 2003a:

Conventional EPA activities such as opening a bore well, constructing a meeting room for panchayat/school etc. involving direct cash gave a wrong signal to the villagers that project has money to invest in our village and for subsequent activities also they expect that full cost should be covered by the project. The EPA should be knowledge-based and should not involve direct cash payment through the project in the village to avoid wrong signal which affected community partnership and ownership. The knowledge-based EPAs were found to be superior to the subsidy- or cash-based EPA for enabling community participation of higher order (cooperative and collegiate) rather than in a contractual mode (Dixit et al. 2007).

- The EPA should have a high success probability (> 80–90%), and be based on proven research results.
- The EPA should involve a participatory research and development approach, and community members should preferably be involved in undertaking the activity in watersheds.
- An EPA should result in the measurable tangible economic benefits to the farming community with a relatively high benefit–cost ratio.
- The EPA preferably should be simple and easy for the participating farmers to undertake its participatory evaluation.

For building rapport with the community, good participatory rural appraisal (PRA) and knowledge about local natural resources can be used to identify a knowledge-based EPA. For example, in *Adarsha* watershed, Kothapally which became model training site, wilt-tolerant pigeon pea cultivar ICPL 87119 (Asha) along with improved management practices was effectively used as EPA (Wani et al. 2003a; Wani and Raju 2020). In *Bhoocheatana* and *Bhoosamruddhi* initiatives in Karnataka (Wani et al. 2011) as well as in Andhra Pradesh Rural Livelihoods Program (APRLP), *Rythu kosam* (Fig. 4.1) in Andhra Pradesh, *Yamanglupa in the Philippines* and other corporate social responsibility (CSR) initiatives well tested and proven soil analysis was used as an EPA for building trust amongst the farmers (Wani and Raju 2018b).

Fig. 4.1 Training of farmers in stratified participatory soil sampling in scaling-up initiatives in Andhra Pradesh and Telangana, India

By adopting stratified soil sampling method (Sahrawat et al. 2008) 5339 soil samples across13 districts in Andhra Pradesh *Rythu* kosam were collected, analysed and soil analysis results were shared with the farmers.

(f) **Awareness creation about the project strategy, and capacity building for empowering stakeholders.** As detailed in Chaps. 1 and 3 in this volume (Wani 2021; Bhattacharyya et al. 2021) formal and informal methods for awareness, capacity building, empowerment and skill development as needed for different stakeholders were undertaken (Figs. 4.1 and 4.2).

For awareness building, training/capacity building/empowerment conventional as well as new technologies/approaches were used in various initiatives such as wall writings, class room trainings, team building workshops, digital technologies such as "*Krishi Gyansagar, Krishi Vani*, farmer to farmer videos", and field days, etc. To overcome the shortage of human resources in the existing AES in Karnataka a cadre of para extension workers (Farm Facilitators) one for each village/cluster of hamlets covering 500 ha was created to serve as link between DoA staff and farmers (for more details refer Chap. 1 and 3 in this volume – Wani 2021; Bhattacharya et al. 2021).

(g) **Adopting principle of "*seeing is believing*" and identification of farmers for conducting participatory demonstrations.** For empowering the farmers participatory field demonstrations approach for "*Seeing is Believing*" was adopted. For participatory demonstrations farm facilitators/ lead farmers identified suitable small farm-holders whose fields are approachable during rainy season and have good relation in the village. For each demonstration two treatments of half acre each were laid out randomly and users pay approach ensuring that no inputs were supplied free to the farmers except 50% government subsidy available for everyone in *Bhoochetana and Bhoosamrudhi* Karnataka. The farmers were registered with the DoA, the selected fields were geotagged along with the farmers' details. The FFs recorded all the details for each of the participatory demonstration and in each *taluk* villages were selected to represent areas, soil types and rainfall, etc. In each village at least five demonstrations for the intervention identified were conducted. The crops were sown and treatment applied in the presence of the FFS/LF and details of the farmers' practice were also recorded. The FFs guided the farmers during regular visits and ensured that the demonstration fields were well maintained during the crop growth. Two to three major crops grown in each *taluk*/district were identified for demonstrations. The number of crop cutting experiments (CCE) were decided by the DoA and ICRISAT technician and required number of villages/farmers were selected randomly and timing for harvesting of CCEs were planned. *District-level CCE Committee* chaired by the Joint Director Agriculture *for random selection of fields and sampling* was formed as the data need to be integrated in the state statistics for agricultural production from the CCEs in *Bhoochetana* plots.

The CCE Committee comprised of the members representing the DoA, the Department of Economics and Statistic (DES), the Watershed Development

Fig. 4.2 Training of different stakeholders for use of solar dryer of vegetables at Sadharahally, Lakya hobli, for *Rythu kosam* and technical training for surveying and protected vegetable cultivation in shade-net and grafted seedlings in *Bhoosamruddhi*, Chikmagaluru District, Karnataka

Department (WDD), the University of Agricultural Sciences (UAS), and ICRISAT represented by a research technician, farm facilitator and lead farmers serving the committee to ensure ownership for the data. Two major crops were identified for CCEs in each taluk of a district based on the DoA's project planning for *Bhoochetana* at its initiation. The Assistant Director of Agriculture (ADA) and Agricultural Officers (AOs) along with the ICRISAT research technician identified the crops in their districts to ensure the selection of major crops in terms of area coverage under *Bhoochetana*. Based on the registration, the data with the officials and the technician, ten farmers for each crop in a taluk were selected for the two identified crops. Three to four representative villages were selected, encompassing different zones of soils, seasonal rainfall and area coverage under *Bhoochetana*. Three to four farmers were selected randomly based on the registrations in the selected village.

However, a minimum number of ten farmers were duly selected per crop in each taluk. Each farmer was provided with a unique identification number (UIN) by ICRISAT before the CCEs were initiated in the season. The concerned in-charge Scientist/Scientific Officer at ICRISAT ensured timely supply of harvest bags (muslin cloth bags for stalk and kora cloth bags for pod/head samples) UIN and necessary data sheets for the CCEs in the district. The improved practice (IP) and farmers' practice (FP) samples were duly collected from the same selected farmer's field from a randomly selected representative area of 5 m × 5 m (total area of 25 m^2) at one spot for undertaking CCE. The samples were cut, separated, fresh weights recorded, bagged and sundried, sub-sampled (2 kg) for each plot harvested and dispatched to ICRISAT head quarter for further processing. The fresh weights were properly recorded in the given format and the signatures of all the representatives of the CCE Committee present in the field were obtained. It was ensured that all the identified team members participated in CCEs. Concerned JDAs had delegated the responsibilities to the ADAs and AOs for undertaking CCEs in the respective taluks. GPS (geographic positioning system)-enabled photographs of CCEs had to be provided to the JDA office. Similar approach with needed changes was adopted in all the scaling-up initiatives. Field days with the farmers from the surrounding villages in each *taluk* were conducted to ensure participatory evaluation of trials and the farmer explained all the details. It's well established that farmers believed much on their peers rather than outsiders explaining the trials which helped in better adoption of technologies by the farmers.

4.3 Scaling-Up of Soil Test-Based Fertility Management Trials Adopting "*Seeing is Believing*" Principle

Liebig's Familiar Letters on Chemistry and Its Relation to Commerce, Physiology, and Agriculture (1848) all advocated transformations in soil management in relation to the linked social and environmental crises of modern global market within agriculture. The practical implication that farmers could reliably overcome the local limits of fertility, however, for a long time the so called NPK mentality harmed the agriculture. Although, soil analysis as a powerful tool and formulation of NPK fertilisers were unique game changing inventions benefitting farmers, the science of soil analysis in totality did not reach to small farm-holders in developing Asia, Africa and other parts of the world. In India, Indian Council of Agricultural Research (ICAR) established the All India Coordinated Scheme of Micronutrients in Soils and Plants during 1967 at Punjab Agricultural University, Hisar with six centres and the project was expanded in terms of mandate as well as spread of centres (Shukla and Behera 2019).

In state agricultural universities as well as in other research institutions also micronutrient research was conducted. Just like NPK syndrome scientists also went in circles to address the soil variability considering statistical methods. For example, a 1 lb soil sample collected from a 5-acre field represents just 1/10,000,000 of the field! Therefore, it is vital that the soil sample be representative of the entire field. The most common and economical method for sampling an area is composite sampling, where sub-samples are collected from randomly selected locations in a field, and the subsamples are composited for analysis.

In a country like India with its 142 million ha arable land cultivated by 145 million farm households, with 46 of the 60 soil types in the world, along with 20 agro-climatic zones varying from arid to humid tropics, hot arid deserts, and a varying rainfall as high as 11,873 mm at Mawsynram, Meghalaya, to as low as 166 mm at Jaisalmer in Rajasthan (Singh and Wani 2020) puts forward a complex and great challenge to the soil scientists for sampling representative samples. Variability of soils in many fields is fairly obvious since there may be significant visual differences in topography, soil types, soil colour or other factors. But field variability exists that is not evident at first glance – even in fields that appear uniform. For +/−5% with reproducibility of 70%, 90 soil core samples are recommended for a composite sample and for 95% reproducibility 325 samples are recommended (Kansas State University) for a field size of 50 acres. Soil sampling is the weakest link in the soil testing-nutrient management plan development process and is the greatest source of error. Considering this challenge to collect representative sub-samples from field along with the mind-set of researchers to work on research farms, deprived the small farm-holders the benefit of soil analysis.

4.3.1 Soil Infertility and Water Scarcity- a Major Constraint for Bridging Yield Gaps in Agriculture

In rain-fed agriculture that covers globally 80% and 52% in India of cultivated land where the importance of water shortage and associated stress effects on crops can hardly be overemphasized, especially in the SAT regions (Bationo et al. 2008; Wani et al. 2009a; Pathak et al. 2009; Rockström et al. 2010). However, soil infertility is the issue for crop production and productivity enhancement even under water limited situations in much of the SAT regions of the world, and SAT regions of India are no exception (Twomlow et al. 2008; Wani et al. 2009a, 2015a, b; Sahrawat and Wani 2013; Chander et al. 2011, 2014). There was a common belief among researchers and agriculturists that at relatively low yields of crops in the rain-fed systems of

India, only the deficiencies of major nutrients (especially those of N and P) are important for the SAT Indian soils (El-Swaify et al. 1985; Rego et al. 2003) and it was assumed that the uptake and mining of secondary and micronutrient reserves in soils is much less than in irrigated production systems (Rego et al. 2003).

Equally importantly, deficiencies of secondary nutrients especially of S and micronutrients have been reported with increasing frequencies from the intensified irrigated production systems where deficiencies are managed through the fertilization of crops (Takkar 1996; Singh 2008) but little attention has been paid to diagnosing the deficiencies of secondary nutrients such as S and micronutrients in dryland rain-fed production systems especially in SAT regions of India (Sahrawat et al. 2007, 2010, 2016; Sahrawat and Wani 2013. On-farm research initiated under the Asian Development Bank (ADB) and several GoI supported watershed projects, Andhra Pradesh Rural Livelihood Project (APRLP), Sir Dorabji Tata Trust (SDTT), Sir Ratan Tata Trust (SRTT), and several corporate social responsibility (CSR) supported watershed projects in India, Thailand, Vietnam and later China since 1999 provided an opportunity to understand wide spread deficiencies of secondary nutrients such as sulphur and micronutrients (Zn, B, Fe, etc.).

Initial on-farm surveys across few states of India, revealed that out of 1926 farmers' fields samples, 88–100% were deficient in available sulphur(S), 72–100% in available boron (B), and 67–100% in available Zinc (Zn) (Sahrawat et al. 2007) and later with large number of samples across the country (Sahrawat et al. 2008, 2010, 2016; Wani et al. 2010, 2011, 2012b, 2017, 2018; ICRISAT 2016). As indicated above, the team continued to liaise with the policy makers in different states and at national level too. The team interacted with the higher authorities in Prime Minister's Office (PMO), India and submitted a strategy paper on soil health mapping (Wani et al. 2016a, b). The department of Agriculture, Cooperation and Farmers Welfare, GoI launched soil health card mission program covering farms in the country (Fig. 4.3). It is planned to cover all 145 million farms in three to four years for soil sampling and issuing soil health cards to all farmers with fertiliser recommendations for the crops grown in particular region.

This clearly indicated that after persuasion by ICRISAT Team as well as NARSs scientists, GoI took up the soil health card mission initiative in 2016, indicating that after starting and demonstrating the benefits of soil analysis and occurrence of multiple nutrients (micro- and secondary- nutrients) across the country since 1999 took almost 17 years to bring in policy at national level. The lag period for scaling-up across the country after Karnataka, Andhra Pradesh, Telangana and few other states showed positive benefits was almost 10 years.

The results presented in Table 4.1 showed widespread deficiencies of multiple secondary and micro-nutrient deficiencies across the rain-fed areas in India (Table 4.1). In Madhya Pradesh in *Milli* watershed at Lalatora micro-nutrient and secondary nutrient deficiencies were recorded in 1999. It was observed that in soybean growing areas of Madhya Pradesh, India sulphur deficiency emerged largely due to policy of subsidy on N-based fertilisers and as a result farmers shifted to di-ammonium phosphate (DAP as a source of phosphorus) for soybean in place of single super phosphate (SSP) which also contained sulphur (S). Soybean being a

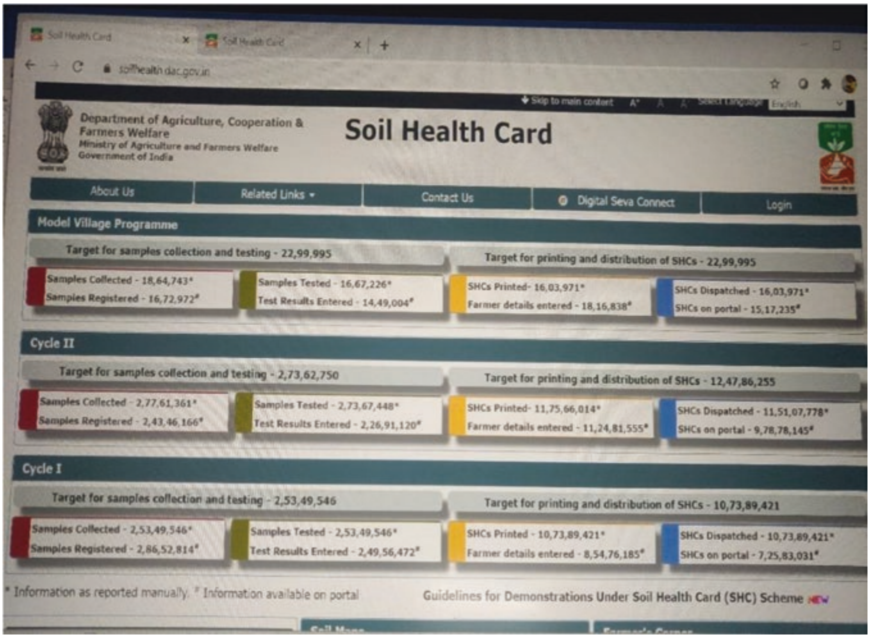

Fig. 4.3 Screen shot of Soil health card mission program of Department of Agriculture, Cooperation and Farmers' Welfare, government of India

crop needing sulphur depleted soil sulphur due to continued cultivation which was not replenished by the farmers. Another fallout of the fertilizer subsidy is that chemical fertilizers are cheaper than organic fertilizers.

Thus, farmers have moved away from using organic manure, which is very critical for preserving good soil health, as organic carbon is the key fuel for keeping the soil microbial activities in a good state. Good soil health is required to ensure the quality of food, and for food and nutritional security. To address malnutrition in India, it is more economical and efficient to address food quality issues through soil health and diet diversification rather than through bio-fortification and nutritional amendments externally.

Imbalance in fertilizer use also leads to depletion of particular nutrients in the soils as well as causing environmental degradation. It also substantially increases the cost of cultivation and also lowers its efficiency (Wani et al. 2016a, b).

For the first time detailed stratified and participatory soil sampling (Sahrawat and Wani 2013) was undertaken for 30 districts of Karnataka in 2009 under *Bhoochetana* initiative by collecting 92,864 farmers' fields' samples from 4699 villages covering 30 districts (Wani et al. 2013). Detailed analysis of farmers' field soil samples revealed that amongst the districts deficiency of macro-, secondary- and micronutrients varied a lot. For example, nitrogen deficiency (using organic C as criterion) varied amongst 30 districts from 0% to78%, similarly for P from 5% to 97%, for K from 1% to 68% for S from 2% to 92%, for Zn from 24% to 92 and for B from

Table 4.1 Diagnostic soil analysis of farmers' nutrient deficient fields in different states, India

State	pH	pH	pH	EC ds/m	OC	Av P	Av K	Av Ca
	Acidic	Neutral	Alkaline	Normal	% [a]	ppm	ppm	ppm
Andhra Pradesh	19	28	53	100	63	22	10	37
Range	4.95–9.59			0.05–3.76	0.1–1.79	0.3–8.97	20–2678	20–4599
Gujarat	5	16	80	100	28	57	4	
Range	6.25–8.98			0.05–2.43	0.21–1.51	0.4–66.5	30–635	
Jharkhand	88	10	1	100	65	51	35	
Range	5–8.3			0.05–0.61	0.12–1.13	0.4–68.6	20–247	
Karnataka	36	25	38	100	53	38	19	25
Range	4.95–9.56			0.05–3.76	0.1–1.8	0.3–68.95	20–2759	52–4597
Kerala	82	18		100	11	21	7	
Range	5.11–6.78			0.05–0.25	0.36–1.17	1.2–68.8	33–313	
Madhya Pradesh	3	19	80	100	22	76	0	
Range	5.56–8.82			0.05–1.56	0.28–1.54	0.3–68	48–895	4442–4525
Maharashtra	22	20	59	100	43	37	1	5
Range	4.95–9.03			0.05–3.75	0.1–1.74	0.3–68.8	23–2678	169–4596
Odisha	87	10	4	100	34	31	20	49
Range	4.95–8.24			0.05–3.75	0.1–1.73	0.35–68.97	20–2678	96–4488
Rajasthan	4	26	70	100	55	50	12	5
Range	5.71–9.43			0.05–3.75	0.1–1.78	0.34–67.6	21–1358	758–3804
Tamil Nadu	7	39	54	100	57	66	10	
Range	5–9.4			0.05–2.29	0.14–1.37	0.4–67.2	20–690	
Telangana	9	35	55	100	72	14	10	25
Range	4.96–9.59			0.05–3.75	0.1–1.79	0.33–68.8	20–2360	25–4593
Uttar Pradesh	9	28	64	100	52	33	14	17
Range	5.23–9.13			0.05–1.81	0.1–1.7	0.31–68.6	20–1009	312–4590
Grand Total	31	26	43	100	55	33	16	32
Range	4.95–9.59			0.05–3.76	0.1–1.8	0.3–68.97	20–2759	20–4599

(continued)

Table 4.1 (continued)

State	Av Mg ppm	Av S ppm	Av Zn ppm	Av B ppm	Av Fe ppm	Av Cu ppm	Av Mn ppm	No of samples
Andhra Pradesh	3	23	49	34	7	1	1	36,756
Range	20–3456	2–292	0.1–5.98	0.1–2.99	0.1–20.62	0.1–9.98	0.1–15.99	
Gujarat		14	83	54				180
Range		5.2–288	0.18–2.45	0.1–1.94				
Jharkhand		49	58	100				91
Range		2–282	0.24–2.9	0.1–0.42				
Karvnataka	2	28	43	53	9	3	9	117,176
Range	20–2672	2–299	0.1–5.99	0.1–2.99	0.1–20.62	0.1–9.99	0.1–15.99	
Kerala		38	4	100				28
Range		2–282	0.56–4.24	0.18–0.48				
Madhya Pradesh		46	49	73				425
Range	289–3276	2–288	0.1–4.36	0.1–1.3	6.1–19.88	1.42–7.38	3.02–15.88	
Maha-rashtra	0	29	59	46	1	0	0	6135
Range	20–2648	2–288	.1–5.93	0.1–2.95	0.2–20.62	0.1–9.7	0.96–15.99	
Odisha	1	25	18	81	0	0	0	3017
Range	20–1435	2–292	0.1–5.9	0.1–2.74	0.65–20.62	0.14–7.22	0.24–15.97	
Rajasthan	0	44	36	51	45	54	15	784
Range	20–488	2–290	0.12–5.92	0.1–2.76	0.12–17.8	0.1–4.4	0.94–15.92	
Tamil Nadu		44	28	83	23	9	23	769
Range		4–288	0.1–5.6	0.1–2.18	0.1–19.78	0.1–6.5	0.23–15.86	
Telangana	1	28	58	54	4	2	3	11,203
Range	20–3194	2–292	0.1–5.86	0.1–2.97	0.1–20.62	0.1–9.76	0.1–15.99	
Uttar Pradesh	1	43	69	58	13	0	2	1473
Range	20–1134	5–290	0.1–4.52	0.1–2.58	0.39–20.6	0.11–9.98	0.1–15.98	
Grand Total	3	28	45	50	7	2	5	177,387
Range	20–3456	2–299	0.1–5.99	0.1–2.99	0.1–20.62	0.1–9.99	0.1–15.99	

Source: Prepared by authors based on data from several projects implemented (ICRISAT 2004, 2009, 2012, 2016, 2018)

a = % deficient farmers' fields

34% to 91% (Wani et al. 2012a) *indicating that the current way of recommending fertiliser doses at state level for irrigated and dryland crops does not work and there is need to develop recommendations at village /taluk level. Similar variability amongst the districts was also observed in Andhra Pradesh across 13 districts after analysing 36,632 soil samples from farmers 'fields* (Table 4.2).

4.3.2 Developing Soil-Test Based Fertiliser Recommendations

Shukla and Behera (2019) assessed soil fertility status in the country based on analysis of GPS-guided more than 200, 000 soil samples and recorded deficiencies of sulphur (S) 40.5%, zinc (Zn) 36.5%, iron (Fe) 12.8%, manganese (Mn) 7.1%, copper (Cu) 4.2% and boron (B) 23.2% fields. Manganese (particularly in rice and wheat growing sandy loam areas) and B deficiencies (in acid soils) have started appearing in a big way. Over the years, multi-micro and secondary nutrient deficiencies have emerged in different areas of the country. Simultaneous occurrence of deficiencies of 4 or more than 4 nutrients was very low (<0.5%) in most of the states (Shukla and Behera 2019). Considering such large variability for soil infertility amongst the states and districts (Tables 4.1 and 4.2) as well as taluks and villages, fertiliser recommendations were developed at village/taluk level considering the state agriculture university recommendations for different crops and the current soil analysis using the critical limits given in Table 4.3. These results demonstrated that only the nutrient identified as deficient through soil or plant analysis should be applied to harvest the sustainable higher productivity.

For practical utilization of the soil-test-based nutrient management, we mapped, using the geographical information system (GIS)-based extrapolation using kriging methodology, the deficiencies of all nutrients including especially those of S, B and Zn along with soil fertility parameters pH, electrical conductivity (EC) (indicator of soluble salts) and organic C in all the 30 districts of Karnataka state, India and soil Atlas was prepared (Wani et al. 2011, 2013). The recommendations for villages/taluks were developed using the following rule, if more than 50% of farmers' fields were deficient then full dose was recommended, for >25–50% deficient fields half of recommended dose and < 25% deficient fields in the village 1/4th of recommended dose as a maintenance dose of a particular nutrient was recommended. For large scaling-up projects like *Bhoochetana, Bhoosamruddhi and Rythu kosam* in states of Karnataka, Andhra Pradesh arrangements were made to ensure availability of needed inputs at village level through policy interventions. For CSR projects as well as for watershed projects covering a village or a group of villages inputs were made available to farmers through project staff albeit on payment basis.

The soil-test-based fertilizer application has been made web-based so that the recommendations can be downloaded and made available nutrient-wise to farmers using colour codes depicting the deficiency or sufficiency of a nutrient. Such information can be easily used by smallholders, and the farmers can be kept updated regularly with the latest results on the website. The soil analysis results as well as

Table 4.2 Diagnostic soil analysis results for nutrient deficiency in different districts of Andhra Pradesh

State	District	pH			EC ds/m	OC	Av P	Av K	Av Ca
		Acidic	Neutral	Alkaline	Normal	% [a]	Ppm	Ppm	Ppm
Andhra Pradesh	Anantapuram	12	27	60	100	86	24	11	41
Range[1]	Anantapuram	5–9.58			0.05–3.68	0.1–1.74	0.33–68.96	20–1061	99–4585
Andhra Pradesh	Chittoor	18	33	49	100	55	18	20	40
Range	Chittoor	4.96–9.39			0.05–3.75	0.1–1.47	0.37–68.8	20–1307	56–4451
Andhra Pradesh	East Godavari	37	34	29	100	50	30	12	36
Range	East Godavari	4.96–9.4			0.05–3.75	0.1–1.79	0.32–68.97	20–2678	20–4599
Andhra Pradesh	Guntur	2	11	87	100	54	4	2	7
Range	Guntur	4.98–9.39			0.05–3.76	0.1–1.42	1–68.88	23–1553	226–4599
Andhra Pradesh	Krishna	10	41	48	100	61	16	3	54
Range	Krishna	5–9.43			0.05–3.75	0.1–1.72	0.33–68.92	21–1572	29–4599
Andhra Pradesh	Kurnool	5	20	75	100	77	20	3	21
Range	Kurnool	5–9.48			0.05–3.75	0.1–1.5	0.31–68.8	20–2409	52–4597
Andhra Pradesh	Nellore	17	23	59	100	60	18	14	32
Range	Nellore	4.95–9.54			0.05–3.75	0.1–1.36	0.4–68.8	20–2069	80–4589
Andhra Pradesh	Prakasam	6	10	83	100	74	25	4	19
Range	Prakasam	5–9.54			0.05–3.75	0.1–1.77	0.3–68.8	21–1529	67–4596
Andhra Pradesh	Srikakulam	44	33	22	100	56	22	18	50
Range	Srikakulam	4.95–9.04			0.05–3.75	0.1–1.62	0.35–68.8	20–2009	25–4526
Andhra Pradesh	Visakhapatnam	40	28	32	100	41	31	6	48
Range	Visakhapatnam	4.95–9.42			0.05–3.75	0.1–1.78	0.33–68.8	22–2037	113–4479
Andhra Pradesh	Vizianagaram	44	32	24	100	64	43	18	52

(continued)

Table 4.2 (continued)

State	District	pH			EC ds/m	OC	Av P	Av K	Av Ca
Range	Vizianagaram	4.95–9.5			0.05–3.75	0.1–1.32	0.3–68.8	20–1071	74–4589
Andhra Pradesh	West Godavari	28	46	26	100	53	11	14	44
Range	West Godavari	4.96–9.39			0.05–3.76	0.1–1.47	0.37–68.8	20–2127	52–4598
Andhra Pradesh	YSR Kadapa	4	10	86	100	71	24	7	17
Range	YSR Kadapa	5–9.59			0.05–3.76	0.1–1.5	0.32–68.8	20–1317	144–4599
Andhra Pradesh total		19	28	53	100	63	22	10	37
Range		4.95–9.59			0.05–3.76	0.1–1.79	0.3–68.97	20–2678	20–4599

State	District	Av Mg ppm	Av S ppm	Av Zn ppm	Av B ppm	Av Fe ppm	Av Cu ppm	Av Mn ppm	No of samples
Andhra Pradesh	Anantapuram	1	32	62	62	11	1	1	3875
Range	Anantapuram	20–1873	2–292	0.1–5.9	0.1–2.94	0.1–20.6	0.1–8.54	0.42–15.98	3875
Andhra Pradesh	Chittoor	2	22	32	45	1	1	1	2577
Range	Chittoor	20–1271	5–290	0.1–5.9	0.1–2.95	0.1–20.6	0.1–8.24	0.1–15.98	2577
Andhra Pradesh	East Godavari	3	21	38	38	26	0	0	2799
Range	East Godavari	20–2378	5.01–292	0.1–5.96	0.1–2.99	0.1–20.62	0.1–9.98	1.18–15.98	2799
Andhra Pradesh	Guntur	0	14	42	4	6	1	2	2263
Range	Guntur	20–2490	5–292	0.1–5.94	0.1–2.96	0.24–20.58	0.1–9.96	0.1–15.92	2263
Andhra Pradesh	Krishna	1	23	49	19	4	0	1	4644
Range	Krishna	20–3310	5.01–292	0.1–5.94	0.1–2.99	0.14–20.6	0.1–9.94	0.82–15.98	4644
Andhra Pradesh	Kurnool	1	31	71	24	7	0	1	2858
Range	Kurnool	23–1766	2–292	0.1–5.96	0.1–2.99	0.36–20.6	0.14–9.72	0.73–15.96	2858
Andhra Pradesh	Nellore	2	13	46	22	3	1	3	2315
Range	Nellore	20–1989	5.02–292	0.1–5.94	0.1–2.96	0.1–20.62	0.1–9.73	0.1–15.98	2315

(continued)

Table 4.2 (continued)

State	District	Av Mg ppm	Av S ppm	Av Zn ppm	Av B ppm	Av Fe ppm	Av Cu ppm	Av Mn ppm	No of samples
Andhra Pradesh	Prakasam	3	25	78	32	17	2	2	2789
Range	Prakasam	20–2240	2–292	0.1–5.96	0.1–2.99	0.1–20.62	0.1–9.38	0.1–15.94	2789
Andhra Pradesh	Srikakulam	12	20	43	50	4	6	1	2799
Range	Srikakulam	20–1956	5–290	0.1–5.82	0.1–2.87	0.52–20.62	0.1–9.52	0.46–15.98	2799
Andhra Pradesh	Visakhapatnam	2	26	35	37	1	0	0	2158
Range	Visakhapatnam	20–1811	5–292	0.1–5.98	0.1–2.98	1.02–20.62	0.1–8.52	1.72–15.96	2158
Andhra Pradesh	Vizianagaram	7	23	49	52	0	0	0	2291
Range	Vizianagaram	20–1699	5.02–290	0.1–5.92	0.1–2.87	0.33–20.62	0.1–9.63	0.28–15.96	2291
Andhra Pradesh	West Godavari	9	17	17	34	1	1	2	2539
Range	West Godavari	20–3456	2–292	0.1–5.97	0.1–2.99	0.1–20.62	0.1–9.98	0.1–15.96	2539
Andhra Pradesh	YSR Kadapa	0	29	64	19	15	0	1	2715
Range	YSR Kadapa	20–1944	2–292	0.1–5.88	0.1–2.99	0.1–20.6	0.12–9.9	0.44–15.99	2715
Andhra Pradesh total		3	23	49	34	7	1	1	36,622
Range		20–3456	2–292	0.1–5.98	0.1–2.99	0.1–20.62	0.1–9.98	0.1–15.99	36,622

Source: Compiled by Authors, ICRISAT (2016)
a = percent deficient farmers' fields; 1 = mg per kg soil

fertiliser recommendations were disseminated amongst the farmers using wall writings, soil health cards as well as through FFs in each village.

4.3.3 On-Farm Participatory Demonstrations, Data Recording and Dissemination of Results

By adopting detailed process described above under 4.2.1 registered farmers were selected based on the crops they were to grow and with half acre plot for each treatment (farmer's practice (FP) and improved practice (IP) soil-test based balanced fertiliser recommendation) were selected. The farmers were guided by the FFs/LFs and farmers had to buy their inputs as recommended. The crops were grown and

Table 4.3 Critical limits in the soil of plant nutrient elements to separate deficient samples from non-deficient samples

	Soil Critical Limits	Soil Critical Limits	Soil Critical Limits
Particulars of analysis			
PH (1:2 soil: Water)	<6.5 acidic	Salinity (electrical)	<1.0 Normal
	6.5–7.5 neutral	Conductivity (dS/m)	1–2 warning
	>7.5 alkaline		>4 injurious to all crops
Organic carbon %		Total nitrogen kg ha^{-1}	<140 very low (62 ppm)
	0.0–0.5 low		140–280 low (62–125 ppm)
	0.5–0.75% medium		280–560 medium (125–250 ppm)
	0.75–1.0 high		560–700 high (250–312 ppm)
			>700 very high (>312 ppm)
Available P_2O_5 (kg ha^{-1})		Available P (ppm)	
(Olsen's method)	5.0–10 low	(Olsen's method)	<5 low
	10–25 medium		5–10 medium
	25–40 high		>10 high
Available K_2O (kg ha^{-1})		Available K (ppm)	
(1 N neutral ammonium acetate)	0–120 low	(1 N neutral ammonium acetate)	0–50 low
	100–280 medium		50–125 medium
	280–560 high		>125High
Available Ca ppm (1 N neutral		Available Mg ppm (1 N neutral	
Am. Acetate)	0–1000 ppm low	Am. Acetate)	0–40 ppm low
	1000–1600 ppm medium		40–80 ppm medium
	1600–2400 ppm high		80–120 ppm high
	Critical limits		**Critical limits**
Cacl2 extractable S ppm	10	Hot water extractable Boron ppm	0.5
DTPA extractable micronutrients ppm			
Zinc (Zn) ppm	0.6	Copper (Cu) ppm	0.2
Iron (Fe) ppm	4	Manganese (Mn) ppm	2

Data gleaned from various literature sources, for details see Rego et al. (2007), Sahrawat et al. (2007, 2016)

Fig. 4.4 Farmers visiting groundnut field demonstration in V. Kota, Chittor district in Andhra Pradesh, Chickpea in Gumla district of Jharkhand and Farmers' Day in Madhya Pradesh

monitored regularly and observations were recorded for both the treatments using randomly selected and labelled plants from each treatment. Field days (Fig. 4.4) were conducted to disseminate the results where farmers explained the interventions as well as explained the results and discussed with the farmers from the neighbouring villages. From the randomly selected farmers' fields crop cutting experiments were done and data recorded as described above under 4.2.1.

Table 4.4a State and crop wise grain yield (kg ha^{-1}) with farmers' practice and balanced micro- and secondary- nutrients participatory on-farm demonstrations in Andhra Pradesh and Telangana states

State	Crop	Yield (kg ha^{-1})		% Increase over FP	No of Samples
		Grain IP	Grain FP		
Andhra Pradesh	*Kharif* Blackgram	590	430	37	15
Andhra Pradesh	*Kharif* Castor	1290	860	50	3
Andhra Pradesh	*Kharif* Chilly	8860	8120	9	25
Andhra Pradesh	*Kharif* Cotton	4610	4040	14	25
Andhra Pradesh	*Kharif* Groundnut	1440	1080	33	171
Andhra Pradesh	*Kharif* Maize	7170	6350	13	13
Andhra Pradesh	*Kharif* Paddy	5250	4330	21	237
Andhra Pradesh	*Kharif* Pigeonpea	2070	1500	38	68
Andhra Pradesh	*Rabi* Chickpea	1920	1510	27	27
Andhra Pradesh	*Rabi* Sorghum	4360	3180	37	11
Telangana	*Kharif* Castor	1130	700	61	27
Telangana	*Kharif* Greengram	1230	790	56	27
Telangana	*Kharif* Groundnut	1240	710	75	15
Telangana	*Kharif* Maize	4590	2670	72	62
Telangana	*Kharif* Pigeonpea	1120	670	67	42
Telangana	*Kharif* Sesame	910	530	72	2
Telangana	*Kharif* Sorghum	1980	910	118	6

Source: Derived from data from different scaling-up projects (ICRISAT 2004, 2016)

4.3.4 Increased Crop Yields and Farmers' Incomes with Improved Fertility Management

In all the scaling-up projects based on soil fertility assessment by adopting stratified soil sampling in the villages/taluks and districts balanced nutrient management recommendations were adopted in "*seeing is believing*" demonstrations (Wani et al. 2012b, 2013). Data from crop cutting experiments were analysed using statistical methods and results are presented as a summary for different states and crops. In scaling-up projects such as in Karnataka and Andhra Pradesh 15,000 participatory trials on farmers' fields were conducted as described above and data collected by adopting crop cutting experiments (CCE) strategy. In Tata Foundation supported projects 1500 trials were conducted in 11 target districts of Madhya Pradesh and Rajasthan. Average data for district and crops are presented in Tables 4.4a, 4.4b, 4.4c, 4.4d, 4.4e, 4.4f, and 4.4g for the farmers' practice (FP) and improved management practice (IP) of balanced nutrient treatments. Response to added balanced nutrients varied with crops, states, districts (Tables 4.4a, 4.4b, 4.4c, 4.4d, 4.4e, 4.4f, and 4.4g).

For example, maximum increase in *kharif* sorghum yield with balanced nutrient management in Telangana state was 118%, in Karnataka, 30%, for soybean in

Table 4.4b State and crop wise grain yield (kg ha^{-1}) with farmers' practice and balanced micro- and secondary- nutrients participatory on-farm demonstrations in Karnataka, Madhya Pradesh and Rajasthan

State	Crop	Yield (kg ha^{-1})		% Increase over FP	No of Samples
		Grain IP	Grain FP		
Karnataka	*Kharif* Blackgram	1030	780	32	114
Karnataka	*Kharif* Cotton	1630	1360	20	497
Karnataka	*Kharif* Cowpea	440	320	38	51
Karnataka	*Kharif* Fieldbean	1110	830	34	56
Karnataka	*Kharif* Greengram	790	580	36	255
Karnataka	*Kharif* Groundnut	1450	1110	31	1355
Karnataka	*Kharif* Horsegram	130	100	30	4
Karnataka	*Kharif* Maize	4650	3730	25	2399
Karnataka	*Kharif* Paddy	4480	3680	22	2277
Karnataka	*Kharif* Pearl Millet	2270	1740	30	565
Karnataka	*Kharif* Pigeonpea	990	770	29	885
Karnataka	*Kharif* Ragi	1910	1470	30	2121
Karnataka	*Kharif* Sorghum	2890	2230	30	245
Karnataka	*Kharif* Soybean	1740	1370	27	459
Karnataka	*Kharif* Sugarcane	131,380	116,960	12	33
Karnataka	*Kharif* Sunflower	1360	1020	33	240
Karnataka	*Rabi* Chickpea	980	750	31	1105
Karnataka	*Rabi* Safflower	820	630	30	56
Karnataka	*Rabi* Sorghum	1540	1210	27	1022
Karnataka	*Rabi* Sunflower	1020	780	31	134
Karnataka	*Rabi* Wheat	750	560	34	33
Madhya Pradesh	*Kharif* Soybean	2290	1830	25	257
Madhya Pradesh	*Rabi* Chickpea	1440	1250	15	169
Rajasthan	*Kharif* Groundnut	1090	960	14	7
Rajasthan	*Kharif* Maize	2980	2730	9	17
Rajasthan	*Kharif* Pearl Millet	2510	2310	9	16
Rajasthan	*Kharif* Sorghum	2980	2740	9	8

Source: Derived from data from different scaling-up projects

Madhya Pradesh maximum increased yield was 34%, in Karnataka it was 27%, for groundnut in Telangana it was 102%, in Rajasthan 14%, in Karnataka 31%, in Andhra Pradesh 33% over the crop yield in farmers 'practice. Similar variation is response to crops was observed for *rabi* crops also. Castor responded well 64% in Telangana, 61% in Karnataka over the farmers' practice (Table 4.4a, 4.4b, 4.4c, 4.4d, 4.4e, 4.4f, and 4.4g and Figs. 4.5a, 4.5b, and 4.5c). All crops responded to balanced nutrient management and minimum increased yield recorded was 10% over the farmers' practice. Similar benefits with balanced nutrient management were also recorded in a collaborative scaling-up project between Central Dryland Research Institute for Agriculture (CRIDA) and ICRISAT in tribal and backward

Table 4.4c State and crop wise grain yield (kg ha^{-1}) with farmers' practice and balanced micro- and secondary- nutrients participatory on-farm demonstrations in Karnataka

State	District	Crop	Yield (kg ha^{-1})		% Increase over FP
			Grain IP	Grain FP	
Karnataka	Ballari	*Kharif* Cotton	2190	1840	19
Karnataka	Chitradurga	*Kharif* Cotton	1220	1050	16
Karnataka	Davanagere	*Kharif* Cotton	1440	1200	20
Karnataka	Haveri	*Kharif* Cotton	1290	1120	15
Karnataka	Mysuru	*Kharif* Cotton	1880	1450	30
Karnataka	Raichur	*Kharif* Cotton	1720	1470	17
Karnataka		*Kharif* Cotton Total	1630	1360	20
Karnataka	Chikkaballapura	*Kharif* Fieldbean	1320	970	36
Karnataka	Davanagere	*Kharif* Fieldbean	1190	930	28
Karnataka	Hassan	*Kharif* Fieldbean	580	450	29
Karnataka	Kolar	*Kharif* Fieldbean	1940	1490	30
Karnataka	Ramanagara	*Kharif* Fieldbean	1030	750	37
Karnataka		*Kharif* Fieldbean Total	1110	830	34
Karnataka	Bagalkot	*Kharif* Greengram	340	250	36
Karnataka	Bidar	*Kharif* Greengram	1270	950	34
Karnataka	Chitradurga	*Kharif* Greengram	360	290	24
Karnataka	Dharwad	*Kharif* Greengram	1380	950	45
Karnataka	Gadag	*Kharif* Greengram	500	340	47
Karnataka	Kalaburagi	*Kharif* Greengram	810	610	33
Karnataka	Vijayapura	*Kharif* Greengram	380	270	41
Karnataka	Yadgir	*Kharif* Greengram	810	600	35
Karnataka		*Kharif* Greengram Total	790	580	36
Karnataka	Ballari	*Kharif* Groundnut	1430	1030	39
Karnataka	Belagavi	*Kharif* Groundnut	1470	1130	30
Karnataka	Chamarajanagar	*Kharif* Groundnut	890	740	20
Karnataka	Chikkaballapura	*Kharif* Groundnut	1570	1140	38
Karnataka	Chikkamagaluru	*Kharif* Groundnut	2220	1680	32
Karnataka	Chitradurga	*Kharif* Groundnut	710	580	22
Karnataka	Davanagere	*Kharif* Groundnut	2060	1650	25
Karnataka	Dharwad	*Kharif* Groundnut	1820	1390	31
Karnataka	Gadag	*Kharif* Groundnut	1300	980	33
Karnataka	Haveri	*Kharif* Groundnut	2560	2050	25
Karnataka	Kolar	*Kharif* Groundnut	1850	1420	30
Karnataka	Koppal	*Kharif* Groundnut	1460	1040	40
Karnataka	Raichur	*Kharif* Groundnut	1910	1500	27
Karnataka	Ramanagara	*Kharif* Groundnut	1380	1060	30
Karnataka	Tumakuru	*Kharif* Groundnut	820	650	26
Karnataka	Vijayapura	*Kharif* Groundnut	640	470	36
Karnataka		*Kharif* Groundnut Total	1450	1110	31

Source: Derived from different scaling-up projects data (ICRISAT 2009, 2012, 2017)

Table 4.4d State and crop wise grain yield (kg ha^{-1}) with farmers' practice and balanced micro- and secondary- nutrients participatory on-farm demonstrations in Karnataka

State	District	Crop	Yield (kg ha^{-1})		% Increase over FP
			Grain IP	Grain FP	
Karnataka	Bagalkot	*Kharif* Pigeonpea	940	740	27
Karnataka	Ballari	*Kharif* Pigeonpea	470	330	42
Karnataka	Bidar	*Kharif* Pigeonpea	1330	1060	25
Karnataka	Chikkaballapura	*Kharif* Pigeonpea	1360	1060	28
Karnataka	Chitradurga	*Kharif* Pigeonpea	460	360	28
Karnataka	Davanagere	*Kharif* Pigeonpea	440	360	22
Karnataka	Hassan	*Kharif* Pigeonpea	270	190	42
Karnataka	Kalaburagi	*Kharif* Pigeonpea	1430	1110	29
Karnataka	Kolar	*Kharif* Pigeonpea	1850	1360	36
Karnataka	Mysuru	*Kharif* Pigeonpea	180	130	38
Karnataka	Raichur	*Kharif* Pigeonpea	910	720	26
Karnataka	Ramanagara	*Kharif* Pigeonpea	1060	770	38
Karnataka	Vijayapura	*Kharif* Pigeonpea	950	730	30
Karnataka	Yadgir	*Kharif* Pigeonpea	1430	1100	30
Karnataka		*Kharif* Pigeonpea Total	990	770	29
Karnataka	Bagalkot	*Kharif* Soybean	1680	1290	30
Karnataka	Belagavi	*Kharif* Soybean	1640	1340	22
Karnataka	Bidar	*Kharif* Soybean	1920	1470	31
Karnataka	Dharwad	*Kharif* Soybean	1610	1240	30
Karnataka	Haveri	*Kharif* Soybean	1810	1460	24
Karnataka	Kalaburagi	*Kharif* Soybean	1830	1390	32
Karnataka		*Kharif* Soybean Total	1740	1370	27
Karnataka	Davanagere	*Kharif* Sugarcane	131,280	120,380	9
Karnataka	Mysuru	*Kharif* Sugarcane	131,450	114,730	15
Karnataka		*Kharif* Sugarcane Total	131,380	116,960	12
Karnataka	Bagalkot	*Kharif* Sunflower	1580	1190	33
Karnataka	Ballari	*Kharif* Sunflower	860	600	43
Karnataka	Chamarajanagar	*Kharif* Sunflower	1720	1350	27
Karnataka	Davanagere	*Kharif* Sunflower	1170	910	29
Karnataka	Haveri	*Kharif* Sunflower	1030	830	24
Karnataka	Kalaburagi	*Kharif* Sunflower	1990	1430	39
Karnataka	Koppal	*Kharif* Sunflower	760	530	43
Karnataka	Raichur	*Kharif* Sunflower	790	580	36
Karnataka	Vijayapura	*Kharif* Sunflower	2070	1550	34
Karnataka	Yadgir	*Kharif* Sunflower	750	600	25
Karnataka		*Kharif* Sunflower Total	1360	1020	33

Source: Derived by authors from data *Bhoochetana* scaling-up projects (ICRISAT 2018)

Table 4.4e State and crop wise grain yield (kg ha^{-1}) with farmers' practice and balanced micro- and secondary- nutrients participatory on-farm demonstrations in Karnataka

State	District	Crop	Yield (kg ha^{-1})		% Increase over FP
			Grain IP	Grain FP	
Karnataka	Bidar	*Kharif* Blackgram	1190	900	32
Karnataka	Kalaburagi	*Kharif* Blackgram	740	550	35
Karnataka	Mysuru	*Kharif* Blackgram	190	160	19
Karnataka		*Kharif* Blackgram Total	1030	780	32
Karnataka	Ballari	*Rabi* Chickpea	900	670	34
Karnataka	Belagavi	*Rabi* Chickpea	730	570	28
Karnataka	Bidar	*Rabi* Chickpea	1660	1300	28
Karnataka	Chitradurga	*Rabi* Chickpea	840	670	25
Karnataka	Davanagere	*Rabi* Chickpea	1210	950	27
Karnataka	Dharwad	*Rabi* Chickpea	1420	1060	34
Karnataka	Gadag	*Rabi* Chickpea	570	390	46
Karnataka	Haveri	*Rabi* Chickpea	700	550	27
Karnataka	Kalaburagi	*Rabi* Chickpea	1230	930	32
Karnataka	Koppal	*Rabi* Chickpea	1120	910	23
Karnataka	Raichur	*Rabi* Chickpea	1010	800	26
Karnataka	Vijayapura	*Rabi* Chickpea	680	520	31
Karnataka	Yadgir	*Rabi* Chickpea	750	560	34
Karnataka		*Rabi* Chickpea Total	980	750	31
Karnataka	Bidar	*Rabi* Safflower	970	740	31
Karnataka	Haveri	*Rabi* Safflower	680	540	26
Karnataka	Koppal	*Rabi* Safflower	270	200	35
Karnataka		*Rabi* Safflower Total	820	630	30

Source: Derived by authors from data from *Bhoochetana & BhooSamruddhi* scaling-up projects (ICRISAT 2009, 2012, 2017, 2018)

districts of Andhra Pradesh (undivided) (Srinivasa Rao et al. 2011). Varied response was associated with soil type, rainfall as well as management practices, however, it established that Indian soils are hungry also along with thirsty.

Increased crop yields with application of balanced nutrients to crops were largely due to increased rainwater use efficiency and it also resulted in increased profitability for the farmers. Highest rainwater use efficiency was observed in case of integrated nutrient management treatments, followed by balanced nutrient management and least was in farmers 'practice (Table 4.5).

As indicated in Table 4.5 application of S, Zn and B above farmers' practice increased RWU as well as profitability for the farmers. Response to balanced nutrient management varied with seasons largely due to rainfall and INM involving 50% N through vermicompost showed highest returns as well as RWU efficiency (Table 4.5) indicating the need to adopt INM strategy for enhancing productivity, profitability as well as sustainability. Similarly, enhanced water use efficiency was recorded across the crops and locations (Tables 4.6 and 4.7). In Chhattisgarh, Jharkhand, Madhya Pradesh and Rajasthan several trials conducted with balanced

Table 4.4f State and crop wise grain yield (kg ha^{-1}) with farmers' practice and balanced micro- and secondary- nutrients participatory on-farm demonstrations in Madhya Pradesh and Rajasthan

State	District	Crop	Yield (kg ha^{-1})		% Increase over FP
			Grain IP	Grain FP	
Madhya Pradesh	Guna	*Kharif* Soybean	1950	1580	23
Madhya Pradesh	Indore	*Kharif* Soybean	2600	2320	12
Madhya Pradesh	Raisen	*Kharif* Soybean	2580	1930	34
Madhya Pradesh	Rajagarh	*Kharif* Soybean	1800	1260	43
Madhya Pradesh	Sehor	*Kharif* Soybean	2500	2090	20
Madhya Pradesh	Sehore	*Kharif* Soybean	1890	1620	17
Madhya Pradesh	Vidisha	*Kharif* Soybean	2360	1770	33
Madhya Pradesh		*Kharif* Soybean total	2290	1830	25
Madhya Pradesh	Barwani	*Rabi* Chickpea	540	520	4
Madhya Pradesh	Guna	*Rabi* Chickpea	1740	1430	22
Madhya Pradesh	Indore	*Rabi* Chickpea	1370	1370	0
Madhya Pradesh	Mandla	*Rabi* Chickpea	610	410	49
Madhya Pradesh	Raisen	*Rabi* Chickpea	1560	1350	16
Madhya Pradesh	Rajagarh	*Rabi* Chickpea	1110	930	19
Madhya Pradesh	Sagar	*Rabi* Chickpea	1560	1330	17
Madhya Pradesh	Sehore	*Rabi* Chickpea	2060	1800	14
Madhya Pradesh	Vidisha	*Rabi* Chickpea	1560	1330	17
Madhya Pradesh		*Rabi* Chickpea Total	1440	1250	15
Rajasthan	Tonk	*Kharif* Groundnut	1090	960	14
Rajasthan		*Kharif* Groundnut Total	1090	960	14
Rajasthan	Sawai Madhopur	*Kharif* Maize	3220	2920	10

(continued)

Table 4.4f (continued)

Rajasthan	Tonk	*Kharif* Maize	2810	2600	8
Rajasthan		*Kharif* Maize Total	2980	2730	9
Rajasthan	Sawai Madhopur	*Kharif* Pearl Millet	2620	2380	10
Rajasthan	Tonk	*Kharif* Pearl Millet	2400	2230	8
Rajasthan		*Kharif* Pearl Millet Total	2510	2310	9
Rajasthan	Sawai Madhopur	*Kharif* Sorghum	2980	2740	9
Rajasthan		*Kharif* Sorghum Total	2980	2740	9

Source: Derived by authors from data from different scaling-up projects supported by Sir Dorabji Tata Trust

Table 4.4g State and crop wise grain yield (kg ha^{-1}) with farmers' practice and balanced micro- and secondary- nutrients participatory on-farm demonstrations in Telangana

			Yield (kg ha^{-1})		
State	District	Crop	Grain IP	Grain FP	% Increase over FP
Telangana	Mahabubnagar	*Kharif* Castor	1650	1050	57
Telangana	Nalgonda	*Kharif* Castor	820	500	64
Telangana		*Kharif* Castor Total	1130	700	61
Telangana	Nalgonda	*Kharif* Greengram	1230	790	56
Telangana	Nalgonda	*Kharif* Groundnut	1240	710	75
Telangana	Mahabubnagar	*Kharif* Maize	4480	2780	61
Telangana	Nalgonda	*Kharif* Maize	4840	2400	102
Telangana		*Kharif* Maize Total	4590	2670	72
Telangana	Mahabubnagar	*Kharif* Pigeonpea	820	410	100
Telangana	Nalgonda	*Kharif* Pigeonpea	1220	760	61
Telangana		*Kharif* Pigeonpea Total	1120	670	67
Telangana	Nalgonda	*Kharif* Sesame	910	530	72
Telangana	Mahabubnagar	*Kharif* Sorghum	1990	930	114
Telangana	Nalgonda	*Kharif* Sorghum	1920	800	140
Telangana		*Kharif* Sorghum Total	1980	910	118

Source: Derived by authors from data collected in APRLPproject (ICRISAT 2004)

nutrition for enhancing WUE (productivity and profitability) through the GoI's program "*More crop per drop*" supported by Water Resources Ministry, GoI demonstrated increased crop yields by 14–33% with balanced nutrient management along with increased benefit: cost ratios 1.6–10 as compared to1.2–9 in case of farmers 'practice (Table 4.6).

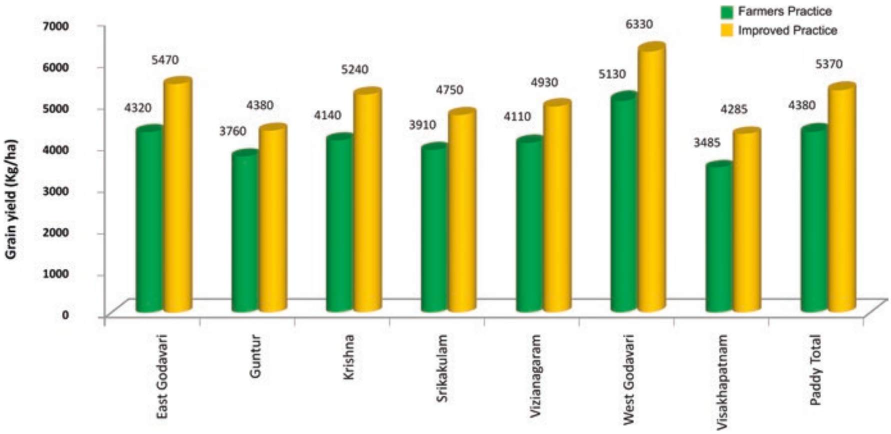

Fig. 4.5a Effect of soil test-based micro & secondary nutrient application in paddy crop yield in Andhra Pradesh

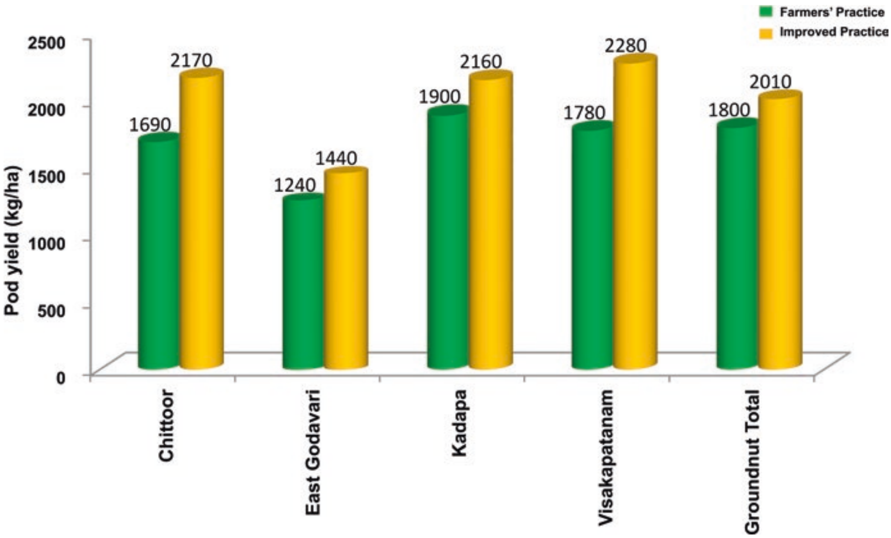

Fig. 4.5b Effect of soil test-based micro & secondary nutrient application in groundnut crop yield in Andhra Pradesh

4.4 Scaling-up of Land and Water Management Interventions

A large yield gap of two-fold to four-fold existing in Asia and Africa between current productivity and achievable potential, with farmers' yields than the achievable yields (Wani et al. 2003b, c; Rockström et al. 2007). Large opportunities for enhancing food production through enhanced water productivity (WP) by adopting

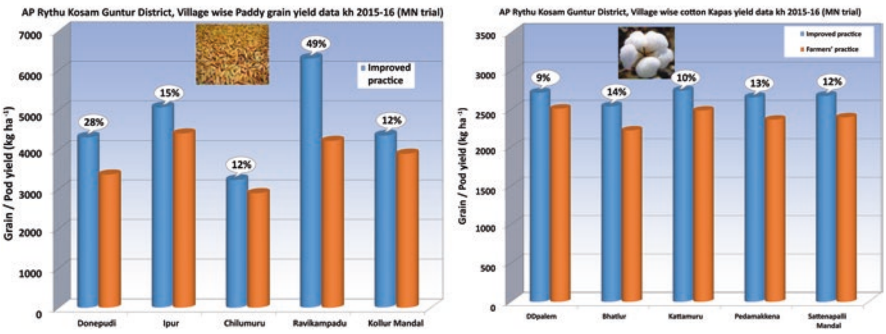

Fig. 4.5c Increased crop yields due to micronutrients application in Andhra Pradesh. (Source: ICRISAT 2016)

Table 4.5 Effects of nutrient managements on soybean (*Glycine max*) grain yield, benefit to cost ratio and rainwater use efficiency under rain-fed conditions in Madhya Pradesh, India

	Grain yield (kg ha^{-1})			Benefit: cost ratio		Rainwater use efficiency (kg/mm/ha)		
District	FP[a]	BN	INM	FP	BN	FP	BN	INM
2010								
Guna	1270	1440	1580	1.31	4.58	1.76	1.99	2.19
Raisen	1360	1600	1600	1.85	3.55	1.76	2.07	2.07
Shajapur	1900	2120	2410	2.99	10.2	3.45	3.85	4.38
Vidisha	1130	1410	1700	2.16	8.43	1.48	1.84	2.22
2011								
Guna	1370	1560	1600	1.47	3.4	0.83	0.95	0.97
Shajapur	1220	1400	1510	2.45	5.8	1.12	1.28	1.38
Vidisha	1190	1380	1460	1.47	3.99	0.88	1.02	1.08

[a]*FP* Farmers'practice (NPK only), *BN* Balanced nutrition (FP + S + B + Zn), and *INM* Integrated nutrient management (50% BN inputs + vermicompost) (Derived from Chander et al. 2011)

appropriate soil, water and crop management options exists to be harnessed (Wani et al. 2009a). A linear relationship is generally assumed between biomass growth and vapour flow/evapotranspiration (ET) for grain yield >3 t ha^{-1}, which describes WP ranging between 1000 and 3000 m^3 t^{-1} for grain production (Rockström 2003). The reason is that improvements in agricultural productivity, resulting in increased yield and denser foliage, will involve a vapour shift from non-productive evaporation (E) in favour of productive transpiration (T) and a higher T/ET ratio as transpiration increases (essentially linearly) with a higher yield (Stewart et al. 1975; Rockström et al. 2007).

Evidence from water balance analyses of farmers' fields around the world shows that only a small fraction, less than 30% of rainfall, is used as productive green water flow (plant transpiration) supporting plant growth (Rockström 2003). In arid areas, as little as 10–15% of the rainfall is typically consumed as productive green water flow (transpiration) and 85–90% flows as non-productive evaporation, that is,

Table 4.6 Effect of balanced nutrient management on water use efficiency of crops and crop yields in different states in India

Sl. No.	State	Crop	Crop yields (kg ha^{-1})			Water use efficiency (kg mm^{-1} ha^{-1})		Benefit cost ratio	
			FP	IP	% Increase	FP	IP	FP	IP
1	Chhattisgarh	Rice[a]	4410	5450	24	7.0	9.0	6.0	6
		Chickpea[b]	Fallow	745	–	–	9.0	–	4
2	Jharkhand	Rice[a]	5160	5982	14	4.7	6.0	9.0	10
		Chickpea[b]	Fallow	975	–	–	6.0	–	7
		Groundnut	1470	1950	33	2.7	3.5	2.45	3.25
		Maize	5500	6970	27	6.9	8.6	2.75	7.5
3	Madhya Pradesh	Soybean[c]	Fallow	2134	–	–	4.5	3.0	4.0
		Soybean	2120	2680	25	2.6	3.7	2.8	3.8
		Chickpea	1562	1817	16	3.0	4.0	2.8	1.9
		Wheat	1848	2305	24	8.0	9.0	2.0	2.6
4	Rajasthan	Black gram	326	385	20	0.7	0.9	1.5	1.8
		Groundnut	734	872	20	1.3	1.6	2.1	2.9
		Maize	1746	2035	17	3.2	3.7	1.5	1.9
		Pearl millet	616	718	16	1.8	2.1	1.2	1.6
		Chickpea	1270	1520	19	6.2	7.8	4.6	5.8
		Wheat	3952	4580	16	4.6	7.3	1.9	2.4
		Mustard	1242	1436	16	8.3	12.3	1.6	2.3
		Green peas	3530	4160	18	7.8	9.2	4.7	5.5

Source: Derived from Wani et al. (2010, 2012a)
[a]Rice in rainy season;
[b]After harvest of rice that is grown in rainy season followed by chickpea in post-rainy season on residual moisture;
[c]Fallow during rainy season in conventional practice

no or very limited blue water generation (Oweis and Hachum 2001). Agricultural water management interventions in the watershed in the Indian SAT converted more rainfall into green water and also reduced the amount of run-off by 30–50%, depending on rainfall amount and distribution (Garg et al. 2011).

In order to bridge the existing yield gaps improved landform management practices were scaled-up in different agro-eco regions of India to benefit the farmers. Different land form treatments in each region as per the soil type and rainfall with major crops were scaled-up based on the earlier on-farm research. Summary results presented in Table 4.8 showed average increased grain yield from 11% to 43% with improved landform treatment over the farmers' practice in different regions. Increased grain yields with improved landform treatment ranged from 7% to 52% over the farmers 'practice with different crops in different regions. Along with land form treatment effects of balanced nutrient management were also demonstrated in

Table 4.7 Average water use efficiency of crops grown with farmers 'practice and balanced nutrient management (IP) from different locations in India

	Crop yields (kg ha^{-1})			Water use efficiency (kg mm^{-1} ha^{-1})			Benefit cost ratio		
Crop	FP	IP	% Increase	FP	IP	% Increase	FP	IP	% Increase
Wheat	2900	3443	20	6	8	33	2.0	2.5	25
Soybean	2120	2407	25	3	4	33	3.0	4.0	33
Rice	4785	5716	19	6	8	33	7.5	8.0	7
Pearl millet	616	718	16	2	2	0	1.2	1.6	33
Mustard	1242	1436	16	8	12	50	1.6	2.3	44
Maize	3623	4503	22	5	6	20	2.1	4.7	124
Groundnut	1102	1411	27	2	3	50	2.3	3.1	35
Green peas	3530	4160	18	8	9	13	4.7	5.5	17
Chickpea	1416	1264	18	5	7	40	3.7	4.7	27
Black gram	326	385	20	0.7	0.9	29	1.5	1.8	20
Mean of all crops	**2166**	**2544**	**20**	**4.6**	**6.0**	**30**	**3.0**	**3.8**	**27**

Source: Derived from Wani et al. (2010), ICRISAT (2012)

Madhya Pradesh with assured rainfall and Vertisol (black cotton soils), the superiority of BBF landform treatment was showed over conservation furrow method (Table 4.8).

4.5 Scaling-up of Improved Cultivars Thorough Participatory Evaluation/Selection

One of the most important intervention for enhancing the productivity and profitability for the farmers is introduction of stress-tolerant climate smart cultivars of the crops and ensure availability of seeds for the farmers along with improved management of soil, water and nutrient management interventions. In all the scaling-up initiatives conducted in Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Jharkhand, Karnataka, Telangana, Odisha, Maharashtra, Gujarat, Rajasthan, Uttar Pradesh, etc. in India, Thailand, Vietnam, and China were conducted with identified improved cultivars. Improved cultivars were identified through discussions with the NARSs partners for each project and seeds were made available to the farmers. List of improved cultivars evaluated in different districts of Karnataka during *kharif* and *rabi* seasons is indicated in Table 4.9.

The efforts were made to make available climate smart crop cultivars which are tolerant of mid-season and end-of-season drought, and are high yielding were made available to farmers for their evaluation. The results are presented in Tables 4.10a, 4.10b, 4.10c, and 4.10d and Figs. 4.8a to 4.8h). In Karnataka yields of improved cultivars of different crops were compared with the average yield of a particular crop in Karnataka and also with average crop yield at national level. The results

Table 4.8 Effect of land management systems on crop yields in different states in India

Sl. No.	State	Crop	No. of trials	Land management system[b]	Grain yield (kg ha^{-1})				% Increase	
					FP[c]	Range	IP[c]	Range	Av.	Range
1	Andhra Pradesh[a]-APRLP-DFID	Groundnut	30	CF	964	910–972	1090	1010–1130	13	9–17
		Green gram	10	CF	810	750–950	1050	900–1150	30	26–33
2	Andhra Pradesh-*Rythu kosam*-GoA.P.	Pigeonpea	20	CF	950	860–1050	1150	950–1240	21	17–24
		Cowpea	20	CF	350	240–480	470	280–720	34	29–38
		Black gram	20	CF	450	360–650	570	380–810	27	24–31
		Maize	10	BBF	2550	1850–3300	3100	1900–3700	22	16–28
3	Madhya Pradesh-WUE-GoI	Soybean	235	BBF	2134	1831–2550	2793	2397–3110	31	22–39
		Chickpea	184	BBF	1240	1050–1480	1610	1580–1650	32	10–52
4	Rajasthan-WUE-GoI	Blackgram	9	CF	326	270–360	385	240–425	18	14–20
		Groundnut	5	CF	734	685–770	872	785–930	19	15–24
		Maize	6	CF	1746	1350–1950	2035	1750–2350	17	13–22
		Pearl millet	8	CF	616	550–660	718	680–760	16	11–24
5	Karnataka-Sujala-WB program	Maize	20	CF	3480	3110–4210	4060	3610–5080	17	13–21
		Soybean	20	CF	1470	1310–1590	1800	1660–1930	23	20–27
		Groundnut	25	CF	1120	500–1240	1320	1070–1930	19	13–22
		Finger millet	25	CF	1280	1120–1480	1590	1380–1840	24	21–29
		Maize	15	BBF	3630	3130–4210	4790	4620–5080	43	21–50

(continued)

Table 4.8 (continued)

Sl. No.	State	Crop	No. of trials	Land management system[b]	Grain yield (kg ha^{-1})				% Increase	
					FP[c]	Range	IP[c]	Range	Av.	Range
6	Karnataka-*Bhoo Chetana*	Pigeonpea	20	CF	925	630–1540	1165	830–1940	26	22–32
		Pearl millet	20	CF	1095	960–1220	1385	1270–1550	26	10–44
		Soybean	10	BBF	1400	1180–1610	1740	1480–2000	24	22–26
		Finger millet	10	CF/BS[1]	1030	800–1440	1330	970–1930	29	24–37
		Groundnut	5	BBF	1160	1070–1270	1470	1370–1590	27	23–29
7	Karnataka-*Bhoo Samrudhi*	Soybean	40	BBF	1238	1380–1500	1523	1580–1960	23	14–37
		Green gram	30	BBF	520	180–880	665	210–1200	28	22–34
		Groundnut	10	BBF	1152	900–1450	1356	1000–1630	18	10–21
		Maize	20	BBF	2400	1800–2900	3000	2500–3600	25	20–28
		Pearl millet	20	BBF	810	700–920	910	800–1020	12	11–14
		Pigeonpea	25	BBF	756	430–1200	840	500–1500	11	7–16
		Chickpea	10	BBF	1250	850–1350	1450	1120–1650	16	11–18

Sources: ICRISAT (2004, 2009, 2012, 2018), Wani et al. (2012a)

[a]Former undivided Andhra Pradesh state

[b]Land management systems – CF: Conservation Furrow; BBF: Broad bed and furrow; BS: Border strip

[c]FP: Farmers practice with flat land configuration; IP: Improved land configuration with CF/BBF

presented in 4.10b demonstrated increased yield of 29% over average Karnataka yield and 67% over national yield average in case of finger millet cv. MR 1 and 144% in case of soybean cv. JS 9560 over average soybean yield in Karnataka and India (Table 4.10b). Maximum yield increase was observed with improved cultivar of sunflower DRSH 1 (166–169%) over average yield in Karnataka and national average. These results revealed that there is ample scope to increase the potential yield of different varieties in the state of Karnataka to benefit small and marginal farmers. Field trials for groundnut crop with cultivar ICGV 91114 were planned in twelve districts of Karnataka. Maximum yield (2590 kg ha^{-1}) was observed in Raichur district (Fig. 4.7b). Low grain yields in Bagalkot (1050 kg ha^{-1}) and Gadag (1140 kg ha^{-1}) were because of poor rainfall. Poor rainfall distribution also affected crop establishment in Dharwad, Davangere and Hassan districts.

Trials for two sorghum cultivars (viz, CSV 15 and CSV 23) demonstrated in eight districts showed maximum yield for CSV 15 was 2640 kg ha^{-1} in Koppal and

Table 4.9 List of crop cultivars demonstrated in farmer's fields in different districts of Karnataka

District Name	Pigeon pea	Green gram	Groundnut	Soybean	Ground nut	Cluster bean	Chickpea
Belgaum	ICPL 87119 (Asha), hybrid (Puskal) ICPH 2671	SML 668	ICGV 91114	JS 9560, JS 335, DSB 21		HG 563	JG 11, JAKI 9218
Davanagere	Lakshmi (ICPL 85063), Asha (ICPL 871119), ICPH 2740, Puskal (ICPH 2671)	–	ICGV 91114			–	JG 11, JAKI 9218, ICCC 37
Haveri	Asha (ICPL 87119), Lakshmi (ICPL 85063), Puskal (ICPH 2671), ICPH 2740	–	–			–	ICCC 37, JG 11, JAKI 9218
Bijapur	Asha (ICPL 87119), Lakshmi (ICPL 85063)	SML668	–			HG 563	KAK 2, ICCC 37, JG 11, JAKI 9218
Chikkamagalur	Lakshmi (ICPL 85063), Asha (ICPL 87119), Puskal (ICPH 2671), ICPH 2740	SML 668	–			HG 563	ICCC 37, JG 11, JAKI 9218
Chamarajnagar	Lakshmi (ICPL 85063), Puskal (ICPH 2671)	SML 668	–			HG 563	KAK 2, ICCC 37, JG 11, JAKI 9218
Gadag	Lakshmi (ICPL 85063), Puskal (ICPH 2671), Asha (ICPL 87119)	–	ICGV 91114			–	JG 11, JAKI 9218
Bangalore 2	Laxmi (ICPL 85063), Asha (ICPL 87119), Puskal (ICPH 2671)	–	–			–	

(continued)

Table 4.9 (continued)

District Name	Pigeon pea	Green gram	Groundnut	Soybean	Ground nut	Cluster bean	Chickpea
Tumkur	Lakshmi (ICPL 85063)	–	ICGV 91114, ICGV 02266, ICGV 00308, ICGV 00351		ICGV 91114,	HG 563	JG 11, JAKI 9218
Chitradurga	Laxmi (ICPL 85063), Asha (ICPL 87119), Puskal (ICPH 2671), ICPH 2740	–	ICGV 91114			HG 563	JG 11, JAKI 9218
Yadgiri	Puskal (ICPH 2671), Asha (ICPL 87119), Laxmi (ICPL 85063)	–	–		ICGV 91114,	–	JG 11, JAKI 9218
Gulbarga	Puskal (ICPH 2671), Asha (ICPL 87119), Laxmi (ICPL 85063), ICPH 2740	SML 668	–		ICGV 91114	HG 563	JG 11, JAKI 9218
Bidar	Puskal (ICPH 2671), Asha (ICPL 87119), Laxmi (ICPL 85063), ICPH 2740	SML 668	–	JS 9560, JS 335, DSB 21		HG 563, N 87, RGE-986	JG 11, JAKI 9218
Bellary	Puskal (ICPH 2671), Asha (ICPL 87119), Laxmi (ICPL 85063), ICPH 2740	SML 668	ICGV 91114			HG 563	JG 11, JAKI 9218, KAK 2

(continued)

Table 4.9 (continued)

District Name	Pigeon pea	Green gram	Groundnut	Soybean	Ground nut	Cluster bean	Chickpea
Raichur	Puskal (ICPH 2671), Asha (ICPL 87119), Laxmi (ICPL 85063), ICPH 2740	SML 668	ICGV 91114, ICGV 02266, ICGV 00308, ICGV 00351			HG 563	JG 11, JAKI 9218, KAK 2

Source: Compiled from data collected from *Bhoochetana* scaling-up projects (ICRISAT 2018)

Table 4.10a Grain yield and pod yield of different participatory demonstrations in Jharkhand

kharif-2013	Crop variety	Yield (t ha^{-1})
Groundnut		Av. Pod yield (t ha^{-1})
	ICGV 9346 with agribore	1.90
	ICGV 9346 with no agribore	1.84
	Jhumku (**local**) with agribore	1.48
	Jhumku with no agribore	1.42
Soybean		Av. Seed yield (t ha^{-1})
	PUSA-9712 with agribore	0.72
	PUSA-9712 with no agribore	0.65

for CSV 23 was 2880 kg ha^{-1} in Raichur. Overall average yield for CSV 15 cultivar was 2240 kg ha^{-1} and for CSV 23 was 2580 kg ha^{1}. Observed data from Belgaum and Davangere indicated that CSV 23 had 18–22% more grain yield than CSV 15 cultivar (Figs. 4.6a1, 4.6a2, and 4.6b). Heavy rainfall during crop season damaged trials of both the cultivars in Bidar and Gulburga districts and CSV 23 cultivar in Koppal and Haveri districts. Similarly, increased crop yields with improved cultivars of pearl millet, finger millet and other crops in different districts were recorded (Figs. 4.6c, 4.6d, and 4.6e). Early maturing cultivar of pearl millet like HHB 67 showed better performance over ICTP 8809 which suffered due to drought at maturity. Maximum yield (2325 kg ha^{-1}) was observed in Yadgir district with average yield of 1370 kg ha^{-1}for ICTP 8203 and1420 kg ha^{-1} for HHB 67. (Fig. 4.6c). Grain yields of castor trials showed maximum yield in Raichur. Yield for DCH 177 that is 5–19% more than cultivar Jyothi (Fig. 4.6e).

In Jharkhand improved cultivars of chickpea benefitted farmers well as they sold green chickpea to the nearby city market and made on an average income of Rs 15,000 per acre as compared to no income from field which they had kept fallow after harvesting rice previously. For seed production, specified farmers' fields were maintained till maturity and both the cultivars produced 1300–1500 kg ha^{-1}. Groundnut yields and other agronomic parameters were analysed among farmers' participatory experimental fields in Jharkhand and compared with traditional variety (*Jhumku*).

Table 4.10b Average crop yields of various varieties during rainy season 2013 in Karnataka and average yields of Karnataka state during rainy season 2011 and average yields of different crop s during rainy season 2012 at all India level

S. No	Crop	Variety	ICRISAT, varietal trial Average yield 2013 (kg ha^{-1})	National Average yield 2012 (kg ha^{-1})[a]	% increase over national average	Karnataka average yield 2011 (kg ha-1)[b]	% increase over Karnataka average
1	Groundnut	ICGV 91114	1517	985	54	665	128
2	Finger millet	MR 1	2527	1514	67	1966	29
3	Soybean	JS 9560	2321	950	144	950	144
4	Sorghum	CSV 15	2240	1070	109	1556	44
5	Sorghum	CSV 23	2579	1070	141	1556	66
6	Pearl millet	ICTP 8203	1372	1124	22	1025	34
7	Pearl millet	HHB 67	1417	1124	26	1025	38
8	Sunflower	DRSH 1	1462	544	169	547	167
9	Castor	DCH 177	1225	1329	-8	926	32
10	Castor	DCH 32	1280	1329	-4	926	38

Source: Compiled by authors from *Bhoocheatana* sites (ICRISAT 2018)
[a]State of Indian agriculture 2012–13
[b]Final advance estimates of area, production and yield of important agricultural crops in Karnataka 2011–12 – Directorate of Economics and Statistics, Government of Karnataka

Table 4.10c Performance of participatory trials at Parasai-Sindh watershed, Jhansi district, Uttar Pradesh during *Rabi*

Crop	Variety	Average grain yield (kg/ha)	Per cent yield increase
Chick pea	Vaibhav	1870	33
	Desi	1402	–
Lentil	DPL 62	1130	18
	Desi	960	–
Mustard	Pusa Bold	1470	25
	Desi	1180	–

Improved groundnut variety (TAG 24) had the highest pods (19.2 pods/plant). Wheat yield obtained by HI 1544, HI 1531, HI 1479 and HI 1418 were found relatively higher than Lok 1. The HI 1544 recorded highest grain yield of 3.59 t ha^{-1} compared to 2.25 t ha^{-1} by Lok 1. Chickpea yield for JG 11 recorded grain yield 2.65 t ha^{-1} compared to 1.24 t ha^{-1} by local cultivars. Due to heavy rainfall in *Kharif 2013,* no effect of agribore observed in groundnut and soybean fields on harvested yield. Groundnut (ICGV 9346) produced pod yield 1.90 t ha^{1} (with agribore) compared to 1.48 t ha^{-1} by local cultivar (*Jhumku)* with application of agribore. Soybean

Table 4.10d Participatory demonstrations at Parasai-Sindh watershed during *Rabi* 2013–2015 seasons

Crop	Varieties introduced	Av. Grain yield kg ha^{-1}		Percent increase over local
		Improved	Local	
Barley	RD 2552	2395	1473	62
Mustard	Maya	1194	1019	17
Chickpea	JG 130	1398	823	69
Pigeonpea	ICPL-85063 (Lakshmi), ICPL 88039	762	628	21
Green gram[a]	Samrat	146	131	11
Chickpea	JG 130	1211	821	47
Mustard	NRC HB 101, NRC HB 506, NRC DR 02	1184	923	28
Wheat	HI 1532; HI 1544; HI 1418; HI 1479	4423	3450	28

[a]Due to long dry spell, crop yield drastically reduced

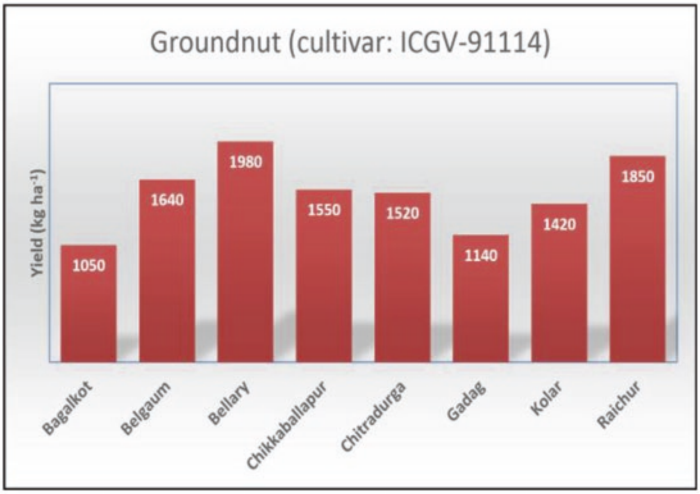

Fig. 4.6a1 Increased pod yield of improved groundnut cultivars over farmers' cultivar in districts of Karnataka

(PUSA 9712) yield was s 0.72 t ha^{-1}(with agribore), and 0.65 t ha^{-1} (without agribore) during *Kharif* 2013. Unexpected rainfall during pod formation reduced total yield in *Kharif* 2013 in watershed (Table 4.10a). Correspondingly, this variety had highest kernel yield (1.68 t ha^{-1}) and pod yield (2.42 t ha^{-1}). Data showed that introducing improved groundnut variety enhanced crop yield by 30–50% compared to local variety. In Uttar Pradesh, increased grain yields with improved cultivars of barley, mustard, pigeon pea, green gram, lentil and wheat were recorded in the range of 11–69% over the local cultivars (Table 4.10c and 4.10d). In Andhra Pradesh grain yield of improved cultivars of green gram and black gram were increased by

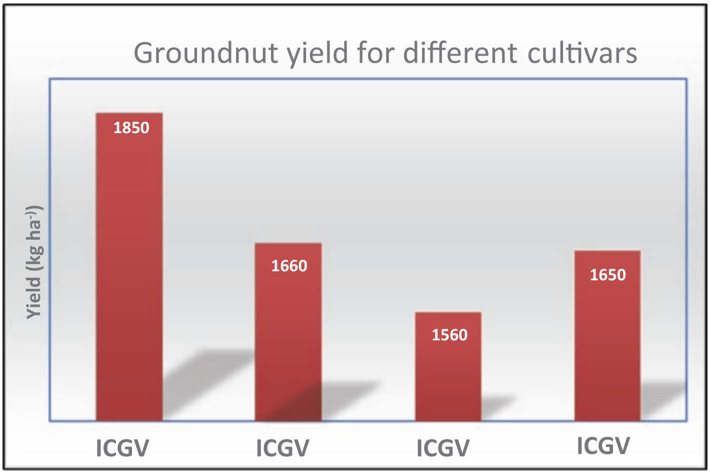

Fig. 4.a2 Yield of participatory trials with different groundnut cultivars in Raichur and Belgaum districts of Karnataka

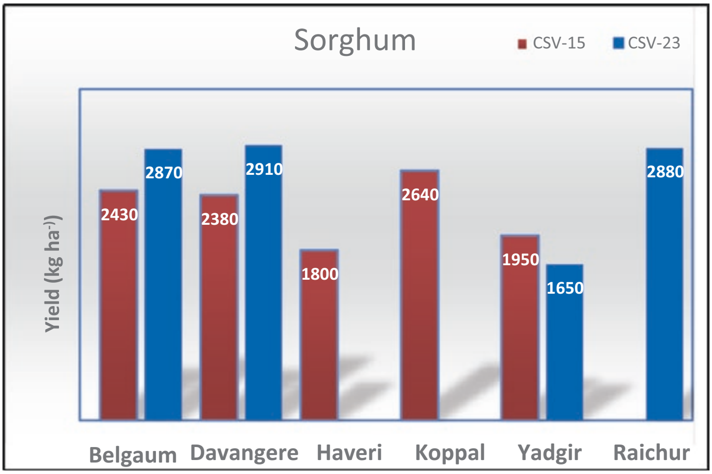

Fig. 4.6b Performance of improved sorghum cultivars (grain yield/ha) in districts of Karnataka

70–126% over the farmers' cultivars. Similarly, the results from farmers' fields revealed 12–24% increased legumes productivity compared to local popular cultivar (Fig. 4.6g).

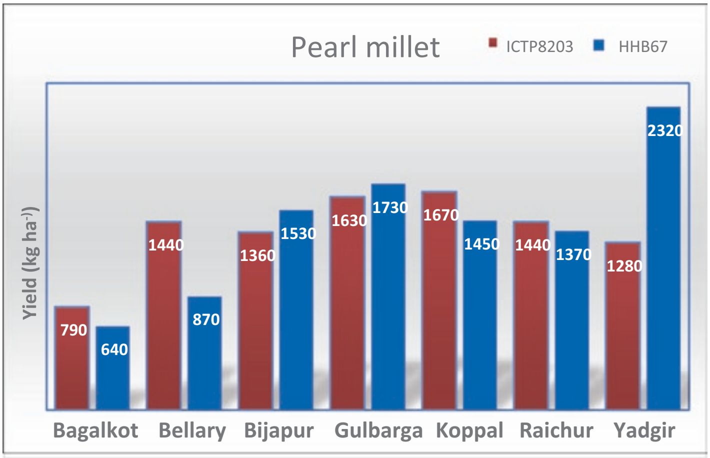

Fig. 4.6c Average grain yield of ICTP 8203 and HHB 67 improved pearl millet cultivars in districts of Karnataka

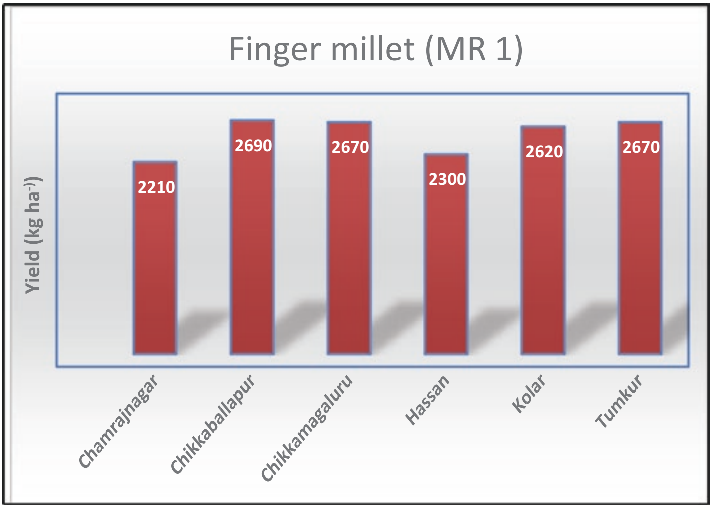

Fig. 4.6d Average grain yield of improved finger millet cultivar MR 1 in districts of Karnataka

4.6 Participatory Evaluation of Crop Diversification, Income-Generating Livelihood Activities

Diversification of livelihood in scaling-up initiatives in rural areas builds income security as well as empowerment of women and youths enabling them to build the resilience against climate change. First and foremost, change after rainwater harvesting interventions is the diversification of crops, cropping systems and livelihood

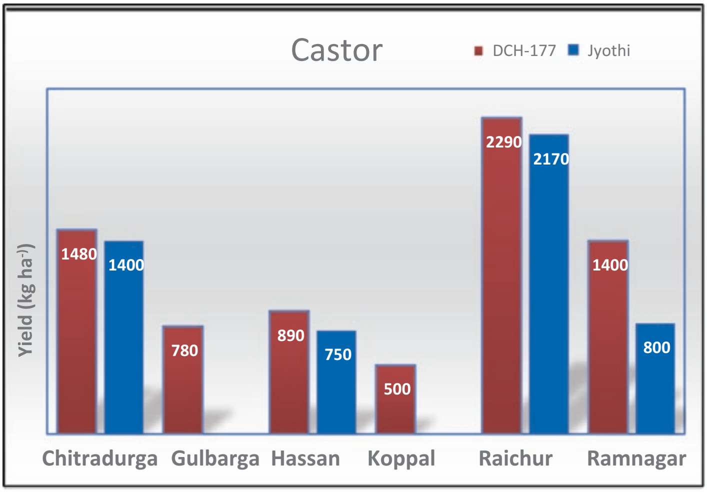

Fig. 4.6e Average yield of improved castor cultivars in districts of Karnataka state

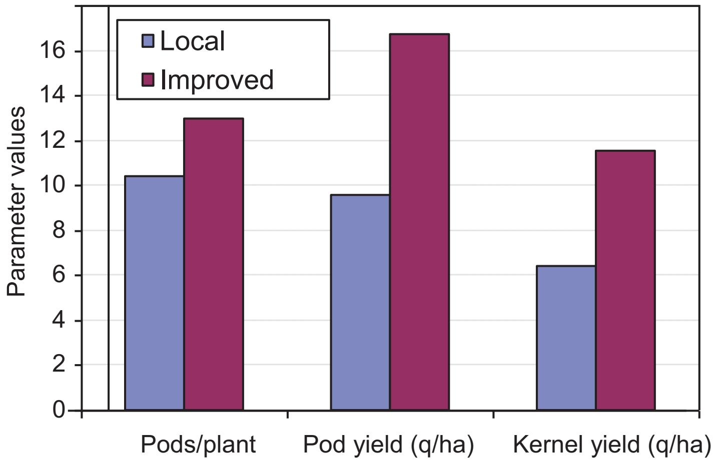

Fig. 4.6f Increased yield of improved cultivars of groundnut and local variety in Jhansi, Uttar Pradesh

systems. With increased water availability cultivation of high-value crops such as fruits, vegetables, flowers and fodder cultivation take place. With the increased water availability and increased crop productivity quantity of crop residues also increased in the area. In addition, introduction of improved dual purpose cultivars improved quality fodder also. With water availability, farmers started cultivating green fodder in the watershed (Chander et al. 2020). Nursery raising of fruits, plantation, vegetable, ornamentals is a potential opportunity for women farmers as a livelihood activity.

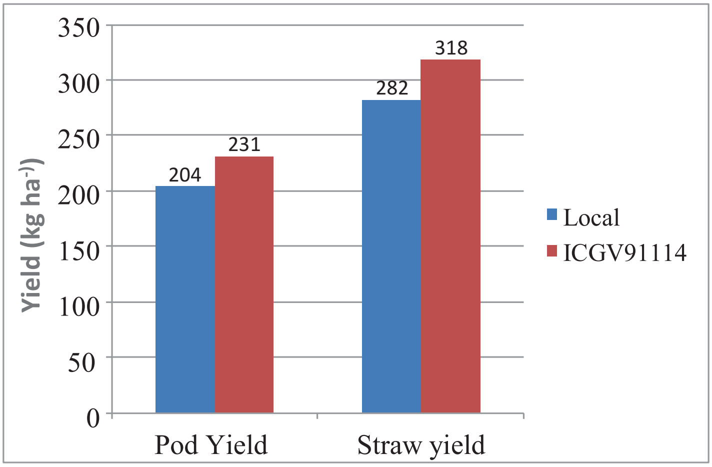

Fig. 4.6g Increased pod yield of improved cultivar ICGV 91114 as compared to local cultivar

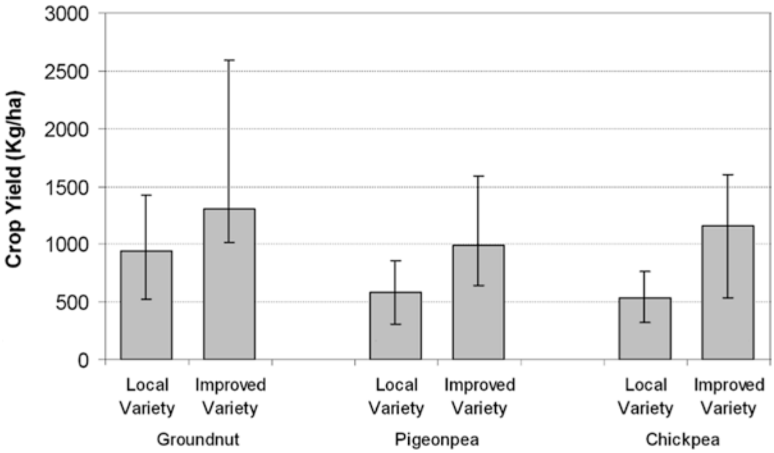

Fig. 4.6h Increased yields with improved varieties of legume over the local varieties in farmers' fields

Women in various villages, adopted nursery raising of fruits, plantation crops as a livelihood activity. Women raised nurseries and supplied hundreds of fruit trees and teak plants along with *Gliricidia* saplings to be planted on bunds for generating N-rich organic matter. Nurseries in horticulture plants is important area for income generation for women due to the large scope of horticulture sector as it contributes share of around 30% in agricultural output and a key area to achieve desired doubling of farmers' income and resilience in the drylands. In horticulture sector, percent share of production of fruits and plantation crops is quite significant at 37%. Raising ornamental plants for city markets is also a big opportunity. Well tested

Table 4.11 Nutritive value of spent malt and recommended mineral mixture

Nutrient	Spent-malt: nutrient composition	2 kg Spent-malt: nutritive value (g)	100 g mineral mixture: nutritive value (g)
Nitrogen (%)	3.66%	73.2	–
Protein (%)	22%	440	–
Phosphorus	0.46%	9.20	9.00
Iron	205 ppm	0.41	0.40
Zinc	52 ppm	0.11	0.30
Copper	248 ppm	0.50	0.06
Manganese	29.5 ppm	0.06	0.10
Sulfur	2655 ppm	5.31	0.40
Calcium	2098 ppm	4.20	18.0
Magnesium	1602 ppm	3.21	5.00

model of nutri-kitchen gardens through which women can improve nutrition of household, and also earn income (or save expenditure) through sale of vegetables was promoted in all the scaling-up initiatives. Women were provided seeds of vegetable for cultivation in 10–20 m^2 as kitchen gardens along with know-how of cultivation. Most women used house-made compost for vegetable production. Nutri-kitchen garden kits with different vegetable crops (Tomato, Brinjal, Okra, Bottle gourd, Bitter Gourd, Ridge gourd, *Palak* and Amaranthus) were provided to households every year to grow vegetables in their backyard for their household consumption resulting in saving expenditure on purchase of vegetables. These households produced thousands of kg of vegetables and marketed collectively. The average household production was about 28 kg of vegetables with a saving of around Rs 800/family while improving household nutrition (Chander et al. 2018, 2020; Petare et al. 2018, Patil et al. 2018; Sawargaonkar et al. 2018; Sudi et al. 2018).

Productivity of milch animals and business profitability is largely dependent on fodder/feed availability as well as its cost and quality. In a common situation of lack of green fodder in general, especially with lactating animal, feed/concentrate is required to make up for lacking protein and nutrients. In addition to cultivating green fodder women groups also were empowered touse spent malt as a good feed material for livestock for improving health, milk yield and fat content. Spent malt is a by-product of brewing industry which contains carbohydrates, proteins, lignin and water-soluble vitamins as animal feed which is quite palatable. Two kg of spent malt (on dry weight basis) provide about 400 g protein which very well meets the requirement of 350 g per day protein required for maintenance of adult cattle of ~500–600 kg weight (Table 4.11). Spent malt provides macro and micro nutrients required for good health and immunity in cattle – 2 kg spent malt provides nutrients at par or more than the recommended 100 g mineral mixture per day.

During exposure visit of farmers to learn the watershed interventions, farmers from Kothapally watershed came to know about the spent malt initiative and its benefits realized by Fasalvadi women. Kothapally is village with milk production activity of around 2100 litre per day. In this context, lead women farmers in *Adarsha* watershed, Kothapally realized opportunities of improving milk production through getting spent-malt from nearby SABMiller brewery. Training of women groups by ICRISAT team to handle spent malt was undertaken and major points to take care in spent malt use are as under:

- Spent malt (wet) to be consumed within 24 h. Thereafter, it gets fermented and sour.
- Not be fed to cattle after 48 h – worms may get developed and cattle health may be affected.
- Fresh spent malt needs to be dried for storage and use later on.
- Quantity to be fed is 4–5 kg spent malt/day/animal (2–2.5 kg in the morning and same in the evening)

The basic requirements in this initiative are;

- Vehicle arrangement for lifting spent malt from brewery to respective village.
- Place with rooftop for unloading and storing spent malt.
- Plastic drums (200 liters' size) for storing spent malt.
- Buckets/baskets for unloading spent malt.
- Weighing balance for distribution of spent malt to farmers.
- Inventory books for maintaining disbursement details etc.

Tejasri womens' SHG (12 women members) in *Adarsha* watershed, *Kothapally* village in Medak (erstwhile Ranga Reddy in undivided Andhra Pradesh) district is handling the spent malt based activity benefitting 96 households in the watershed to feed around 559 milch animals. Daily around 2580 kg spent malt is used to feed cattle. With use of spent malt as animal feed, farmers have observed increased milk production of about 2 litre per animal per day with improved fat content. Due to this the gross income in the village is increased by about Rs. 46,000 per day (about Rs 36,000 net income) on account of increased milk production in the village. On a monthly basis, more than Rs 11,000/− net income is increased per household of participating farmers. *Tejasri* group that handles the activity procure spent malt at the rate of Rs 2.75 per kg and sells at the rate of Rs 4 per kg. Members use Rs 1.25 per kg for transportation and handling charges by the group. Through this, member handling day to day operations get around Rs 10,000/− per month income and contributes Rs 1000/ – for the group corpus fund (Chander et al. 2020).

Composting activity adopted by women farmers (Wani et al. 2016a, b), one unit produces around 2500 kg compost in a year. Farmers got a price of about Rs 4/− per kg compost and thus each person was able to earn around Rs 10,000/− a year through this activity. This side activity not only brought incomes to women farmers, but also recycled household and on-farm wastes which otherwise did not find any effective alternate use except creating a nuisance. This activity also contributed to cleanliness drive in the village. Some SHGs are also engaged in making vermi-wash through making outlets for collection of washings in composting unit. Per unit 150–200 litre vermi-wash was produced and is sold at Rs 4/− per litre. It is quite

Fig. 4.7a Income-generating activities undertaken in scaling-up initiative in Andhra Pradesh, India

popular with vegetable farmers to improve quantity and quality of the produce. (Wani et al. 2014; Chander et al. 2013).

In addition, based on the needs assessment, potential and availability of market, specific activities were identified as livelihood activities for women and youths in the villages. For example, in Lucheba watershed in Guizao province of China, women undertook grading, sorting and packaging of vegetables which were directly marketed on line to city markets (Wani et al. 2009b) in addition to rearing of rabbits, goats, pigs, biogas production etc. (Wani et al. 2012b). In India, women groups took up value addition to pigeon pea through processing for making *Daal* (Split pigeon pea) which is consumed in India and fetches good price over the unprocessed pigeon pea. In several initiatives women took up sewing activities as well as power generation using *Pongamia* seeds oil and also running highway restaurant as IGA (Sreedevi and Wani 2007). Wherever, opportunities existed for undertaking fisheries related activities, in addition to collecting/catching fish, sun drying of fish using solar dryers was taken up as income-generating activity (Fig. 4.7 & ICRISAT 2016; Raju et al. 2017. For young educated boys and girls opportunities for employment as farm facilitators, lead farmers as well as para-extension workers were created in villages by linking them with knowledge generating institutions

Fig. 4.7b (continued)

Fig. 4.7c (continued)

(Chap. 1 by Wani 2021 and Chap. 3 by Bhattacharyya et al. 2021). With support of knowledge-generating institutions like ICRISAT, SAUs, KVKs, women SHGs also undertook specialized activities like *Helicoverpa* nuclear polyhedrosis virus (HNPV) production for minimizing pest damage in crops like cotton, pigeon pea and chickpea.

4.7 Lessons Learnt and A Way Forward

Most important learning is the realisation of "*Death Valley of impacts*" which must be crossed to achieve the SDGs particularly 1, 2 and 3 related with no poverty, zero hunger and well-being of people. The poverty is not reduced largely because the scientists have worked in isolation without involving small farm-holders across the world as described by the CERES 2030 team based on meta-analysis of >100,000 research papers published globally. Change of mind-set of researchers as well as policy makers, development investors, extension agencies and the editors/publishers of the scientific journals is must to transform small farm-holders particularly in developing world. Blasting of compartmentalization for providing solutions to the farmers is urgently needed to provide integrated and holistic solutions to the farmers. Changing mind-set of all the stakeholders is a challenging task and parameters for scientific evaluations for scientists need to be changed by the research managers from research papers published to on-farm impacts achieved by introducing new products/knowledge.

Similarly, for overcoming compartmental solutions the funding agencies need to adopt a basic criterion along with involving small farm-holders for approval of the research proposals. For encouraging and promoting partnerships the World Bank aided projects like National Agriculture Technology Project (NATP) and National Agriculture Innovation Project (NAIP) in India adopted such criteria for approval. Building partnerships amongst different stakeholders through consortium is essential for providing holistic solutions and particularly corporates should be involved and their strength for networking as well as establishing backward and forward linkages to benefit farmers are essential. The approach proposed should be innovative, inclusive, integrated and impact oriented to provide sustainability, scalability, socially acceptable and synergistic by ensuring economic gain, equity, environment protection and efficient by promoting collective action, converging with different schemes and departments, cooperative consortium through consortium formation (4 ISECs approach).

Most important thing is to empower farmers with knowledge and enabling them to take right decisions based on new knowledge developed by the researchers as well as the market information to guide them for undertaking diversification. The existing gap in the extension systems/knowledge delivery systems in the diverse country like India must be eliminated by harnessing new scientific tools like IT, 5 G, IoT, GIS, RS, modelling and small farm-holders must be empowered. For increasing adoption of improved technologies/products by the small farm-holders "*Seeing is believing"* principle is a well-tested and validated method during scaling-up. It is of paramount importance to work with small farm-holders for participatory on-farm demonstration through highest rung of collaboration i.e. collegiate mode over cooperative, consultative and contractual mode of community participation.

The technologies/products to be provided must be demand driven based on the detailed needs assessment of the farmers and solutions must be holistic i.e. end to end and not only recommendations as against supply driven solutions as generally provided by the researchers. The on-farm *"Seeing is believing*" demonstrations must be at least half to one-acre plot size for each treatment and must be managed by small farm-holders and not by the research team. The researchers should empower the farmers to take right decisions and interventions for managing demonstrations. The researchers must adopt different methods of empowerment/capacity building for the farmers and the results as well as the interventions must be described by the farmers to other farmers during formal field/farmers' days or informal meetings. It is essential that to adopt *"Seeing is believing"* approach in the selected village there must be three to four participatory demonstrations.

Important thing is to maintain transparency in all operations, accounts, crop cutting experiments and evaluations must be done collectively by all the concerned partners and farmers. The evaluation and monitoring must be concurrent and not as a post-mortem activity and should be used as learning tool. The results should be publicised amongst policy makers, researchers, extension staff as well as farmers and consortium partners with clear SOPs to benefit the farmers. For farmers' meetings, Field Days, workshops, training events suitable policy makers should be involved for greater impact.

As the small farm-holders' livelihood systems are complex, we need to ensure that for improving livelihoods and incomes for small fam-holders allied sector activities for livelihoods also must be integrated in to scaling-up initiatives. Selection of allied sector activities should be based on needs, availability of market as well as raw material and such activities need to be promoted collectively through SHGs, FPOs, etc. Empowerment of women, youths for undertaking IGAs is critical and suitable consortium partner must be identified for providing quality trainings holistically ensuring credit as well as market for the produce.

In order to achieve the SDGs of zero hunger, no poverty and wellbeing through balanced nutrition of people in the country/region scaling-up of new technologies, knowledge, products through building partnerships adopting 4 ISECs model to build consortium is essential. Changing mind-set of stakeholders particularly researchers and policy makers is a must and efforts must be made to achieve this for meeting the SDG goals.

Acknowledgement We gratefully acknowledge the help of team of scientists, all our partners involved in the scaling-up initiatives in different countries and most importantly the policy makers for putting enabling policies in place for scaling-up and farmers who readily conducted participatory trials and shared all the information for analysis which is used in this chapter.

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