S. P. Wani · K. V. Raju *Editors*

Community and Climate Resilience in the Semi-Arid Tropics

A Journey of Innovation

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Foreword

As we progress through the twenty-first century, the great challenge for humanity, of maintaining food and nutritional security, grows along with the Earth's population, the pressure on natural resources and climate change. This is particularly the case in Asia and Africa. Declining per capita the availability of water and land resources is threatening our ability to feed a growing human population, which is expected to reach over 9 billion by 2025. In India, the per capita water availability in 2011 has decreased to 1,545 cubic metres against the international threshold for water stress of 1,700 cubic metres. The National Institute of Hydrology estimates India's utilisable per capita water availability at just 938 cubic metres in 2010 and expects this to drop to 814 cubic metres by 2025.

Rainfed agriculture occupies 80% of the global arable land and contributes half the global food basket. While climate variability, resulting in droughts and floods, is a major driver of food insecurity in Asia and Africa, rainfed agriculture must continue to adapt in managing the inherent risks in food systems. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and our partners have found, through meta-analysis of watershed programmes in India, that rainfed agriculture in India is quietly revolutionising and that huge scope exists to enhance further the impacts of the watershed programmes – only 32% watershed performed above average.

On-station research at the ICRISAT has demonstrated over many years that the productivity of rainfed agriculture can be enhanced three- to fivefold over current yields through an integrated watershed management (IWM) approach. However, scaling-up adoption of IWM practices had been negligible despite the widespread on-farm demonstrations conducted in the States of Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh.

An adoption survey undertaken in 1997 by a multidisciplinary team of scientists at the ICRISAT demonstrated the real potential of IWM approaches on major Indian soils (Vertic Inceptisols) covering 60 million ha. Subsequently in 1999, a pilot study was developed and implemented in Kothapally village (Adarsha Watershed), Telangana State, to demonstrate an innovative model of partnership. With the Kothapally community, the ICRISAT partnered with the state government, non-government organisations (NGOs), national research institutions such as the National Remote Sensing Centre (NRSC) and the Indian Council of Agricultural Research-Central Research Institute for dryland Agriculture (ICAR-CRIDA) and private sector companies to plan the implementation and monitoring of various watershed interventions.

A critical principle of the Kothapally experience was that beneficiaries paid in cash or in kind for the interventions that they received directly. The active participation of women and youth in watershed development and income-generating activities was essential. The two-decade experience in Adarsha Watershed at Kothapally (1999–2018) has resulted in accumulated lessons to guide India in its policies of watershed development and management at the national level.

This book, entitled *Community and Climate Resilience in Semi-arid Tropics*, is a substantial contribution by an ICRISAT-led consortium in the area of integrated watershed management that benefits smallholder communities in India. While it reports on benefits to millions of farmers in India, the flow-on impacts can already be seen in China, Thailand and Vietnam. This impressive contribution articulates scientific and policy measures for scaling-up appropriate community-based institutions and market linkages through public-private partnerships. The journey of Adarsha Watershed, Kothapally, serves as a lighthouse for guiding the development of rainfed areas in Asia and Africa.

I personally applaud Dr. S. P. Wani and Dr. K. V. Raju – who are not only the book's editors but also key leaders and implementors in the Kothapally story – for their meticulous efforts in bringing this book to publication. The same commendation goes to the chapter authors, most of whom worked in the fields with the Kothapally farmers and their community over the past decade. I am sure that this book will serve as a very valuable resource for development agencies, policymakers, development investors, students and researchers.

I am particularly proud to see this publication from the ICRISAT and partners that documents how to enact ICRISAT's message of 'from science of discovery to science of delivery'. This publication reports good science, great impacts and, critically, their connections and lessons to improve our own practices in research. Well done to all the contributors, including our farmer and community partners in Kothapally.

Director General, ICRISAT Peter Carberry
Hyderabad, India

Acknowledgements

We are very much thankful to all the stakeholders and consortium partners whose dedicated efforts made the Kothapally watershed as *Adarsha*, meaning a model watershed which served as lamppost for the development of watershed approach in India and parts of Asia, and to the tireless efforts of the dedicated team of scientists who initiated watershed research at the ICRISAT in 1976 and put up a strong foundation for watershed research in the institute and in India and the multidisciplinary team of scientist, namely Drs. P. K. Joshi, G. Algarsamy, T. J. Rego, Piara Singh and P. Pathak along with Editor S. P. Wani who initiated a multidisciplinary approach for watershed development at ICRISAT Center, Patancheru, based on the learnings from the adoption study undertaken in on-farm watersheds in Madhya Pradesh and Maharashtra. We sincerely acknowledge them as the team's efforts have showcased the success of integrated approach to the donors and policy-makers.

The unstinted support and efforts of Mrs. Rani Kumudini, IAS, Collector of Ranga Reddy District, is gratefully acknowledged as without her confidence and support, the journey of innovation in Kothapally would not have started as such. The financial support for this initiative from the Government of India through Drought Prone Area Programme (DPAP) through Government of Andhra Pradesh and also from the Asian Development Bank (ADB), Manila, Philippines (RETA 5812), enabled the team to establish the innovative pilot watershed and also piloted in other benchmark locations in India, Thailand, Vietnam and China. The support from the directors, DPAP, Ranga Reddy District, Government of Andhra Pradesh, since 1999 is acknowledged, especially the unstinted support by Dr. T. K. Sreedevi, Director, DPAP, Ranga Reddy District, who initiated the scaling up of the pilot in surrounding watersheds.

The consortium partners, namely Dr. H. P. Singh, Director, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad; Dr. R. Navalgund, Director, National Remote Sensing Agency (NRSA), Hyderabad; Dr. Shantha Sinha, CEO, MV Foundation, Hyderabad; and their team of scientists, contributed a lot in the development of *Adarsha* Watershed Kothapally. The farmers and the Watershed Association, the Watershed Committee and the self-help groups (SHGs) continually reposed their faith and provided all the support for evaluating new approaches and technologies as suggested by the scientists. The ICRISAT staff, notably Raghvendra Sudi, L. Jangwad, M. Babu Rao, D. S. Prasad Rao, Ch. Srinivas Rao, G. Pardhasardhy, K. N. V Satyanarayana, N. Sri Lakshmi, Y. Prabhakar Rao, Suchita Vithalani, M. Irsha and, late K. Srinivas, worked tirelessly to collect data, document results, prepare literature, organise visits and conduct training courses during the journey of innovation. During the process of innovation, several scientists, namely Drs. Joshi, P. K., Rego, T. J., Piara Singh, Pathak, P., Kesava Rao A. V. R., worked as a team initially, and later, other scientists who have contributed chapters worked and documented the learnings; their support and help are gratefully acknowledged. The unstinted support by Director General Shawki Barghouti and later Dr. William D. Dar who took the challenge to take the watershed research on farmers' fields was very critical and is thankfully acknowledged. During the journey of Kothapally Watershed, a large number of scientists and staff from the ICRISAT have contributed directly and indirectly, and their contributions are acknowledged. Last but not the least, the community in Kothapally always helped and ensured proper conduct of trials, without which, this book compilation would not be possible. We are highly thankful to all the chapter writers and other staff who have put together the learnings. We also thank Dr. Peter Carberry, Director General, ICRISAT, for writing the Foreword of this book.

S. P. Wani and K. V. Raju

Contents

Chapter 1
Need for Community Empowerment and Climate Resilience in the Semi-arid Tropics

S. P. Wani and K. V. Raju

Abstract The vast semi-arid tropics (SAT) area covering 120 million ha in Asia is also the home for 852 million poor and 644 million food and nutrition insecure people. Growing water scarcity and increasing land degradation in the dryland SAT areas are further aggravated due to impacts of climate change. In order to transform the dryland areas, innovative integrated watershed management model was developed and piloted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in partnership through consortium approach, convergence with the government programs, collective action, and cooperation (4Cs) approach. How resilience of the communities was built through integrated watershed approach encompassing the livelihoods is described fully. The outlines of different chapters indicate briefly the strategy and various aspects including the process adopted and its impacts are covered.

Keywords Climate resilience · Integrated management · Watershed development · Drylad agriculture

1.1 Introduction

The semi-arid tropics (SAT), which covers 120 million ha area in Asia largely, is the home for the 852 million of poor people and 644 million nutritionally insecure people in Asia. Although, the SAT is blessed with weather where three crops can be grown, however, as water is the most scare resource in the region, large areas are cultivated by the farmers only with a single crop in a year. The impacts of climate change are also felt severe in this region largely because of increasing temperatures and growing water scarcity, which further get complicated with small land holders

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and resource-poor farmers, who have neither access to the technologies to adapt to the impacts of climate change nor the financial resources to cope with. Under such circumstances, there is an urgent need to develop a model for adapting to the impacts of climate change and cope with the growing water scarcity, land degradation, and food production for sustainable development. To address the issue of improving the livelihoods of dryland farmers in the SAT, a model was planned and initiated in 1995 to harness the potential of dryland agriculture to bridge the yield gaps between the current farmers' yields and achievable potential.

The model, which was a holistic systems approach for enhancing crop productivity, was initiated on the ICRISAT campus in 1995. Based on the results of integrated watershed approach through multidisciplinary research by bridging the yield gaps, we demonstrated the potential to grow two crops successfully on large plots of Vertic Inceptisols. The approach was scaled up further in a 500 ha watershed in erstwhile Ranga Reddy district of Andhra Pradesh (Kothapally) (currently it is in Sangareddy District of Telangana state after the bifurcation of the state in 2014).

1.2 Focus of the Study

The focus of this study was on developing integrated holistic approach for harnessing the potential of rain-fed agriculture. In this approach, rainwater management through harvesting and recharging the groundwater was used as an entry point activity for increasing the productivity for the farmers through enhanced water use efficiency. To provide holistic and integrated solutions, the approach of consortium through building partnerships with different stakeholders like different research institutions (state, national, and international), development departments like Department of Agriculture, Department of Animal Husbandry, non-government organizations (NGOs), and Farmers' Organizations Community-based Organizations (CBOs), along with market linkages through private companies was adopted.

The focus of this initiative was on the 4Cs, namely, consortium, as explained above; convergence of various activities and schemes operated in the area; collective action of the farmers; and most importantly, the capacity building of the stakeholders mainly for adopting integrated approach in place of compartmental approach for providing solutions to the farmers. This particular approach of the 4Cs was expected to benefit the stakeholders through enhanced efficiency, environment protection, economic gain, and addressing the issues of equity (4Es) as the power of these 4Cs was far larger than the financial capital power. With this focus in mind, bridging the yield gaps for increasing the production and improving the livelihoods of the farmers through minimum environment damage for sustainable development was promoted through enhanced natural resource use efficiency. The success of this initiative was largely because of providing holistic solutions in a timely manner to the farmers and converging agriculture and allied sector activities for increasing the incomes of the farmers through capacity building; farmers got empowered and were wined away from the free inputs syndrome to ensure that the ownership is built amongst the farmers that will result into the demand-driven supply of knowledge/technologies/inputs by researchers and development agencies rather than the supply-driven approach, which was not successful.

The main focus of this book is to document the learnings and share with other practitioners with an aim of scaling up in large areas to benefit millions of farmers in the country and other regions of the SAT in Asia and Africa. The success which we have recorded is not without trekking the difficult path dealing with communities who were accustomed to free dole outs and always were expecting something to get from the project as a passive partner in the initiative to a participatory approach for development, ensuring that they contribute in cash or kind to demonstrate/to take ownership and also ensuring that demand-driven-proven technologies are piloted to benefit the farmers. With this in focus for this book, the outline has been adopted as mentioned below.

1.3 Outline of the Study

For this innovative experiment of building the resilience of the community for climate change through innovative integrated watershed model, the chapters have been put in a simplistic manner for the reader to understand the whole process as well as the challenges and how the opportunities are harnessed resulting into impacts to benefit the farmers. Once the pilot was successful, it generated the demand from the surrounding villages because of the tangible economic benefits to the farmers, which clearly proved our first hypothesis that anything given free to the community does not get valued appropriately and in the process even the best of the technologies/products fail, and also the researchers/development workers cannot push the supply-driven technologies/products to the farmers as farmers are contributing and always look for value or satisfy themselves for getting tangible benefits from the technologies/products which are to be piloted.

- The first chapter deals with the need for community empowerment and climate resilience and the purpose of the study; provides the outline of the material practiced in a free flow for readers to understand; and describes in detail the methods used/adopted along with the impacts, the observations, and what ensured the success of the model.
- The second chapter deals with the farmers and ICRISAT's journey of innovation about how the Kothapally model was conceived based on the learnings of low adoption of on-farm watershed work, which was done through contractual participation of community and results from on-station multidisciplinary holistic experiments which enabled us to grow two crops without any supplemental irrigation on light black soils (Vertic Inceptisols), using sequential crops like soybean followed by chickpea and intercropping soybean with medium-duration pigeon pea using landform treatments for enhancing the harvesting of soil moisture storage and excess runoff water, which was used for recharging the

groundwater. The main focus of ICRISAT's journey is how the demand for a holistic and integrated approach emerged from the policy makers?.

- Based on this outcome and strategy, first and foremost, Chap. 3, titled "Climate Variability and Projected Change," explains the impacts of climate change and climate variability in the target eco-regions for which long-term weather data sets from the district were used and also presents the results. Once climate variability and its impact on the length of the growing period (LGP) was understood, the appropriate cropping systems were planned and piloted to address the issues of enhancing agricultural incomes in the Adarsha watershed, Kothapally.
- In addition to climate variability, soil health mapping was identified as an important constraint as farmers were not aware what they needed to apply for different crops based on the nutrient content in their soils. The results of soil health mapping in terms of physical, chemical, and biological properties was taken up and the results are presented in Chap. 4, along with providing an integrated soil management strategy. Soil-test-based nutrient management benefited the farmers through enhanced rainwater-use efficiency increasing the productivity per unit of rainfall, which really benefitted the farmers.
- Chapter 5 on rainwater management and eco-system services through integrated watershed management covers components of water balance and how these are affected due to integrated watershed management?. Integrated rainwater management interventions of in situ moisture conservation as well as ex situ rainwater harvesting for groundwater recharge as well as to be used for supplemental irrigation when rainwater is harvested within the field boundaries through integrated watershed development. This chapter also covers a number of ecosystem services provided through community participation, such as, provisioning, regulating, cultural/spiritual, and supporting.
- Chapter 6 deals with various cropping patterns/systems and crop intensification due to increased water availability in the watershed and also presents the results. Evaluation of improved crop cultivars as well as crop diversification using high-value crops with increased water availability to benefit farming families with enhanced incomes results are reported. The new cropping systems impacted changes in the cropping pattern and also increased net incomes for the farmers as well as sustainable use of natural resources. The results of these studies are presented in Chap. 6.
- In Chapter 7, the impacts of integrated watershed management are assessed using the economic surplus method. The results are reported as impacts covering social, economic, and biophysical effects that addressed natural resource issues for sustainable development, and social institutional impacts researched for the success of various initiatives resulting in tangible economic benefits to the community members are reported over the years from 1999 to 2016. The value chain for the agricultural products as well as allied sectors has been studied and proposed. This is the forward-looking approach as once the production and incomes have increased for the farmers, definitely they will have appetite for adopting value chain approach through collectivization, etc. The approach and possible

potential value chains are discussed along with market linkages and strategies to minimize the post-harvest losses as discussed in Chap. 7.

- Chapter 8 deals with the use of digital technologies, including the implementation of satellite imageries since 1998, the land-use pattern , and the results of changes in the land-use pattern and the crop inventory. For geotagging the fields, a cell-phone-based app was developed and used successfully to map the farms along with the farmers' resource inventory, waterbodies, and land-use patterns during three seasons of the year.
- Chapter 9 deals with empowerment of women through income-generating micro enterprises, specifically through self-help groups (SHGs), in order to ensure their involvement in watershed activities. A number of income-generating initiatives, including the safe drinking water schemes and how over the years community evolved and took the ownership and initiative for new and improved lifestyles, are also reported. The role of empowered women in the sustenance of various watershed interventions is critical and a must for the success of sustainable management of integrated watershed approach.
- Chapter 10 deals with rural institutional governance mechanisms and how infrastructure (hardware as well as soft institutional mechanisms) has been developed and is being continued in the project area, although the project was withdrawn in 2003. The role of empowered rural institutions in the governance of watershed activities in this chapter provides the nuances of participatory and effective management of successful innovative watershed development model.
- The final chapter summarizes the whole concept of how the initiative was conceived based on a strategic research conducted on campus at ICRISAT and piloted in a village of 500 ha through community participation. Various interventions, the methods adopted, the institutional arrangements made, and the principle on which the project worked resulting into tangible economic benefits not only for the farmers but also for the team members, development workers, and development investors, which resulted in scaling up of this model from one village to thousands of villages in the country and also changed the watershed development guidelines at the national level.

Chapter 2
Adarsha Watershed, Kothapally, ICRISAT's Innovative Journey: Why, How and What?

S. P. Wani and K. V. Raju

Abstract The ICRISAT was working in watershed development since 1972 with Vertisol technology and piloted on farmers' fields in different agro-eco regions. However, it was not scaled up/adopted by the farmers in spite of the involvement of concerned state government agencies. In 1995, a multidisciplinary team of scientists' assessment of watershed studies in different agro-eco region pilot/benchmark sites indicated low adoption of Vertisol technology, although demonstrated on farmers' fields, was due to poor participation of the farmers as the approach was contractual participation and a one-size-fits-all approach was adopted. The new multidisciplinary experiment on station in Vertic Inceptisols demonstrated that using integrated watershed management approach these soils can be cropped during two seasons. Based on the demand of the district officials, Kothapally watershed was selected based on severe water scarcity, extent of rain-fed areas and the community's need and willingness to participate in the programme through full ownership/participation. The journey of innovation in Kothapally and how it became an exemplary (Adarsha) watershed with different strategies adopted are described. It evolved by the consortium of research institutions, government department, non-government organization and the farmers' community. The drivers of success are identified and the complete journey of innovation through a detailed timeline is covered in this chapter.

Keywords Holistic watershed · Innovation · Community empowerment · Watershed development · Climate change · Resilience · Drivers of success

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2.1 Background

The genesis of Adarsha watershed, Kothapally, can be traced back to the efforts of the team of scientists who realized that in spite of the long history of the watershed research by ICRISAT team since 1972 and also taking it to on-farm locations in different agro-climatic zones covering Andhra Pradesh, Karnataka, Maharashtra and Madhya Pradesh, the technology did not reach to the farmers in these states. If the technology has not benefitted the farmers in spite of strategic research on station and piloting in the on-farm sites, there was an urgent need felt to understand the reasons for the low adoption of such a technology which can double the farmers' incomes. To a certain extent why the study of Adarsha watershed, Kothapally, is covered in Chap. 1 in brief indicates the broad objective of this book. In this chapter, we dwell in detail on the genesis of the study; why it was undertaken; what were the compelling reasons to initiate this study and then how it evolved into a new strategic multidisciplinary study on the research station, piloting it to on-farm situation by changing the rules of the game of on-farm research?.

Further, what we did to take it to scaling up through adoption of the consortium approach to converge agriculture and related activities through collective action and capacity-building approach are reported. This chapter describes in detail the golden circle for integrated watershed approach of why, how and what.

2.2 Genesis of Adarsha Watershed, Kothapally, Why?

2.2.1 The Genesis of Adarsha Watershed

2.2.1.1 Rediscovering the Learning Cycle

The ICRISAT had undertaken watershed development approach since 1972 particularly for Vertisols (deep black cotton soils) which were left fallow during the rainy season, and farmers cultivated these soils on stored soil moisture during the post-rainy season (*rabi* season). Actual surveys of annual yields from farmers' fields in selected villages of peninsular India have been reported to be as follows:

Sorghum, (*Sorghum* bicolor)
Wheat (*Tritricum durum* Desf.)
Chickpea (*Cicer arietinum)*
Safflower (*Carthamus tinctorius* L.)
Chillies, dry (*Capsicum annuum* L.).

The reason for fallowing during the rainy season was as a risk mitigation strategy (Binswanger et al. 1980) to alleviate the waterlogging problem associated with Vertisols (Kanwar 1979; El-Swaify et al. 1985). The technology developed was called "Vertisol technology", which was a holistic farming systems approach, by following the watershed concept. The technology is comprised of several components, viz. contour field bunding; summer cultivation of soil taking advantage of off-season rains; broad bed and furrow (BBF) for addressing the issue of alleviating waterlogging as well as storing more rainwater as soil moisture (green water); dry seeding of seeds for most crops, except oil seed crops like groundnut (*Arachis hypogea*) and soybean (*Glycine max*) and small grains like millets (*Pennisetum glaucum*) and setaria (*Setaria italica*); balanced nutrient management; adoption of intercropping or sequential cropping to ensure double cropping (Krantz et al. 1976); rainwater harvesting; and integrated crop management, including pest management along with supplemental irrigation using harvested rainwater in the farm pond (Kampen 1982; El-Swaify et al. 1985). Long-term experiments conducted at ICRISAT centre, Patancheru, since 1976 clearly demonstrated that by adopting this technology using a number of crop combinations in intercropped as well as sequential crops, these soils can be cropped during rainy (*kharif*) and post-rainy (*rab*i) seasons even without any supplemental irrigation in assured rainfall regions. This path-breaking demonstration on farmers' field-scale (large) plots demonstrated that current farmers' crop yields were lower by four- to fivefolds as compared to the achievable crop yields under pure rain-fed situation. As per the farmers' practice (applying farm yard manure at 5 t/ha once in 2 years (Wani et al. 2003a)), cultivation of plots during the rainy season to keep plot weed-free and growing traditional *rabi* crops such as sorghum, safflower and chickpea on stored soil moisture yielded 1.1 t/ha as compared to 5.2 t/ha with improved management practice as mentioned above (Fig. 2.1, Tables 2.1, 2.2 and 2.3; Kampen 1982; Wani et al. 2001b, 2002b, 2003a). These levels reported from farmers' fields, sharply contrast with projected yields of up to 6 Mg/ha reported from research on several crops based on effective use of potentially available water (Kampen 1982; Swindale 1982). Not only the crop yields were higher by four- to five folds in improved management plots as compared to farmers' practice plot, but substantial improvement in soil physical, chemical and biological

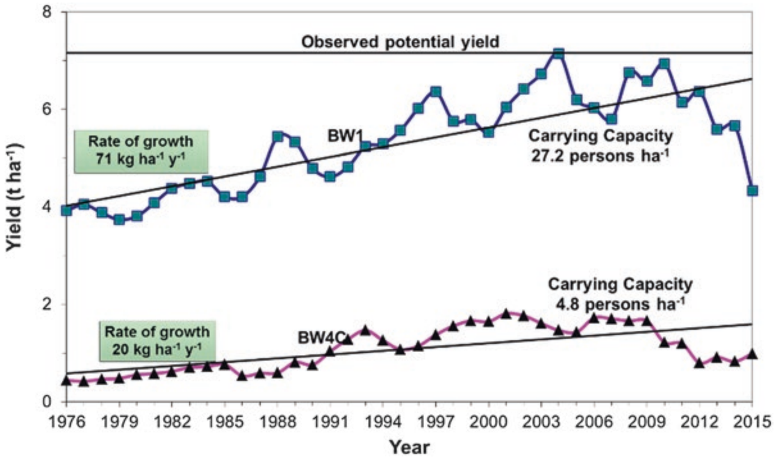

Fig. 2.1 Crop productivity of improved and traditional farmer's practice plots from long-term experiment at Heritage Watersheds at ICRISAT since 1976 (Source: ICRISAT 2017)

Table 2.1 Grain yields[a] (kg/ha) and gross monetary returns[b] (Rs/ha) for several crops at Kanzara village in 1979–1980

Watershed no.	Cropping system	Soil management	Sorghum	Pigeon pea	Cotton	Groundnut	Black gram	Gross value
Improved technology								
1	Sorghum/pigeon pea	Beds	2000	200	–	–	–	2630
1	Sorghum/pigeon pea	Flat	1470	210	–	–	–	2100
1	Cotton/sorghum/pigeon pea	Beds	760	60	630	–	–	3382
1	Cotton/sorghum/pigeon pea	Flat	560	60	490	–	–	2633
Existing technology[d]								
1	Cotton/sorghum/pigeon pea	Flat	20	20	180	–	–	767
1	Cotton/black gram	Flat	–	–	250	–	60	1112
Improved technology								
2	Sole groundnut	Beds	–	–	–	670	–	2177
2	Sorghum/pigeon pea	Beds	1470	200	–	–	–	2073

[a]The yields are based on small samples; actual threshing floor yields were somewhat (5–10%) lower

[b]The momentary values are based on the following prices at harvest time; sorghum Rs 105/100 kg, cotton Rs 385/100 kg, pigeon pea Rs 265/100 kg, groundnut Rs 325/100 kg, black gram Rs 250/100 kg

[c]"Improved" technology implies the use of recommended agricultural techniques in terms of seed, fertilizers, weed and insect control; existing: technology represents examples of the productivity attained with practices that are presently most common in the region

[d]Estimates of yields in adjacent fields (Source: Kampen 1982)

Table 2.2 Grain yields from a maize/pigeon pea intercrop system and a maize-chickpea sequential system compared with traditional rainy season fallow from deep Vertisol operation-scale watersheds at ICRISAT centre

	Grain yields (mg/ha)				
Cropping system	1976–1977	1977–1978	1978–1979	1980–1981	Mean
Maize/pigeon pea intercrop system					
Maize	3.29	2.81	2.14	2.92	2.79
Pigeon pea	0.78	1.32	1.17	0.97	1.06
Maize-chickpea sequential system					
Maize	3.12	3.34	2.15	4.18	3.20
Chickpea	0.65	1.13	1.34	0.79	0.98
Traditional fallow and single post-rainy season crop					
Chickpea	0.54	0.86	0.53	0.60	0.63
Sorghum	0.44	0.38	0.55	0.56	0.48

Source: El-Swaify et al. (1985)

Table 2.3 Physical properties of semi-arid tropical Vertisols under improved and conventional systems in a watershed at ICRISAT centre, Patancheru, India

Soil textural properties			
Texture	Improved system	Traditional system	SEM
Clay (%)	51	46	0.985
Silt (%)	22	22	0.896
Fine sand (%)	15	15	1.089
Coarse sand (%)	12	17	0.741
Gravel (%)	5	15	2.102
Hydrological properties			
Moisture retention (g g^{-1}) of 0–10 cm depth at 0.33 bar	0.35	0.33	
Moisture retention (g g^{-1}) of 0–10 cm depth at 15 bar	0.22	0.20	
Cum. infiltration in first 1 h (mm)	347	265	20.6
Sorptivity (mm $h^{-1/2}$)	121	88	14.6

Source: Pathak et al. (2011)

properties was also observed (Tables 2.4, 2.5a and 2.5b; Wani et al. 2003a). Similar results were observed in different studies during the same period. The success of watershed management largely depended on the community's participation. In a review (Joshi et al. 2000, 2008; Kerr et al. 2000) on the watershed projects in India, it was observed that most watershed projects could not address the issues of equity for benefits, participation of community scaling-up approaches, monitoring and evaluation measures. Moreover, most of these projects relied heavily on government investments. Also, most projects were structures driven (rainwater harvesting and soil conservation structures) and failed to address the issue of efficient use of conserved natural resources (soil and water) for translating them into increased systems productivity on large areas owned by smallholders mainly due to lack of technical support to such projects implemented by NGOs (Wani et al. 2001b).

Table 2.4 Biological and chemical properties of semi-arid tropical Vertisols under improved and conventional systems in a watershed at ICRISAT centre, Patancheru, India

Properties	System	Soil depth (cm)	
Soil respiration	Improved	723	342
(kg C ha^{-1})	Conventional	260	98
Microbial biomass	Improved	2676	2137
(kg C ha^{-1})	Conventional	1462	1088
Organic carbon	Improved	27.4	19.4
(t C ha^{-1})	Conventional	21.4	18.1
Mineral N	Improved	28.2	10.3
(kg N ha^{-1})	Conventional	15.4	26.0
Net N mineralization	Improved	−3.3	−6.3
	Conventional	32.6	15.4
Microbial biomass N	Improved	86.4	39.2
(kg N ha^{-1})	Conventional	42.1	25.8
Non-microbial organic N	Improved	2569	1879
(kg N ha^{-1})	Conventional	2218	1832
Total N	Improved	2684	1928
(kg N ha^{-1})	Conventional	2276	1884

Source: Wani et al. (2003a)

Table 2.5a Grain yield under soybean/pigeon pea intercrop and soybean-chickpea sequential cropping system in a Vertic Inceptisol watershed at ICRISAT, 1995–1996 to 2003–2004

Soil depth	Mean grain yield (kg ha^{-1})					
	Improved	Traditional	Improved	Traditional	Improved	Traditional
	Soybean		Pigeon pea		Soybean+pigeon pea	
Medium deep	1130	1150	920	940	2060	2080
Shallow	1060	1040	950	850	2010	1890
	Soybean		Chickpea		Soybean+chickpea	
Medium deep	1530	1450	1050	880	2570	2340
Shallow	1380	1350	640	560	2000	1930

Source: Singh et al. (1999)

Table 2.5b Grain yield under soybean/pigeon pea intercrop and maize-safflower sequential cropping system in a Vertic Inceptisol watershed at ICRISAT, 2004–2005 to 2011–2012

Soil depth	Mean grain yield (kg ha^{-1})					
	Improved	Traditional	Improved	Traditional	Improved	Traditional
	Soybean		Pigeon pea		Soybean + pigeon pea	
Medium deep	1159	1080	918	832	2132	1962
Shallow	1028	856	701	590	1795	1501
	Maize		Safflower		Maize + Safflower	
Medium deep	4901	4623	864	682	5765	5305
Shallow	4301	3437	635	441	4936	3878

Source: Singh et al. (1999)

2.3 On-Farm Evaluation of Watershed Technologies (Vertisol Technology)

Following the excellent results observed in long-term on-station plots, scientists decided to take this technology package for on-farm evaluation in Andhra Pradesh, Karnataka, Madhya Pradesh and Maharashtra. Field-scale watersheds were selected and with the farmers contracts were made for undertaking the demonstration of Vertisol technology as a package comprising the components mentioned above as a holistic system. Although, the proposed approach was a holistic farming system approach, the implementation was not truly holistic. ICRISAT staff were posted at sites to collect all data as well as proper implementation of all the components of the Vertisol technology. During the demonstration phase the results were excellent as farmers could grow two crops and their family incomes increased more than two-folds (Walker et al. 1983) and also generated employment for longer period for the family members as well as hired labourers (Table 2.4). Once the technology was demonstrated for 4–5 years, scientists withdrew the technical support as well as ICRISAT staff who used to undertake implementation of various activities as planned. It was anticipated that the farmers on whose fields the technology has been demonstrated and also to others disseminated by conducting Field Days the technology adoption would increase, as economically the technology was excellent with more than 100% increase in incomes and government departments in the states were also associated with the demonstrations. There were sporadic reports about non-functioning of Vertisol technology package as such, and it was thought that the technology which is suitable for deep black cotton soils covering 12 million ha in India which are prone to waterlogging was applied by the farmers/officers/researchers to inappropriate adoption zone (shallow black soils with less rainfall, etc.), and that's why such reports were emerging. At the same time, the on-station demonstration plots were showing good successful results over a long period.

2.3.1 Revisit to On-Farm Watersheds to Understand Low Adoption of Technologies

In 1995, under a newly formed system project III dealing with medium rainfall zone, the multidisciplinary team of scientists (natural resource economist, soil physicist, land and water management scientist, agronomist and soil biology cum plant nutrition scientist) decided to assess the reasons for poor adoption of Vertisol technology. The team visited Raisen Watershed in Madhya Pradesh as well as Aadgaon Watershed in Maharashtra and interacted with the farmers who had participated in the on-farm demonstrations as well as scientists from the State Agriculture University and Water and Land Management Institute (WALMI) in Bhopal and Aurangabad. This was the first time that a multidisciplinary team of scientists from ICRISAT with local region scientists together interacted with the farmers 15 years after withdrawal of the project to understand the reasons for failure or low adoption of Vertisol technology in the regions where technology demonstrations were conducted.

The multidisciplinary team was unique as they were willing to learn afresh from the farmers the reasons for low adoption of technology. Their genuine urge to understand the reasons without any attachment with the technology helped to come out with the learnings based on the interaction with the farmers who undertook demonstrations as well as the surrounding farmers and the scientists working in the region. The results were eye opening for the team as lot of new learnings were emerging during the evening frank discussions amongst the team members from different perspectives. The purpose of the mission was not to find faults with the earlier thinking or implementation but a real urge to make the watershed technology (Vertisol technology) popular amongst the farmers to benefit them as evident from the strategic research in Heritage Watersheds at ICRISAT campus. The major findings indicated that even in the same regions which were selected for demonstrations, except improved seeds and fertilizers, other components of the technology were not even seen on any fields. Even field bunding, which was undertaken on contours, was demolished, and no rainwater harvesting in farm ponds, no summer cultivation, nor dry seeding was followed by any of the farmers. The team was surprised that no farmers were following the critical components of the technology except the improved seeds and fertilizers, which were more largely due to persuasion, and other incentives provided by the private companies. During the detailed discussions amongst the team members as well as documenting the process, it was observed that the approach adopted for conducting on-farm demonstrations was a contractual collaboration with the farmers as farmers were paid the charges for their land use, inputs were provided by the institute, all field operations were undertaken by the institute staff located on site and farmers were getting all the benefits of increased crop productivity, plus getting the attention and popularity in the village during the Field Days. This learning loop opened the eyes of the team and initiated the thinking how watersheds can be popularized and farmers could benefit from the technologies developed by the researchers?.

2.4 How Adarsha Watershed, Kothapally, Was Conceived?

2.4.1 Designing New Multidisciplinary Experiment for Technology Development for Vertic Inceptisols

After learning from the survey and looking at the long-term experiments conducted in the Heritage Watersheds, the team felt that the Vertisol technology application domain in India is only less than 12 million ha as many of Vertisols do not get waterlogged as they are in low rainfall zones or have a good drainage. However, in 60 million ha Vertic Inceptisols (shallow and medium deep black soils) in India, the institute has no technologies to demonstrate that two crops can be grown on these soils without supplemental irrigation. Equipped with the eye-opening revelations from the survey, availability of proven Vertisol technology and the need to develop technology to grow two crops on Vertic Inceptisols, the team started planning an experiment to demonstrate that even with 800 mm annual average rainfall on medium to shallow black soils, two crops can be grown with appropriate technologies and crop combinations. In addition to the learnings from the assessment survey and the need for developing suitable technology for unlocking the potential of Vertic Inceptisols, there was another important but compelling reason to join hands for a multidisciplinary experiment at ICRISAT centre. In the new organization, the NRM programme was leading three systems projects, and for assured medium rainfall zone PS III (production system III) project, the operational funds for the team of five scientists were very meagre with which it was not possible for the individual scientists to run independent research experiments.

With this background, the lead was taken to design a multidisciplinary experiment to develop technology for double cropping of shallow to medium depth black soils. The team started its search for a suitable site to be developed as a research scale watershed and zeroed on a field (BW 7) which had varying soil depth from 75 to 5–10 cm along the slope mimicking the real-world situation in the watersheds. The team designed the main treatment as soil depth (three depths, viz. deep, medium and shallow) and sub-treatment as landforms (two, viz. broad bed and furrows and flat on contour) and the sub-sub-treatment as cropping systems (two, viz. sequential soybean (later replaced with maize to avoid continuity of legumes) followed by chickpea and soybean intercropped with medium-duration pigeon pea). The team consulted a statistician to avoid the later complications to undertake analyses of data to test the designed hypotheses. Each scientist collected the needful data for their study from the same experiment. Once the team decided and finalized the design, it moved along to plant the first crop in 1995 in a newly started experiment in BW 7. As the team members were on board from the beginning, the team looked after the experiment regularly and many a times together to discuss and address the on-ground issues during the field visits. The main plots of soil depths were separated by contour bunding, and all the bunds were planted with *Gliricidia sepium* saplings to address the issue of low soil carbon content using the N-rich organic matter generated in the field. The crop residues were composted in the compost pits.

Automatic weather station near the field provided all daily weather data, and each main plot was equipped with automatic hydrological gauging station to monitor runoff and soil loss from the main plots. The excess rainwater was harvested in two farm ponds and all the waterways were fully grassed. All the operations were undertaken using the bullock-drawn *tropicultor*. The success was evident from the first season itself as the total system productivity was around 3–4 t per ha as against 0.5–0.8 t/ha on farmers' fields depending on soil depth without any supplemental irrigation (Singh et al. 1999, Tables 2.5a and 2.5b). Soon this became one of the best spots for the institute visitors to see the systems research with all the scientific data collected explaining various processes of rainwater management, runoff and groundwater recharge, crop growth parameters, productivity, integrated soil fertility management and soil biology and most importantly to manage green water (soil moisture) efficiently for enhancing crop productivity and profitability for the farmers while minimizing land degradation.

The team leader was interacting with the important visitors and also liaising with the government officials from the district (Ranga Reddy District in erstwhile Andhra Pradesh). During one of the visits, the officials from the Asian Development Bank, Manila, Philippines, visited ICRISAT and during the field visit, visited BW 7 integrated system's approach experiment during 1997–1998 when the experiment was already in third year. The excellent results demonstrating the technology to unlock the potential of rain-fed agriculture in the tropics attracted the attention of the ADB officials. During the field visit, the ADB officials enquired about scaling-up plans for the technology which is ripe to take to the farmers' fields. The team expressed their confidence but highlighted the scarcity of funds to take the technology to the on-farm testing. During the wrap-up meeting, the ADB officials indicated that the bank will be happy to support a scaling-up pilot for the BW 7 technology, which is matured enough in their opinion. The ADB asked the team and the institute to submit the proposal covering three countries with varying rainfall situations. This was the first sign of success of the multidisciplinary system's approach for the team which pushed their confidence to greater heights.

At the same time, the collector of Ranga Reddy district (Mrs. Rani Kumudini, IAS), with whom the team leader was liaising, requested the team's help to plan a watershed for the land to be allocated to 12–15 landless families in the district. The team decided to survey the available land and plan the watershed before distributing the *pattas* (land ownership papers) to the families. The team planned the common waterways, the contour bunds to divide the land into equal land parcels and a place for the farm pond. The mapped watershed plots were distributed by the government to the landless families, and a new way to manage rainfall in the common/wastelands in the state was introduced. Following this exercise then the collector requested to organize a training course for the watershed committees in the district at ICRISAT. During the inaugural session of the training course, the honourable minister of agriculture was the chief guest. After the inaugural session the minister visited the on-station watershed experiments along with the collector. During the lunch discussions, the honourable minister said, "you have excellent technologies on the station. You should demonstrate these technologies outside the compound of the institute. The government will be willing to provide the needed funding". The collector was told to take this initiative forward in the district and help the farmers with ICRISAT developed technologies.

Following these discussions, the collector asked ICRISAT team to select a 500 ha watershed in the district as per their choice and demonstrate the technologies on pilot scale. The government indicated that funding will be provided as per the needs. This was the second success for the team following the ADB's willingness to support the scaling-up initiative. The leadership deliberated the options and it was decided that if the scaling-up model has to be developed, then it would be better to work within the existing government system instead of taking the funding and developing a pilot which will again face the challenges of enabling institutional and policy with the government setup. As the ADB funding was on the horizon to undertake strategic research as well as cover the team's cost, a calculated risk was taken and indicated to the collector that normal funding for the watershed programme under the Drought Prone Area Programme (DPAP) needs to be provided for the pilot but with a caveat that being the pilot to be developed as a model, the new initiatives, approaches and implementation arrangements need to be permitted overriding the existing government guidelines which could be restrictive for new interventions. The district collector readily agreed to this approach and said "you will have all permissions to develop a model as you like and no questions will be asked by the officials for any deviations made to the existing policies". That's how a foundation for the new watershed model was laid by the ICRISAT and the district administration of the Ranga Reddy district under the leadership of the collector.

2.5 What We Did to Establish Adarsha Watershed, Kothapally?

Once we had these two offers for developing a model for the new watershed management approach from the undivided government of Andhra Pradesh and also from the ADB to demonstrate the integrated watershed management technology, the team moved ahead to plan and take up the challenge thrown at us by the honourable minister of agriculture of Andhra Pradesh.

2.5.1 Selection of Kothapally Watershed Based on the Learnings from the On-Farm Survey by the Multidisciplinary Team of Scientists

For selecting the watershed the team had followed a set of criteria such as:

maximum cultivable area in the village should be rain-fed and water scarcity should be the main concern of the villagers (demand driven) for developing agriculture;
poverty, which is directly associated with availability of water in rural India, should be there;
little area under irrigation using groundwater;
people should be willing to collaborate as per the terms;
good local leadership should be available;
the site should be accessible during the rainy season and a representative for the district/region in terms of soil type, rainfall, socioeconomic parameters and around ICRISAT campus so that visitors can be taken to the site as and when needed; etc.

Once the criteria were developed, a team of ICRISAT scientists along with the representative from the DPAP for the government of Andhra Pradesh visited a set of three villages around the ICRISAT campus. The three villages, viz. Kothapally, Parveda and Urella, in the Ranga Reddy district were evaluated based on the criteria. In each village after the transect walk with the villagers, a meeting was held with the villagers. The purpose of the visit of the team was elaborated, details of the project were discussed and people's feedback/reactions were noted. Based on the cumulative score of the team members, Kothapally was ranked as the first choice for developing a model, Urella was the second and Parveda village was the last one which, was a predominantly cotton-growing village with groundwater availability.

Once the first and second choices of villages were identified, again a second detailed consultation with all the villagers by conducting a village meeting was undertaken. During this meeting it was highlighted how their village has been selected as potential village for the project. However, the criteria of people's willingness to collaborate were retested by detailing the terms and conditions of the collaboration. It was made clear to the villagers that:

- In this project except knowledge and technical support by the team of scientists no other inputs will be provided by the project free of cost. Each participant in the project will have to contribute their share in cash or kind (by those farmers who cannot contribute upfront cash). *This was the first new parameter included in the project.*
- The whole village should be united as one as far as their project activities are concerned and political association with particular political party should not interfere in the project.
- The villagers will need to select unanimously the watershed committee (WC) members as per the criterion provided by the DPAP department officials within 2 weeks.
- The WC will have to be registered with the Department of Cooperatives, GoAP, and bank account has to be opened by the WC in the nearest bank.
- All payments for the watershed activities undertaken will be through bank cheque payments, and transparency will have to be maintained for all the expenses from the project as well as the contributions made by the members.
- Most importantly, whenever the team is visiting and a specified time is indicated, community members should be present on time as during the second meeting, in spite of fixing the time, people were to be called and gathered after the team arrived, which should not be the case in future.
- In future, no ICRISAT team member will accept tea, snacks, lunch or any favours from the villagers (*this was the second new parameter included in the process*) to avoid any misconception about favouritism shown by the project team for specific activities for the influential people in the village.

Once the agreement was reached on the modalities of collaboration, then Kothapally was finalized as the final site for the new model of integrated watershed development. This process was to ensure that the community members were proactively engaged from the inception phase of the project to avoid the mistake of contractual participatory research undertaken during the earlier phase of on-farm watershed development and ensure that the participation is at the highest order of collaborative participation as against the contractual, consultative or cooperative participation of the community. Once the community agreed to follow the project guidelines, the leader had promised the community in 1999 that if the community implement the proposed activities fully and wholeheartedly, we assure that the