Suhas P. Wani
K.V. Raju
Tapas Bhattacharyya *Editors*

Scaling-up Solutions for Farmers

Technology, Partnerships and Convergence

Springer

Scaling-up Solutions for Farmers

Suhas P. Wani • K. V. Raju
Tapas Bhattacharyya
Editors

Scaling-up Solutions for Farmers

Technology, Partnerships and Convergence

Springer

Editors
Suhas P. Wani
Secunderabad, Telangana, India

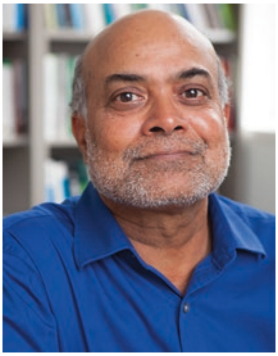
K. V. Raju
Bengaluru, Karnataka, India

Tapas Bhattacharyya
Nagpur, Maharashtra, India

ISBN 978-3-030-77934-4 ISBN 978-3-030-77935-1 (eBook)
https://doi.org/10.1007/978-3-030-77935-1

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

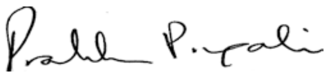


Meeting the sustainable development goals (SDGs) 1, 2 and 3 by 2030 for achieving poverty elimination, zero hunger and good health and human well-being is the greatest challenge faced by the global development community. With the increasing population, changing food habits due to increased incomes, impact of climate change and the recent COVID-19 pandemic, the challenge of achieving the SDGs has become even more daunting. Smallholder farms face an unduly larger share of the aforementioned risks and threats to agriculture and food security. Enhancing productivity growth and promoting sustainable intensification of small farms could contribute directly to the achievement of the SDGs. Scientific knowledge and technologies targeted towards small farm systems are available but have not been adopted widely due to poor extension and "last mile delivery" problems.

This book, *Scaling-up Solutions for the Farmers: Technologies, Partnerships and Convergence*, is a very timely publication that addresses the issues of delivery of new knowledge and technologies to smallholder farmers across the globe. Neglecting scaling-up of improved interventions by researchers resulted in the Death Valley of Impacts. In one of its articles in 2020, *Nature Food* reported that researchers worked in isolation without involving smallholder farmers and provided compartmental solutions resulting in low adoption and low impacts on poverty and food security. The CGIAR's numerous efforts in multi-disciplinary on-farm research are an exception and have often resulted in positive impacts for small farm households. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) adopted the tagline "Science with a Human face" and later "Science of Discovery to Science of Delivery", indicating the farmer-focused vision of the institute. A multidisciplinary watershed team from the institute adopted an open-minded and learning-cycle approach to assess low adoption of earlier technologies such as Vertisol by the farmers. This resulted in developing a multi-disciplinary and multi-institutional consortium approach which was piloted by farmers in *Adarsha* Watershed, Kothapally, AP, India. This consortium approach was scaled-up with financial support from several national and international donors in China, India, Philippines, Thailand and Vietnam. A similar consortium approach is now being initiated in South East Africa.

The chapters in this book are based on the learnings during scaling-up initiatives implemented by CGIAR institutes such as ICRISAT, IRRI, ICARDA, CIP and ICAR. The chapters cover holistically all the aspects of scaling-up technology based solutions for farmers through building partnerships, achieving convergence of schemes and departments to achieve sustainable impact on rural lives and livelihoods.

The editors have made a laudable effort in presenting an outstanding set of case studies of successful conduct of farm-based research for enhancing last mile delivery. The way-forward suggestions, based on the long experience of the consortium partners in different scaling-up initiatives, will definitely help scientists, students, development workers, policymakers and development investors alike. I appreciate the timely efforts of the editors and chapter authors who have put together this book and for sharing their learnings for the benefit of all the stakeholders involved in meeting the SDGs.



Cornell University, Ithaca, NY, USA Prabhu Pingali

Professor of Applied Economics, Director
Tata-Cornell Institute (TCI), New Delhi, India

Chair, ICRISAT Governing Board
Patancheru, Telangana, India

Foreword

I must first pay a special tribute to the coordinating editors, Dr. Suhas Wani, Dr. K.V. Raju, and Dr. Tapas Bhattacharya, for taking the initiative to produce this book, ***Scaling-up Solutions for Farmers: Technology, Partnerships, Convergence for Farmers.*** They have brought together leading institutions and renowned experts to collaborate on writing this very authoritative book.

In some ways, the title says it all, in terms of what is necessary for smallholder farmers in the drier regions of the world to create opportunities of improved social and economic livelihoods. For indeed that is a key goal of farmers in the tropical developing world – how to secure prosperity for their future generations. For many decades, in fact since the Green Revolution, scientific institutions and universities have been bringing new technologies and improved farming practices to the cultivators of the land. Indeed, new crop varieties, fertilizer technologies, crop protection breakthroughs, and improved water management systems have all contributed to the betterment of the food system in Asia, Africa, and Latin America.

However, agriculture is now facing new challenges in terms of environmental degradation, loss of biodiversity, depletion of soil nutrients and loss of organic matter, and climate change, as well as the effects of the COVID-19 pandemic. All these factors bring one word to mind – ***resilience***. It is therefore commendable that the authors of chapters have sought to underline the necessity of addressing crop diversity, soil quality, drought-resistant farming, conservation agriculture, and sustainable intensification with urgency going forward.

Of course, technologies will not succeed if farmers do not attain new skills, such as digital farming, and utilize value chains and the social-institutional infrastructure led not just by government but also by community-based organizations. Governments can provide the enabling environment in which farmers' organizations are empowered to attain highest levels of self-sufficiency, so as to take advantage of value chains, for example.

A highlight of this book is its focus on ***scaling-up***. The coordinating editors quite appropriately recognize that the outputs from the labs, field trials, experimental farms, and on-farm demonstration sites will only have impact if scaled up to meet the needs of thousands of farmers, collectively. This is a brave and daunting proposition, but one that is necessary if we are to witness the next high level of productivity gains, innovation, environmental sustainability, and socio-economic benefits in the farming sector.

I commend this book to practitioners, researchers, university students, agribusiness leaders, thought leaders, and government decision makers.

Professor, McGill University
Montreal, Canada

Chandra A. Madramootoo

Former Chair, ICRISAT Governing Board,
and President Honoraire, ICID
New Delhi, India

Foreword

This is a timely book addressing the challenges of scaling-up research products to benefit millions of farmers across the developing countries in Asia. The experience and learnings of many partners – International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Rice Research Institute (IRRI), International Center for Agriculture Research in the Dry Areas (ICARDA), International Potato Centre (CIP), Food and Agriculture Organization (FAO), Tamil Nadu Agricultural University, and ICAR-Indian Institute of Soil and Water Conservation – have been distilled into this book.

Increasing distress for the 500 million smallholder farmers globally is largely due to large yield gaps between the current farmers' yield and the achievable potential under a given environment. This situation arises primarily due to piecemeal solutions provided to the farmers as the emphasis was on increasing the productivity and not the profitability, increasing cost of inputs, low price realization for farm produce, and poor extension services for the farmers.

The CERES 2030 team had undertaken a meta-analysis based on more than 100,000 published papers/reports and highlighted that the main reasons poverty was not reducing across the globe was that scientists, except those associated with CGIAR network, do not work with smallholder farmers; farmers receive piecemeal solutions and lack access to markets.

ICRISAT focuses on the livelihoods of smallholder farmers through a value-chain approach giving primacy to market-oriented development. With a large footprint across many states in India and also neighbouring countries of China, Thailand and Vietnam, ICRISAT has partnered with national and international institutions, farmers' organizations, and the private sector to reach millions of farmers with science- and evidence-based approaches to improve profitability and ensure the sustainability of dryland farming.

Meeting the Sustainable Development Goals (SDGs) of No Poverty, Zero Hunger, and Good Health and Well-Being is a challenging task with increasing land degradation, reduced per capita land and water availability, changing food habits due to rising incomes, and the impacts of climate change. The lessons learnt over the years have been put together in this book to benefit researchers, policymakers, development investors, extension workers and students across the developing world. I congratulate the editors for bringing out this timely publication.

Jacqueline Hughes

Director General
ICRISAT
Hyderabad, Telangana, India

Preface

The greatest global challenge for humanity in the twenty-first century is to achieve food, nutrition and income security for an ever-growing population. More than 690 million people globally were still hungry in 2019, accounting for 8.9% of the world population – up by 10 million people in 1 year and by nearly 60 million in 5 years, a number which underscores the huge challenge for achieving the Zero Hunger target by 2030. Climate change is looming large and is threatening the smallholder farmer due to increased rainfall variability, occurrence of dry spells, and fluctuating temperatures, further affecting the existing poor crop yields. Large yield gaps between current farmers' yield and achievable potential yield are due to the Death Valley of Impacts as farmers lack updated knowledge. Most researchers worked in isolation without involving smallholder farmers and provided supply driven compartmental solutions which are not adopted by smallholder farmers. With all these challenges things around and occurrence of epidemic COVID-19 which has driven food crises as the pandemic's knock-on effects aggravated pre-existing drivers of hunger as per the new report by the UN's FAO and World Food program (WFP) which has identified 27 countries heading towards food crises. Achieving sustainable development goals (SDGs) addressing hunger, malnutrition and poverty is a great challenge.

To minimise distress for small farmholder farmers, scaling-up holistic solutions for farmers through improved science delivery by adopting partnerships, convergence and collective action and ensuring economic gain for the smallholder farmer, which are innovative, science-based, scalable and efficient through collectivisation, is the way forward. Value addition and ensuring market linkages for the farm produce along with reduced cost of cultivation using new science tools, knowledge and technologies developed by the researchers are all the more necessary. The use of appropriate knowledge delivery systems to reach 500 million smallholder farmers is a must to cross the Death Valley of Impacts.

This book, *Scaling-up Solutions for Farmers: Technologies, Partnerships and Convergence*, is based on the learnings obtained by a number of CGIAR centres in Asia and ICAR and various State Agricultural Universities (SAUs) in India. The learnings as well as the strategies adopted by the teams are boundary neutral and scalable in any part of the developing world. Recent meta-analysis undertaken by the CERES 2030 team based on more than100,000 published papers and reports stated that the researchers in CGIAR, ICAR and SAUs are working together to bring all-round happiness and prosperity to the smallholder farmer. This book will serve the needs of all stakeholders who are involved in improving livelihoods of smallholder farmers globally.

Secunderabad, Telangana, India — Suhas P. Wani

Bengaluru, Karnataka, India — K. V. Raju

Nagpur, Maharashtra, India — Tapas Bhattacharyya

Contents

Chapter 1
Death Valley of Impacts in Agriculture: Why and How to Cross It with Scaling-Up Strategy?

Suhas P. Wani

Abstract Achieving zero hunger, alleviating poverty, improving nutrition and wellbeing of growing population in Asia and Africa are the main challenges during the twenty-first century with increasing land degradation, decreasing per capita availability of land and water and impacts of the climate change. In spite of available game changing technologies small farm-holders in Asia are having large yield gaps mainly due to science of discovery without science of delivery. Lack of integrated approach, compartmentalization of solutions, poor delivery systems have resulted in low adoption of improved sustainable technologies. Business as usual won't help the farmers and there is an urgent need to transform agriculture as a business in India by adopting 4 ISECs (Innovative-integrated- scalable& sustainable environment-friendly& economically remunerative consortium-collective action) approach. Learnings from the number of scaling-up initiatives benefitting >10 million famers are documented which will enable to cross the "*Death Valley* of impacts" and benefit the small farm-holders in Asia and Africa ensuring food, nutrition and income security through climate resilient sustainable agriculture. The chapter describes in detail the reasons for existence of "*Death Valley*" of impacts, how it can be crossed and what needs to be done and explained all the three principles based on the several scaling-up initiatives undertaken benefitting millions of farmers in Asia. The results of meta-analysis undertaken by the CERES 2030 team also described as confirmatory statements for the learnings from scaling-up initiatives.

Keywords Impacts · Scaling-up · Integrated solutions · Demand-driven research · Partnerships · Consortium · Convergence · Collective action · Capacity building

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

S. P. Wani et al. (eds.), *Scaling-up Solutions for Farmers*,
https://doi.org/10.1007/978-3-030-77935-1_1

1.1 Challenges of Agriculture Development in Developing Countries

1.1.1 Need for Increased Food Production to Meet the Food Demand for Growing Population

The greatest challenge in the twenty-first century for the humankind is to have food (SDG 2- Zero hunger) and nutrition security (SDG 3- good health and well-being) along with income security (SDG 1- Poverty reduction) as more than 690 million people globally were still hungry in 2019, accounting 8.9% of the world population-up by 10 million people in 1 year and by nearly 60 million in 5 years, a number which underscores the huge challenge for achieving the Zero Hunger target by 2030 (FAO, IFAD, UNICEF, WFP and WHO 2020). New report by the UN's FAO and World Food program (WFP) has identified 27 countries heading for Covid 19-driven food crises as the pandemic's knock-on effects aggravated pre-existing drivers of hunger (FAO-WFP 2020). It is anticipated that globally total food demand in year 2050 will be approximately 11,200 million tons out of which 9300 million tons food will be required for developing countries (Rockström et al. 2007; Hanjra and Qureshi 2010). Agriculture is of prime importance for the world's food systems, a complex adaptive system, that include many actors, interacting institutions, social, environmental, biological, institutional, political, governance, and demographic considerations as it has special significance for achieving the stated sustainable development goals. In addition, agriculture is at the nexus of three of the greatest challenges of the twenty-first century – sustaining food and nutrition security, adaptation and mitigation of climate change, and sustainable use of critical resources such as water, energy and land. Agriculture is also acquiring renewed importance for gainful employment due to failure of manufacturing sector to pull labour out of agriculture and to keep pace with the growth in workforce in countries like India (Chand 2019). Ensuring global food security for the ever-growing population, which will reach over nine billion by 2050 and reducing poverty is a challenging task in the current setting of climate change impacts, as agricultural production is estimated to rise by approximately 50% from 2013 to 2050 considering the revised estimates by the United Nations for population growth and the increase in agricultural production by 15% between 2005/06 and 2012 (FAO 2017).

1.1.2 Growing Per Capita Incomes in Emerging Economies and Changing Food Habits

With the growing incomes in emerging economies such as Brazil, Russia, India, China, and South Africa (BRICS) imply additional pressure on global food production due to changing food habits. The World Economic Forum estimated that in

India by 2030, 51% of population adding 350 million individuals will be in upper middle and high income and high consuming category as compared to 24% in 2020. With Increasing urbanization, shrinking farm size, development in education and migration to cities in search of better livelihoods is increasing food demand. For example, in India with the growing population as well as increasing incomes more people are taking animal-based food and shrinking the number of vegetarian diet people (Table 1.1). Such a situation puts more pressure to have sustainable food systems with scarce water and land resources. In addition, harvest and post-harvest loss of major agricultural produce in 2018 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. Prevention of these losses could feed 50 million people per year. About 30–45% of the loss is due to food wastage – a crime indeed. One of the five pillars of Zero Hunger Challenges is "Zero loss or waste of food", seeking change in the mind-set of people to adopt "Save and Grow" (FAO 2011).

1.1.3 Land and Water Scarcity for Food Production

Water is an elixir of life which is one of the five eternal elements (namely, earth, water, fire, air, and ether) which are also known in ancient Indian literature as "*pancha maha bhuta*". Without water life would be impossible as it is an essential part of world's eco-system. Historically, many of the early great civilizations the so-called cradle of civilization like Mesopotamia, was situated between the major rivers Tigris and Euphrates; the ancient society of Egyptians depended entirely on Nile; the Indus Valley civilization in India flourished along the once famous *Sarasvati* river. Water has always a pervasive influence on the cultural and the religious life of Indian people. The great bath of *Mohenjo-Daro* is a great testimony to this fact. The bath is considered by scholars as the "earliest public water tank of the ancient world" (Singh et al. 2020).

Table 1.1 Increasing population, water footprint and freshwater demand: Indian scenario

Year	2010	2025	2050
Population in India (Million)	1150	1394	1750
Vegetarian percentage population	60	50	40
Vegetarian Population (Million)	690	697	700
Non-Vegetarian Population (Million)	460	697	1050
Daily water foot print for Vegetarian diet, Liter/day	4500		
Daily water foot print for Non-Vegetarian diet, Liter/day	15,000		
Annual Water requirement for Vegetarian diet (BCM)	1133	1145	1150
Annual Water requirement for Non-Vegetarian diet (BCM)	2519	3816	5749
Total water requirement (BCM)	3562	4961	6899

Source: Derived from Central Water Commission, Source: Wani (2020a, b)

Increased food production has to come from the available, finite and limited water and land resources that are declining in quality and quantity (Wani et al. 2011a, b).Water's importance for life on planet earth is well known and is the most precious naturally occurring resource is known in Indian civilization since ancient times. The Vedic texts which are more than 3000 years old contain valuable references to water and the 'hydrologic cycle'. As mentioned earlier, the most important concepts, on which the modern science of Hydrology is founded, are mentioned in *Rig Veda* in various verses in the form of hymns and prayers addressed to various deities and divinities such as *Indra* (firmament), Agni (fire), *Maruts* (wind) and so on (Singh et al. 2020).

Water a finite natural resource keeps circulating through the hydrological cycle of evaporation, transpiration, and precipitation mainly driven by various climatic and land management factors (Falkenmark 1997). Total water on earth is 1385.5 million km^3 (Shiklomanov 1993) out of which 97.3% is salt water in oceans. Fresh water constitutes only 2.7% of total global water resource and is the lifeline of the biosphere where forest, woodlands, wetlands, grasslands and croplands are the major biomes (Postel et al. 1996; Rockström et al. 1999). Rockström et al. (1999) reported that about 35% of annual precipitation (110,305 km^3) received on earth surface returns back to ocean as surface run off (38,230 km^3) and the remaining 65% converted into water vapor flow. Moreover, major terrestrial biomes *i.e.*, forest, woodlands, wetlands, grasslands and croplands together consume almost 98% of global green water (soil moisture) flow and generate essential ecosystem services. Fresh water availability for producing balanced food diet is estimated around 3000 Kcal/person per day under present conditions concomitant and with increasing population pressure is an important concern. At present some 11% (1.5 billion ha) of the globe's land surface (13.4 billion ha) is used in crop production (arable land and land under permanent crops). There is also a perception, at least in some quarters, that there is no more, or very little, land to bring under cultivation and it could be true in Asia and east Africa, however, the FAO stated that potential exists in sub-Saharan Africa and Latin America but infrastructure for cultivating these lands is a limitation (FAO 2016).

Model pathways that limit global warming to 1.5 °C with no or limited overshoot project a 4 million km^2 reduction to a 2.5 million km^2 increase of non-pasture agricultural land for food and feed crops and a 0.5–11 million km^2 reduction of pasture land, to be converted into a 0–6 million km^2 increase of agricultural land for energy crops and a 2 million km^2 reduction to 9.5 million km^2 increase in forests by 2050 relative to 2010. Such large transitions pose profound challenges for sustainable management of the various demands on land for human settlements, food, livestock feed, fibre, bioenergy, carbon storage, biodiversity and other ecosystem services (high confidence). Mitigation options limiting the demand for land include sustainable intensification of land-use practices, ecosystem restoration and changes towards less resource-intensive diets. The implementation of land-based mitigation options would require overcoming socio-economic, institutional, technological, financing and environmental barriers that differ across regions (IPCC 2018).

In India, agriculture is a primary sector providing livelihood for 58% population, however, it contributes only 17–18% to national gross domestic product (GDP). India has the largest arable agricultural land (142 m ha) in the world followed by USA and China. Enabling food security for 1.3 billion people with 291.95 million tonnes food grain production in 2019–2020 which is higher by 6.64 million tonnes than the record production of 285.21 million tonnes in 2018–2019 is a remarkable achievement (Department of Agriculture, Cooperation and Farmers Welfare) from 126 million ha under food grain cultivation. India's agriculture is unique in terms of 145 million land holdings (86% of them small and marginal farmers with <2 ha land holding) in the country with an average farm size of 0.97 ha per house-holds with 20 agro-climatic zones with 46 of the 60 soil types in the world 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, has huge untapped potential to become powerhouse of growth to achieve food, nutrition and income security for the 1.3 billion plus population as well as for the world (Wani and Singh 2019; Singh and Wani 2020). However, growing population in India is putting severe pressure on water resources which are decreasing year over years along with associated increase in demand from different sectors (Table 1.2) 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 and safety, and availability are the key factors considered for comparing the food security levels among the countries (Global Food Security Index 2020).

Drier climate and water scarcity in India led to numerous innovations in water management. Since Indus valley civilization, irrigation systems, different types of wells, water storage systems and low-cost sustainable water harvesting techniques were developed throughout the region. The reservoir built in 3000 BC at Girnar and

Table 1.2 Water resources availability and demand in India

Water resources availability	2010	2025	2050
Estimated annual precipitation (including snowfall) (km^3)	4000		
Average annual potential in rivers (km^3)	1869		
Estimated utilizable water (km^3)	1123		
Surface water (km^3)	690		
Groundwater (km^3)	433		
Existing surface storage (km^3)	214	412	412
Population (Million)	1150	1394	1750
Per Capita water availability (m^3)	977	806	685
Water demand in different sector (Km^3)			
Domestic	43	62	111
Irrigation	557	611	807
Industry	37	67	81
Energy	19	33	70
Total	656	773	1069

Source: Central Water Commission, Adapted from Wani (2020a, b) the ancient step wells in Western India are examples of some of the schemes. Water technologies such as manually operated cooling device "*Variyantra*" (revolving water spray for cooling the air) is given in the century's old writings "*Arthasastra*" of Kautilya (400 BC). The *Arthasastra* and *Astadhyayi* of Panini (700 BC) give reference to rain gauges (Singh et al. 2020). India has also implemented the biggest integrated watershed management program for rainwater harvesting silently revolutionising the rain-fed agriculture in the country (Wani et al. 2008, 2011a, b; Wani and Raju 2018). The concept of safe operating space for humanity suggested consideration of nine biophysical processes linked to the earth system to remain in the current stable state (Rockström et al. 2009a, b).

1.1.4 Climate Change and Vulnerability of Small Farm-Holders in India

Climate change phenomenon is an imminent based on the IPCC (Intergovernmental Panel on Climate Change) assessment reports and evidences of cases occurring around the globe. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2007, 2018). Constant increase in greenhouse gases concentrations, since preindustrial times, has led to positive radiative forcing of the climate, tending to warm the surface. The fourth assessment report of IPCC confirmed the rise in atmospheric temperature by 0.74 °C over the last 100 years due to global warming and projected a temperature increase of 1.8–4 °C by 2100, global latitudes, especially in seasonal dry and tropical regions of the world (IPCC 2007). Populations at disproportionately higher risk of adverse consequences with global warming of 1.5 °C and beyond include disadvantaged and vulnerable populations, some indigenous peoples, and local communities dependent on agricultural or coastal livelihoods. Regions at disproportionately higher risk include dryland regions, small island developing states, and Least Developed Countries, poverty and disadvantage are expected to increase in some populations as global warming increases (IPCC 2018).

The IPCC in its 5th Assessment Report noted that future yields of rice, wheat, maize, and soybean will likely decrease significantly, by at least 25% in tropical and temperate regions. Aggarwal (2008) reported that in north India, irrigated wheat yields are decreased as the temperatures increase and a 2 °C increase resulted in a 17% decrease in grain yield and with the further increase in temperature the decrease in yield was very high. The highest decrease in chick pea grain yield per degree rise in seasonal *rabi* temperature was observed in Haryana (3.01 q ha^{-1}), followed by Punjab (1.81 q ha^{-1}), Rajasthan (1.27 q ha^{-1}) and Uttar Pradesh (0.53 q ha^{-1}) (Kalra et al. 2008). It was further indicated that due to climate change, there is reduction in crop yield of 10–40% at the present yield level by the turn of the century. Changes in patterns and magnitudes of precipitation are also likely to affect rain-fed crop productivity and influence the availability of water resources for irrigation. So, the effect of climate change scenario of different periods can be positive or negative depending upon the magnitude of change in atmospheric CO_2 and temperature. Using an emissions scenario that represents ecologically friendly economic growth Avnery et al. (2011) estimated that ozone-induced global yield reductions by the year 2030 would be 10.6% for wheat, 4.3% for maize, and 12.1% for soybean. Temperature is an important factor in ozone generation.

Climate change is real and already at our doorstep, its implications are going to be borne by the poorest of the poor. Climate change will have large effect on water globally which will vary regionally. This is due to spatially variable changes in precipitation, increased rate of glacier melt and retreat affecting river water flows, greater evaporation due to increase in temperature and higher water demand. These changes are likely to affect all aspects of agricultural water management including irrigation availability, soil moisture, evapotranspiration and run-off (Boomiraj et al. 2010). Rao et al. 2013 have studied the changes in agro-eco regions in India due to climate change. They reported increased semi-arid areas by 8.45 M ha in Madhya Pradesh, Bihar, Uttar Pradesh, Karnataka and Punjab resulting in over all 3.45 m ha addition to SAT (Fig. 1.1). Dryness and wetness are increasing in different parts of the country in the place of moderate climates existing earlier in these regions. Number of rainy days during the season are decreased and rainfall intensities increased resulting in frequent occurrence of dry spells during the crop growth period (Rao et al. 2013).

The rain-fed agriculture which have economies largely based on weather-sensitive agricultural productions systems, are particularly vulnerable to climate

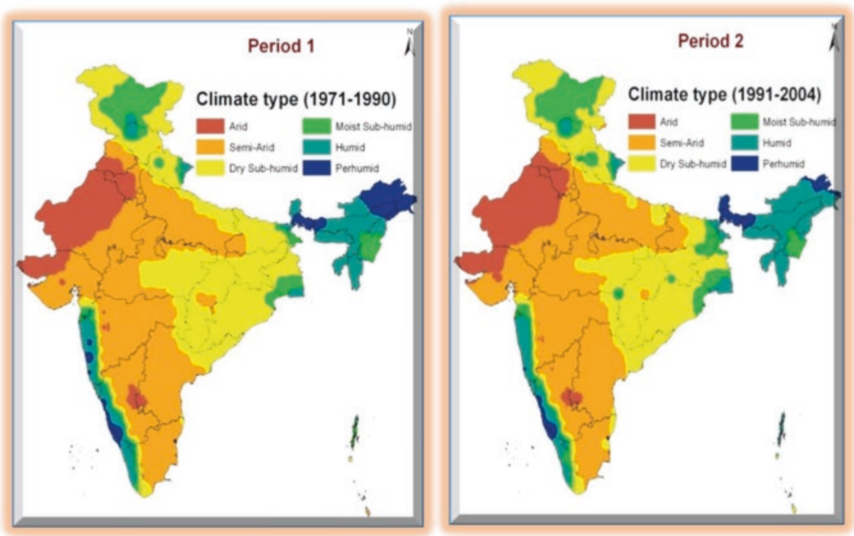


Fig. 1.1 Changes in agro-climatic regions in India due to climate change during 1971–1990 and 1991–2004. (Source: Authors)

change. This vulnerability has been demonstrated by the devastating effects of recent flooding and the various prolonged droughts during the twentieth century. Thus for many poor countries that are highly vulnerable to effects of climate change, understanding farmers' responses to climatic variation is crucial in designing appropriate coping strategies to climate change (Wani et al. 2010). If climatic change is accompanied by an increase in climate variability, many agricultural producers will experience definite hardships and increased risk due to reduced water availability and increased demand for irrigation.

1.1.5 Low Productivity and Existing Large Yield Gaps

Currently, farmers' crop productivity is low particularly in Asia, Africa, WANA and Latin America with large yield gaps for the crops grown worldwide (difference between achievable potential and actual yield) varies from 0.5 to 5 t ha^{-1} as per the agro-ecological zone and the available technologies used by the farmers (Anderson et al. 2016; FAO and DWFI 2015). Yield gap analyses carried out for Comprehensive Assessment for major rain-fed crops in semi-arid regions in Asia and Africa and rain-fed wheat in WANA, revealed large yield gaps with farmers' yields being a factor 2 to 4 times lower than achievable yields for major rain-fed crops (Agarwal 2000; Aggarwal 2008; Rockström et al. 2007; Singh et al. 2009; Bhatia et al. 2008; Wani et al. 2011a, b). In India current farmers' yields are lower by two to fivefolds than the achievable crop yields (Rockstrorm and Falkanmark 2000; Wani et al. 2003b, d; Rockström et al. 2010) with average yields in rain-fed areas hovering around 1–1.5 t ha^{-1} Fig. 1.2.

Huge yield gaps for rice (5.47 q ha^{-1}), maize (12.77 q ha^{-1}), oil seeds and field peas were reported in India (Beigh et al. 2015). In many countries in West Asia, farmers' yields are threefold lower than achievable yields, while in some Asian countries the figure is closer to twofold (Fig. 1.3). Across the top wheat producing countries of the world, there are differences in the progress for increasing yield. In France and Germany, the yield increase is near 100 kg ha^{-1} year^{-1}, while in Australia, it is 15 kg ha^{-1} year^{-1}, which can be attributed to a large difference in the variation in the climate between these two regions. Evaluating smaller-scale yields, e.g., developing county, reveals that weather within the growing season is the dominant factor affecting yield gaps (Lobell et al. 2009). Technological advances have increased the attainable yields at a greater level than the yield trends, indicating that to close the yield gap, wheat producers will have to adopt practices at the local scale that will allow the technology improvements to be realized. These are local decisions made by individual producers; however, efforts to demonstrate how soil and agronomic practices that increase productivity could reduce the yield variation among years will pay dividends in closing the yield gap in wheat.

Historic trends present a growing yield gap between farmers' practices and farming systems that benefit from management advances (Wani et al. 2003d, 2009, 2011a, b). Rosegrant et al. (2002) noted that in the last four decades, 30% of the

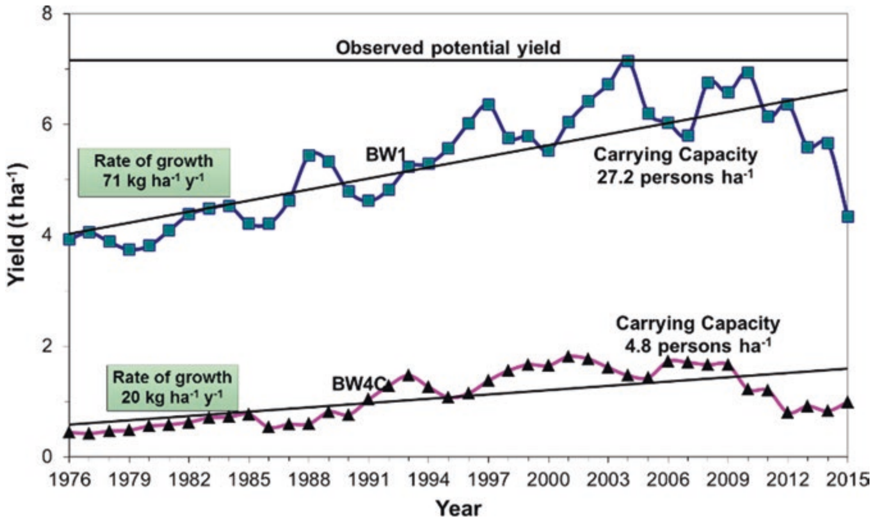


Fig. 1.2 Crop productivity of improved and traditional farmer's practice plots from long-term experiment at Heritage Watersheds at *ICRISAT* since *1976.* (Source: ICRISAT 2017)

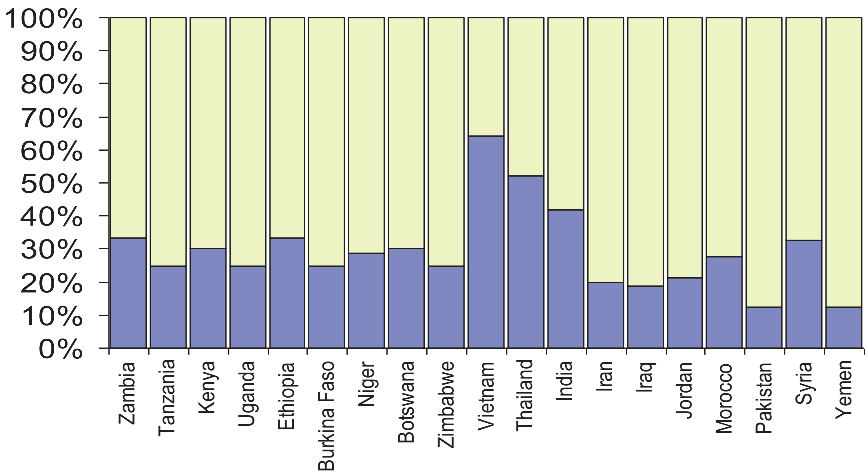


Fig. 1.3 Examples of observed yield gap (for major grains) between farmers' yields and achievable yields (100% denotes achievable yield level, and column actual observed yield levels). (Source: Rockström et al. 2007 cited by Wani and Rockström 2011)

overall grain production growth is due to expansion of agricultural areas and the remaining 70% growth originated from intensification through yield increases per unit land area with large regional variation as well as between irrigated and rain-fed areas. During last four decades in sub-Saharan Africa, with 99% rain-fed production of main cereals such as maize, millet, and sorghum, the cultivated cereal area has doubled since 1960 while the yield per unit land has nearly been stagnant for these staple crops. In South Asia, farmers shifted away from more drought tolerant low-yielding crops such as sorghum and millet, whilst wheat and maize have approximately doubled in area since 1961 (FAOSTAT 2010). Main reason for large yield gaps in most countries are lack of suitable management practices and weather (Aggarwal 2008; Rockström et al. 2007; Singh et al. 2009; Bhatia et al. 2008; Lobell et al. 2009; Wani et al. 2011a, b). Large yield gaps along with lack of holistic approach to target system-level productivity, value-chains, and market linkages added to the plight of small farm-holders in the country (Wani et al. 2018). With the impacts of climate change these yield gaps could widen further, unless technological innovations are taken at the doorstep of farmers urgently (Wani and Raju 2018).

1.2 Why *Death Valley* of Impacts?

In spite of a large number of game-changing technologies, there are large yield gaps in farmers' fields across the world and more so in developing countries in Asia and Africa (mainly due to lack of awareness and access to the technologies (Rockström and Falkanmark 2000; Wani et al. 2003b, c; Lobell et al. 2009; Rockström et al. 2010; Anderson et al. 2016; FAO and DWFI 2015). Most of the technologies rarely moved beyond proof of concept/pilot stage and failed to reach millions of farmers' fields for a significant impact largely due to existence of "*Death Valley* of impact" (Fig. 1.4) largely due to lack of synergy amongst the actors and deficiencies in technology delivery systems as compartmental approach is adopted by the scientists and rarely farmers' requirements are considered while providing the solutions (Wani and Raju 2016, 2020).

These findings of low impacts of technologies particularly on ending hunger are confirmed by CERES 2030 Team (Nature 2020; Laborde et al. 2020, Bizikova et al.

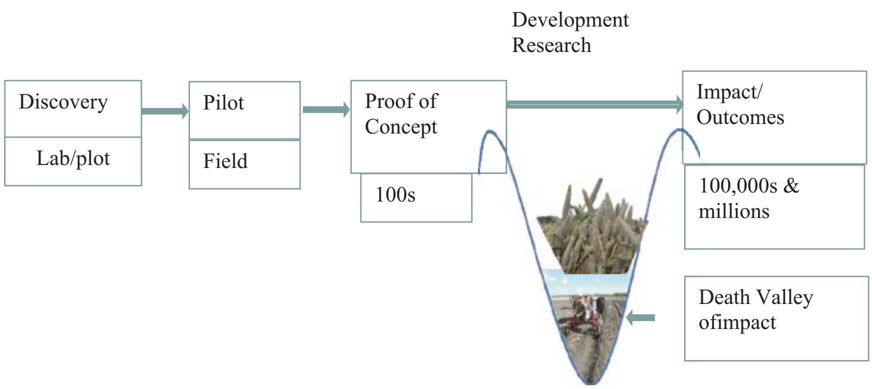


Fig. 1.4 Death Valley of impacts: Pictorial representation of the life cycle of technology/product. (Source: Wani and Raju 2016)

2020) based on its 3-year effort to review more than 100,000 articles published by researchers, think tanks, non-governmental organizations, many UN agencies and the World Bank as follows:

- It's clear from the review that, despite being involved in making and tracking SDG policies, such organizations (NGOs, World Bank, many UN agencies, Think Tanks), indicated above are not producing nearly as much relevant research as needed.
- Smallholders need new technologies, but they also need research on the effectiveness of existing interventions. One of the papers detailing the CERES 2030 team's findings includes the striking statement that "most of the included studies only involved researchers without any participation from farmers" (Stather et al. 2020).
- So why aren't more researchers answering more practical questions about ending hunger that are relevant to smallholder farmers? Many of the key reasons can be traced to the changing priorities of international agricultural-research funding where during last four decades more than half funding is from agribusinesses (Pardey et al. 2016).
- Applied research involving working with smallholder farmers and their families doesn't immediately boost an academic career. Many researchers – most notably those attached to the CGIAR network of agricultural research centres around the world – do work with smallholder farmers. But in larger, research-intensive universities, small is becoming less desirable. Increasingly, university research-strategy teams want their academics to bid for larger grants – especially if a national research-evaluation system gives more credit to research income.
- Publishers also bear some responsibility. The subject matter for smallholder-farming research might not be considered sufficiently original, globally relevant or world-leading for journal publication.
- National agricultural research systems (NARSs), too, need to listen, because they are the major funding source for researchers in universities. There's a place for collaborating with big businesses, but achieving the SDG to end hunger will require an order of magnitude more research engagement with smallholders and their families.
- Small farm-holders' incomes increase when they belong to cooperatives, self-help groups and other organizations that can connect them to markets, shared transport or shared spaces where produce can be stored. Farmers also prosper when they can sell their produce informally to small- and medium-sized firms (Bizikova et al. 2020). That seems to be because such companies share information with farmers and provide sources of credit.

1.2.1 How to Cross **Death Valley** *of Impacts to Transform Livelihoods of Farmers?*

For achieving the impacts by crossing the *Death Valley* of impacts as stated above science must change its focus (Nature Food 2020) and scientists as well as research managers, extension staff, policy makers, donor agencies, publishers of the research journals and farmers must change their mind set (Wani and Raju 2018, 2020). Change of Mind-set of people through awareness building and community participation which is driven by the tangible benefits for the society through their demand-based solutions rather than the supply driven solutions. Agriculture and staying in rural areas is considered as no choice option which need to be changed through development of rural areas with provision of urban facilities in rural areas (PURA) like initiatives. Good example of a national initiative "*Swach Bharat*" with community participation, building public-private-people centric- partnerships (PPPP) as well as qualitative and quantitative monitoring evaluation and learning (MEL) made 98% rural areas open defecation free. *Change of people's mind-set and seeking their participation is a challenge which has to be pursued vigorously and rigorously.*

Several authors (Wani et al. 2011a, b; Wani and Raju 2018; Raju and Wani 2020) suggested the need to go beyond the compartmental approach for achieving a significant impact on ground. The results till to date clearly suggest that business as usual does not serve the purpose of achieving large impacts on ground from the new technologies/products and there is an urgent need for a new paradigm of holistic and integrated approach through innovative partnerships, delivery mechanisms/strategies, policies, institutional arrangements and new technology-based knowledge delivery systems. Transforming our small farm-holders (*Annadatas*- food providers*)* in to climate resilient farmers we need to adopt urgently a new paradigm involving a consortium approach through building partnerships amongst knowledge generating institutions (researchers), Knowledge transforming agencies (government departments, civil society organizations and development investors), private and corporate companies, service providers (Wani et al. 2003b), for adopting inclusive market-oriented development (IMOD) approach as a business rather than just for subsistence (Wani et al. 2011a, b). Important lessons learnt from earlier watershed-based research were listed elsewhere (Wani et al. 2003a, 2011a, b; Wani and Raju 2018, 2020) as mentioned in the following:

- Researchers generally worked with progressive farmers and as a result equity for benefits to small holders and landless was compromised.
- Researchers adopted contractual mode of participation which resulted in low and passive community participation, lack of tangible economic benefits for small far-holders resulting in low community participation (5–10%) as farmers having access to groundwater were only deriving benefits from the interventions.
- Emphasis was on establishing/demonstrating pilots and not Scaling-up as it was supposed to happen through automatically with dissemination process (trickle-down effect).

- Evaluation was undertaken as a postmortem activity and not as a concurrent learning process.
- Scientists were working independently for pilots and as result technical support for most development projects implemented by NGOs/government departments was lacking to address the issues holistically.

Based on these learning the earlier consortium model was developed with following salient constituents (Wani et al. 2003a, 2011a, b; Wani and Raju 2018, 2020):

- Strengthening science of delivery along with science of discovery to benefit farmers through new knowledge-based technologies/products.
- Demand driven approach ensuring tangible private economic benefits to small farm-holders along with eco-system services benefits, landless families, youths and women through income-generating activities was adopted for selecting the watershed and the farmers collectively identified and prioritized the problems for possible technical interventions.
- Consortium approach involving needed research (national, international and local), development institutions along with government departments need to be adopted from the beginning.
- Participatory planning, promoting collective action along with capacity building for implementation along with concurrent participatory monitoring, evaluation and learning (MEL) of watershed research and development with the involvement of all stakeholders.
- New science and technology tools such as remote sensing (RS), geographical information system (GIS), digital terrain modelling (DTM), soil health mapping including soil depth, integrated nutrient management (INM) and crop simulation models with amalgamation of validated conventional/traditional knowledge of the community along with new knowledge dissemination methods.
- Linking successful on-station watersheds and on-farm watersheds for strategic research enabled the farmers as well as researchers to think differently to solve their problems. The "*Islanding Approach*" within the watershed which served as site of learning within the village itself and also to build the confidence of farmers by undertaking research.
- In place of mere soil and water conservation (compartmental approach) a holistic system approach for livelihood improvement to benefit all the community members who were deprived off the project benefits in earlier programs.
- Increased individuals' participation by emphasising on *in-situ* conservation of rainwater and translating benefits of increased soil water availability through integrated genetic and natural resource management (IGNRM) approach enhancing use efficiency.
- For technical development and inputs on individual/private land users to pay 50% (with incentive) and for community-based interventions largely government pays with 10–30% contributions from beneficiaries.
- For scaling-up and technology dissemination use of bench mark sites as training/learning sites for partners, farmers and for sensitizing the policy makers with an intention to develop scaling-up model for the successful pilot.

1.2.2 To End Hunger, Science Must Change Its Focus

An international research consortium Ceres 2030 undertook meta-analysis by reviewing more than 100,000 articles published and found that although policy makers need research on ways to end hunger but most research has had the wrong priorities confirming our findings of existing *Death Valley* of impacts as mentioned above (Wani et al. 2002, 2003e).Two-thirds of hungry people live in rural areas. One of the paper from Ceres 2030 team's findings (Stathers et al. 2020) includes the striking statement that "most of the included studies only involved researchers without any participation from farmers" as recorded above that watershed researchers adopted contractual mode of on-farm research without actively involving small farm-holders (Wani et al. 2003a, 2011a, b, 2020; Wani 2020a, b). The team was able to identify ten practical interventions that can help donors to tackle hunger, but these were drawn from only a tiny fraction of the literature. The Ceres 2030 team members found that the overwhelming majority of agricultural-research publications they assessed were unable to provide solutions, particularly to the challenges faced by smallholder farmers and their families (Nature 2020). Other studies found that these farmers' incomes increase when they belong to cooperatives, self-help groups (SHGs) and other organizations that can connect them to markets, shared transport or shared spaces where produce can be stored (Bizikova et al. 2020).

1.2.3 Small Is Less Desirable

Of some 570 million farms in the world, more than 475 million (83%) are smaller than 2 hectares. Rural poverty and food insecurity go hand in hand, and yet the Ceres 2030 researchers observed that more than 95% studies – were not relevant to the needs of smallholders and their families (Nature 2020). India's agriculture is unique in terms of 145 million land holdings (86% of them small and marginal farmers with <2 ha land holding) in the country with an average farm size of 0.97 ha per household (Wani 2020a, b). At the same time, as mentioned above, researchers always preferred to work with farmer leaders with larger farms who can take risk and also serve as opinion makers in the village. It was also reported by the Ceres team that applied research involving working with smallholder farmers and their families doesn't immediately boost an academic career. Many researchers – most notably those attached to the CGIAR network of agricultural research centres around the world – do work with smallholders. But in larger, research-intensive universities, small is becoming less desirable. Increasingly, university research-strategy teams want their academics to bid for larger grants – especially if a national research-evaluation system rewards those who bring in more research income. Publishers also bear some responsibility. Ceres 2030's co-director, Jaron Porciello, a data scientist at Cornell University in Ithaca, New York, told Nature that "smallholder-farming research might not be considered sufficiently original, globally relevant or world-leading for journal publication". This lack of a sympathetic landing point in journals is something that all publishers must consider in the light of the Ceres 2030 team's findings (Nature 2020).

1.2.4 Lack of Extension Support to Small Farm-Holders

As per the national sample survey data, 51% of farmers in India do not get any knowledge support (extension support) and only 11% farmers get support from the government machinery while remaining 38% farmers get support from peers, media and private agencies (NSSO 2013; GoI 2013). The situation cannot be different in other developing countries in Asia, Africa and Latin America. The Ceres 2030 researchers found that major constraint for adoption of new approaches/technologies/products was lack of technical advice, input and ideas, collectively known as extension services for the small farm-holders. The small farm-holders are more likely to adopt new approaches – specifically, planting climate-resilient crops – when they are supported by technical advice, input and ideas (Nature 2020). As reported above, weak science of delivery is the main constraint for benefitting small farm-holders from new technologies/products.

For *Bhoochetana* innovative extension mechanism was developed through an innovative institutional arrangement to rejuvenate the extension system in the state of Karnataka, India as well as to empower farmers through *Ryatu samparka kendras* (RSKs). This initiative also helped to create a new institutional arrangement such as creation of the '*Bhoochetana* cell' in the state to deal with agricultural extension services and input delivery. Since the inception of the initiative, farmer facilitators (FFs) and lead farmers (LF) were the new extension agents who effectively disseminated the knowledge to the community by serving as a link between the extension staff and farmers, which made huge impacts on the state's agricultural scenario. After realizing the importance of FFs in the extension system, this concept was adopted by other departments of the Government of Karnataka such as the Departments of Horticulture and Sericulture to implement other schemes such as *Suvarna Bhoomi Yojane* in the state (Raju et al. 2013a, b; Krishnappa et al. 2016). In all scaling-up projects results of farmer participatory experiments were shared with the farmers by the farmers as well as staff from the "islanding approach" by conducting Field Days (Fig. 1.5)

Fig. 1.5 Dissemination of results from the farmer participatory trials in the presence of policy makers in Karnataka, India. (Source: Authors)

1.2.5 Rapport Building with Community Through Knowledge-Based Entry Point Activity (EPA)

Introducing any development program to the community has always been recognized as an important activity. This is done through what are called 'entry point activities' (EPA) in the parlance of watershed literature. It involves building the rapport with the community, strengthening and sustaining it throughout the program and beyond. To build a rapport between the project implementing agency (PIA) and the villagers before initiating the programs, an EPA is envisaged. The entry point intervention/activity is identified through participatory rural appraisal (PRA). An EPA, such as providing drinking water and sanitation to the community, conducting health awareness camps, construction of community halls, class rooms, repairing or construction of culverts, approach roads, promotion of kitchen gardens, etc., are carried out. Support to group income activities such as fish farming in village tanks and providing power threshers with the community contribution are some other rapport building measures that are practiced (Fernandes 2000). In an innovative farmer participatory consortium model for watershed management by ICRISAT-led consortium, one of the important components was no subsidy for interventions on private farmlands and need-based interventions as demanded by farmers instead of supply-driven interventions padded with free inputs (Wani et al. 2003a). An important lesson learned during that time was that undertaking community level EPA such