15 Assessing the Climate Resilience of Semi-Arid Farming Systems in India: Framework and Application

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Abstract

Semi-arid regions in India are characterized by poor natural resources, smallholder farmers and an increasing frequency of extreme weather events. The vulnerability of semi-arid farming systems to climate change and the state of agrarian distress in India underscore the need to assess their climate resilience. We observe weaknesses in existing frameworks for assessing resilience, such as a bias toward assessing a system's status quo and the lack of clarity between assessing resilience to specific stresses and a system's more general resilience attributes. The need for context-specific tools and frameworks has also been highlighted in literature on climate resilience. To address these gaps, we develop a context-specific framework to assess the climate resilience of semi-arid farming systems in India and evaluate its relevance. The Climate Resilience In Semi-arid India (CRISI) framework, with customized system functions, indicators, resilience capacities and attributes, has been developed by combining insights from existing literature, from the local knowledge and expertise of the research team and from a case study application. Considering emerging climate change risks, the case study further shows us there is an urgent need to build the resilience capacities of adaptability and transformability of the farming system. CRISI's inclusiveness in identifying stakeholder needs, its systemic understanding of resilience and its provision of information for decision-making make it useful for the farming community, practitioners and policymakers in assessing and building climate resilience.

15.1 Introduction

Dryland regions, consisting of arid, semi-arid and sub-humid climates, cover about 55% of India's areal extent. The semi-arid regions in particular are dynamic, influenced by changes in temperature and precipitation patterns as well as anthropogenic land-use changes (Ramarao *et al.*, 2019). Even small changes in temperature and rainfall patterns can impact natural resources such as water availability, soil health, forest cover and pastureland – and in turn, the agrarian livelihoods of the vulnerable communities who live in these regions (Kuchimanchi *et al.*, 2019; Ramarao *et al.*, 2019). Agriculture and allied livelihoods employ more than 50% of India's population (Birthal *et al.*, 2017), and more than 85% of the farming community

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consists of small and marginal farmers (GoI, 2016). More than half of these small and marginal farmers are located in the resource-poor arid and semi-arid regions, adding to their vulnerability and poor adaptive capacities (Behera and France, 2016).

Given the complexity of the challenges such farmers face, several studies recommend using the lens of resilience to assess a farming system's sustainability and its ability to cope with shocks (Folke *et al.*, 2010; Bullock *et al.*, 2017; Meuwissen *et al.*, 2019). A farming system is a unit of analysis that is above individual farms and consists of a network of farms, farmers and other actors interacting in a specific agro-ecological context (Giller, 2013; Dixon and Stringer, 2015). Many frameworks exist to assess the resilience of socio-ecological systems and farming systems (Resilience Alliance, 2010; Walker and Salt, 2012; UNDP Drylands Development Centre, 2013; Nemec *et al.*, 2014; Quinlan *et al.*, 2016). They vary from more conceptual (e.g. Cabell and Oelofse, 2012) to data-intensive, quantitative approaches (e.g. FAO, 2016). O'Connell *et al.* (2015) reviewed and described some of the weaknesses in existing frameworks for assessing resilience, such as who is included in the process, a narrow understanding of resilience that focuses on the status quo and a lack of clarity between assessing resilience to specific stresses and a system's more general resilience attributes.

In the context of farming systems, Meuwissen *et al.* (2019) adapt earlier frameworks specifically paying attention to the importance of multiple value chains, relationships between farm and non-farm populations and the role of the enabling environment. One aspect that all resilience assessment frameworks recommend is adapting and operationalizing the steps and indicators to the local context. Dixon and Stringer (2015) review tools and frameworks that focus on the climate resilience assessments of smallholder farming systems in sub-Saharan Africa and highlight the need for context-specific tools and frameworks that analyze local power relations, capture existing vulnerability and promote participation, flexibility and learning. Here, we understand climate resilience as the capacity of a system to dynamically respond to, recover from and even thrive in changing climate conditions while continuing to maintain essential functions, identities and structures (Rockefeller Foundation, 2009; Dixon and Stringer, 2015).

The objective of our research is to develop a context-specific framework to assess the climate resilience of semi-arid farming systems in India and evaluate the framework's relevance. We develop the framework by combining insights from existing literature, from the local knowledge and experience of the research team and from a case study application. We refer to our framework as the Climate Resilience In Semi-arid India (CRISI) framework (phonetically similar to *Krisi* or *Krishi*, which translates to 'agriculture' in Hindi). In semi-arid India, where farming depends on water harvested within a catchment area, we use the watershed boundary to demarcate the farming system. The scale at which we apply the CRISI framework is the micro-watershed. Micro-watersheds are the smallest hydrologic unit in the hierarchal system of watersheds, typically 500–1000 ha in India (Symle *et al.*, 2014). The technically correct term 'micro-watershed' is used interchangeably with the more generic term 'watershed' throughout the chapter.

We apply the framework to assess the resilience of Kalamkarwadi, a micro-watershed in the state of Maharashtra, to provide additional insights to refine the framework. We evaluate the framework's relevance for assessing the climate resilience of farming systems in semi-arid India against three criteria: (i) identification of all relevant stakeholders and their needs; (ii) following a systems perspective while assessing resilience (as opposed to a disciplinary/sectoral perspective); and (iii) providing information for decision-making processes. We find that the CRISI framework adequately meets these three criteria and believe it has application potential in generating evidence-based insights that can guide climate change adaptation and climate-resilient development policies at the state and national levels, not just in semi-arid regions of India but in other parts of the world with similar socio-ecological contexts.

This chapter is organized into five sections. After this introduction, we discuss in Section 15.2 how the CRISI framework was developed. Section 15.3 presents the application of the framework to the Kalamkarwadi case study and the insights that contributed to making the framework context-specific. In Section 15.4 we evaluate the framework's relevance for assessing the climate resilience of farming systems in the context of semi-arid India. Our final discussion and conclusions are presented in Section 15.5.

15.2 CRISI – A Context-Specific Framework to Assess the Climate Resilience of Farming Systems in Semi-Arid India

To develop a climate resilience assessment framework specific to semi-arid regions in India, we followed a two-stage process. The first stage involved identifying the broad steps and generic functions, and resilience capacities and attributes from existing literature on the resilience of farming systems. Literature on the impact assessment of watershed development (WSD) interventions in India (e.g. Bharucha *et al*., 2014; Taylor and Bhasme, 2020; Shah *et al*., 2021) and the local knowledge and experience of the research team also contributed to this first stage. The second stage involved applying the framework in a case study and using the insights generated to refine the context-specific list of system functions, indicators, and resilience capacities and attributes. This application of the CRISI framework was done through a participatory rural appraisal (PRA) process that involved semi-structured discussions with a multi-stakeholder group and focus group discussions (FGDs) with marginalized sections of the local community. The multi-stakeholder discussions included the local community as well as researchers and development professionals who have been working with the Watershed Organisation Trust (WOTR), the partner non-governmental organization involved in the research. Quantitative data available at the village council and from project baseline and endline reports also contributed to the assessment of the case study.

The CRISI framework consists of the following six steps as shown in Table 15.1. These steps are: (1) system description; (2) challenges; (3) system functions; (4) resilience capacities; (5)

Table 15.1. Steps of the Climate Resilience In Semiarid India (CRISI) framework. (Source: Authors' analysis.)

Step	Actions to be undertaken in the assessment
1. System description	a) Identify stakeholders, governance structures and power dynamics within the farming system. b) Describe the context and explore the stakeholders' views of the farming system, including what they value and why. c) Discuss the scope of the climate resilience-building interventions and the time and spatial scale.
2. Challenges	a) Explore stakeholders' views on existing stresses and vulnerabilities, particularly climate-related, and what they expect, including short-term and long-term views. b) Describe the environmental, economic, social and institutional issues and stresses.
3. System functions	a) Discuss the different functions provided by the farming system and appropriate indicators to reflect their functions. b) Assess the performance of these indicators in response to (specific) known stresses over the assessment period.
4. Resilience capacities	a) Define the four resilience capacities (*Anticipation*, *Robustness*, *Adaptability* and *Transformability*) in the local context and discuss relevant indicators for each. b) Assess the capacities by factoring in the story behind the performance of system function indicators (3b) and the contribution of any strategies adopted to cope with climate stresses on the farming system.
5. Resilience attributes	a) Discuss the list of resilience attributes identified for semi-arid farming systems and their relevance to the local context. b) Assess the status of these attributes over the assessment period.
6. Reflection	a) Discuss the outcomes of the resilience assessment with the community, reflecting on its accuracy and making revisions when required. b) Over the assessment period, reflect on the adequacy of the resilience-building measures and the need for additional adaptation or transformative changes.

resilience attributes; and (6) reflection. The first five steps are based on a holistic understanding of resilience by Meuwissen *et al.* (2019) that pays attention to the farming system as a whole and emphasizes the importance of assessing both resilience to specific stresses and the more general resilience attributes of a system. With respect to Step 4, Meuwissen *et al.* (2019) conceptualize resilience through the capacities of robustness, adaptability and transformability. Considering the increasing frequency of extreme weather events being experienced in semi-arid India, we add a fourth capacity, anticipation, as suggested by Mathijs and Wauters (2020). We also add a sixth and final step, reflection, based on insights from the Resilience, Adaptation Pathways and Transformation Assessment (RAPTA; see O'Connell *et al.*, 2015). The RAPTA framework has been tested in development contexts and suggests that this final step helps to improve the quality of the resilience assessment, in adaptive management of the resilience-building measures, and also to assess the need for additional adaptation or transformative changes in building resilience (Grigg *et al.*, 2015; Maru *et al.*, 2017).

The first two steps of system description and challenges focus on outlining the system boundary, the relevant stakeholders, governance structures, climate-related stresses and other existing socio-economic vulnerabilities. Step 3 addresses the functions of the farming system. In the context of semi-arid India, we identify ten functions (Table 15.2). Eight of these are based on the public and private functions of farming systems used by Paas *et al.* (2021) in the context of European farms. In the context of semi-arid India, two more functions – social organization and equity (standard of living) – were added based on the analysis of semi-arid watersheds by Kerr *et al.* (2002). With regard to equity, we use two perspectives based on principles of 'fairness' (Jones, 2009) and the research team's experience in the local context: (i) standard of living through access to employment, income and assets; and (ii) decision-making and power dynamics in local governance. We include the former perspective as a system function in Step 2 (Table 15.2) and include the latter as a resilience attribute in Step 5. The PRA exercise during the application of the framework in the case study helped arrive at appropriate indicators for the system functions.

Table 15.2. Farming system functions and indicators used in the CRISI framework.

No.	Farming system functions	Indicators in local context / What to look for
1	Social organization[a]	No. of community-based institutions; membership and participation; readiness for voluntary labor
2	Economic viability[b]	Income from the farming system (crop and livestock); total per capita income (including non-farm income)
3	Food and nutrition security[b]	Total food production (cereals, vegetables, milk, etc.); data on malnutrition and anemia; diversity in diet
4	Animal health and welfare[b]	Total livestock ownership; production of meat and milk; health and well-being of animals
5	Other bio-based resources[b]	Production quantity from sources such as non-timber forest produce, from common lands; diversity of resources; income from such sources
6	Health of ecosystem[b]	Soil quality; forest cover; water-table depth
7	Biodiversity of habitat[b]	Diversity of crops, other plants, trees, animals and wildlife
8	Attractiveness of area[b]	Waste management; composting; roadside plantation; public toilets
9	Quality of life[b]	No. of families and months of migration under distress; ownership of TVs, smartphones, internet access; working hours (men and women); returning families; perception of village youth
10	Equity (standard of living)[a]	Access to employment; quality of the house; number of households with assured income; number of households with BPL (below poverty line) cards

Note: [a]Based on Kerr *et al*. (2002) and [b]based on Paas *et al*. (2021).

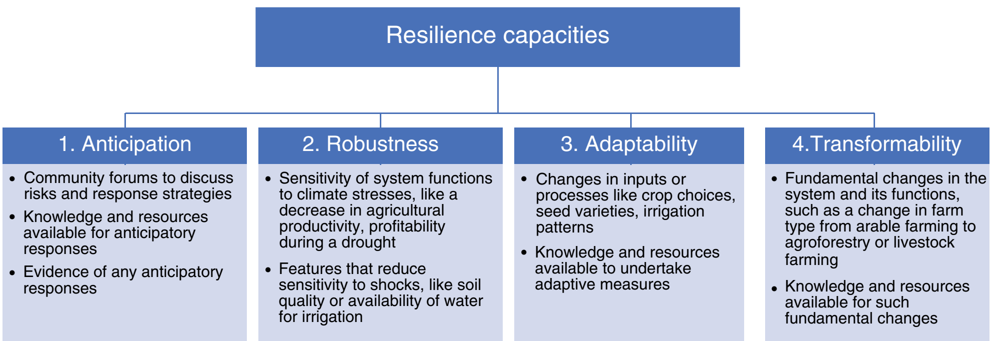
In Step 4, we expand the possible range of resilience-building interventions that can be assessed by incorporating the four resilience capacities of: (1) anticipation – the capacity to identify potential risks and take proactive steps; (2) robustness – the capacity to withstand stresses and (un)anticipated shocks; (3) adaptability – the capacity to change the composition of farming system inputs, outputs and risk management strategies in response to shocks and stresses (without changing the system's structure and feedback mechanism); and (4) transformability – the capacity to significantly change the farming system's internal structure and feedback mechanism in response to either severe shocks or enduring stress that makes business as usual impossible. The PRA exercise during application of the framework in the case study helped arrive at appropriate indicators for each of the resilience capacities (Fig. 15.1). The indicators provide guidance on what to look for in the local context.

Step 5 aims to discuss the system's capacity to deal with new and/or unforeseen stresses to the system, also known as general resilience. To assess this, Meuwissen *et al*. (2019) describe resilience attributes as 'individual and collective competencies that along with an enabling (or constraining) environment affect the general resilience of a system.' An initial list of resilience attributes that combined all the indicators and attributes mentioned in Cabell and Oelofse (2012) and Paas *et al*. (2021) was used as a starting point. The PRA exercises during the application of the framework in Kalamkarwadi helped introduce new attributes relevant to the local context and remove those that were deemed redundant or not applicable. The final list of attributes is presented in Table 15.3.

Step 6 is an iterative step of reflection, in which we focus on reviewing the assessment results from Steps 1 to 5 and improving the assessment's accuracy. We discuss issues such as the adequacy of the resilience-building measures and the need for additional adaptation or transformative changes. This step also gives stakeholders the chance to reflect on indicator dynamics over the time frame of the assessment.

15.3 Applying the CRISI Framework: The Kalamkarwadi Case Study

We applied the CRISI framework to assess the resilience of Kalamkarwadi, a micro-watershed in the state of Maharashtra, to validate the customization made and to provide additional insights to refine the framework. The farming system in the watershed of Kalamkarwadi, located in the Parner block of the Ahmednagar district of Maharashtra, was chosen as the site for the case study (Fig. 15.2). This case was selected based on its semi-arid ecosystem, the history of WSD interventions, data availability and consent from the local community. Falling in the rain-shadow region of the Western Ghats, this area receives about 500 mm of rain annually. About 90% of the rainfall occurs during the monsoon season from June to September. The



Source: Authors' analysis.

Fig. 15.1. The four resilience capacities and indicators in the local context for each capacity.

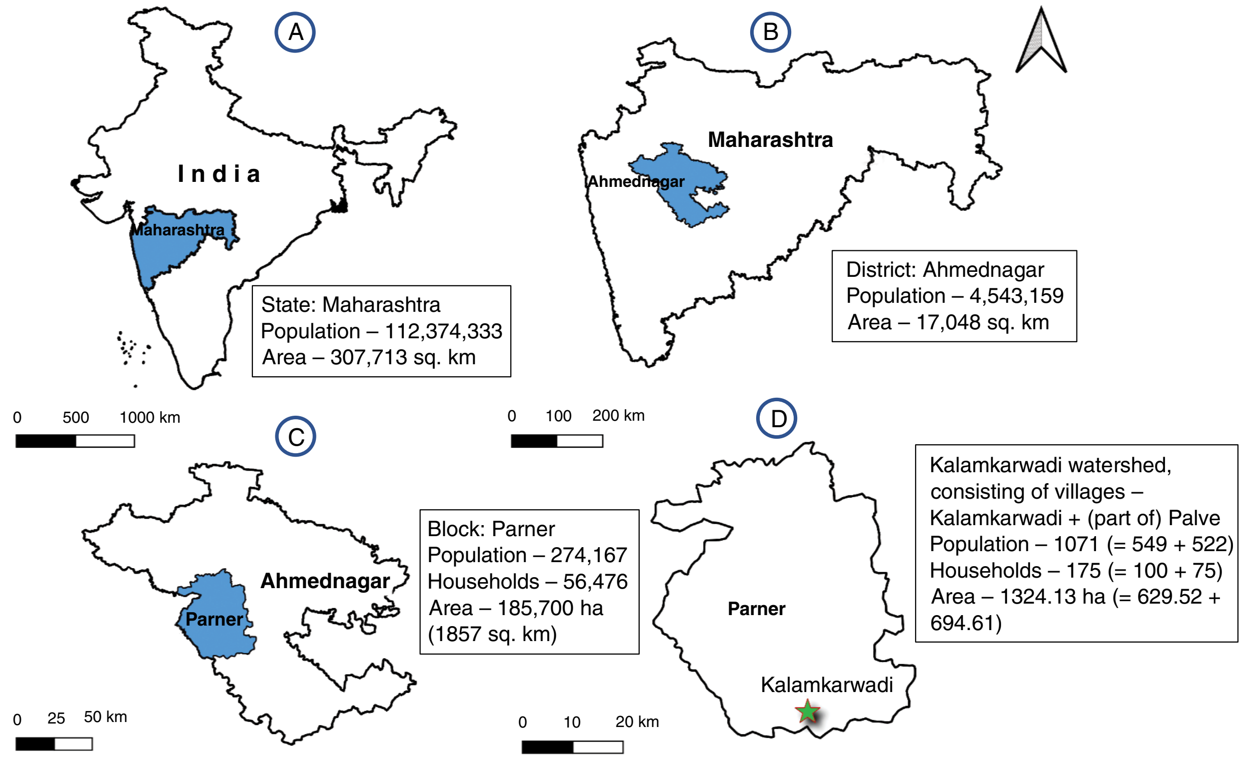
Table 15.3. Resilience attributes and indicators.

	Resilience attributes	Indicators in local context / What to look for
1	Reasonable profitability[a]	Economic viability in the long run; evidence of profits; extent of reliance on subsidies; type and size of investments
2	Social self-organization[a]	Community-based organizations that are inclusive and actively involved in decision-making
3	Ecological self-regulation[a]	Reliance on ecosystem services and common property resources in place of external inputs
4	Appropriate connectedness[a]	Connectedness between components of the system, such as crops and livestock, large farmers and landless laborers
5	Functional diversity[a]	Diversity in the ecosystem services provided within the watershed and on the farm; a variety of water resources; forest produce and other bio-based resources
6	Optimal redundancy[a]	Duplication or redundancy in the system, such as multi-cropping, a mix of livestock breeds, alternate irrigation sources, alternate livelihood sources
7	Spatial and temporal heterogeneity[a]	Diversity in the landscape, farm types, soil types and different cropping patterns in farms and over time (seasons/years)
8	Exposure to disturbance[a]	Small disturbances that test and increase the resilience of a system, such as exposure to droughts, leading to a shift to drought-resistant crops
9	Reflectivity and shared learning[a]	People and institutions that learn from past experiences and each other; specific changes or new practices introduced after significant shocks
10	Human capital building[a]	Education; diversified skills in the local community; adopting new practices and technology
11	Diverse policies[b]	Appropriate state and national policies (incentives, pricing, access to markets, etc.) that help farming systems become more profitable and sustainable in the long-term
12	Infrastructure and information for innovation[b]	Existing infrastructure; the adoption of new knowledge and cutting-edge technologies such as weather-based farm advisories through smartphone apps
13	Support for rural life[b]	Livelihoods attractive to all sections of the community; a lifestyle that is deemed as dignified by the community
14	Access to credit, insurance and other financial safety nets[c]	Credit from institutional lenders with viable terms, interest rates; awareness of and access to insurance; compensation for damages not covered by insurance
15	Equity (decision-making and power dynamics)[c]	Participation of marginalized sections of society (women, tribal, elderly, landless, etc.) in project planning, execution and general decision-making
16	Governance arrangements that support transformation[c]	Community-based institutions with discussions on climate, markets, disasters (pandemics like COVID); changes or preparedness for change among such institutions and community

Note: [a]attributes from Cabell and Oelofse (2012), [b]attributes introduced by Paas *et al*. (2021) and [c]new attributes added to the CRISI framework based on authors' analysis.

district experiences significant rainfall variability – varying from less than 200 mm to more than 900 mm annually.

Social Centre, a non-governmental organization based in Ahmednagar, Maharashtra, implemented a WSD project between 1996 and 2001. Considering the long-term impacts of climate change and the need to assess the sustainability of resilience-building interventions, data availability for more than 20 years was a key



Source: Government of India, Census 2011.

Fig. 15.2. Demographic details of the Kalamkarwadi watershed and its location vis-à-vis the country, India (A); the state, Maharashtra (B); the district, Ahmednagar (C) and the block, Parner (D).

consideration in selecting the case study. Care was taken to obtain consent from the local community for the research and ensure the case study had no unusual or unique characteristics, such as special caste and class demographics or proximity to urban areas. The Kalamkarwadi watershed satisfied these criteria and qualified as a representative WSD project in semi-arid Maharashtra.

Applying the CRISI framework to assess the resilience of Kalamkarwadi involved three visits between October and November 2020. The first visit involved an introductory and rapport-building meeting in the village, where the study's purpose was explained and consent for documenting all the discussions and use in research was sought. The system boundary for the study was discussed, and a detailed list of all relevant stakeholders was created. In the next two visits, we followed a PRA process (see Narayanasamy, 2009) for the assessment in Kalamkarwadi. The appraisal exercises consisted of semi-structured discussions with a multi-stakeholder group as well as FGDs with marginalized sections of the local community. The multi-stakeholder discussions had two to three members representing each stakeholder group, such as large farmers, small farmers, women, youth and elderly members of the local community, as well as researchers and development professionals who have been working with the WOTR for several years and experts in the areas of agriculture, land and water resource management. The FGDs were undertaken with members of marginalized groups like women and smallholder farmers to ensure their opinions and issues around the local power dynamics were appropriately captured. Quantitative data available at the village council and from project baseline and endline reports also contributed to the assessment of the case study.

Step 1: System description. The selected watershed consists of the entire village of Kalamkarwadi and a part of the Palve village. The total area of the watershed is 1324.13 ha, with a population of 1071 in 175 households. The Kalamkarwadi village has a larger proportion of households and agricultural lands within this watershed and lends its name to the watershed. Kalamkarwadi is distinct with a very homogeneous demographic in terms of caste – most families are *Marathas*. About 50% of the families are small and semi-medium farmers (< 4 ha), about 30% are medium farmers (4 to 8 ha) and the rest are large farmers (> 8 ha). The watershed has no landless families. The soils are light and highly permeable and have very low depth. Agriculture and livestock are the primary sources of livelihood in the watershed. In terms of local governance bodies, there are several active ones – a functioning village development committee (VDC), three self-help groups (SHGs) with 15 to 20 women in each, a dairy cooperative and a youth group.

WSD interventions were carried out under the Indo-German Watershed Development Programme (IGWDP) between 1996 and 2001. As documented in project completion reports and validated through interactions with the local community, the WSD project contributed to several positive impacts, such as increased water availability, reduced land erosion, better soil quality, an increase in the cropped area of more than 25% during the *Kharif* (monsoon) and 50% during *Rabi* (winter) season, increases of about 135% in grain yields and 42% in fodder yields and an improvement in milk production from about 705 l/day to 2024 l/day (Social Centre, 2002). Traditional crops in Kalamkarwadi included sorghum, pearl millet, wheat and pulses. After WSD, cropping patterns changed to include more cash crops, including vegetables, soybean and horticulture. These changes resulted in a significant improvement in income levels (Social Centre, 2002). Since 2017, the WOTR has been implementing a new project with the aim of climate-proofing the watershed. This project includes some maintenance work on older watershed structures, training programs on organic farming and improved agronomic practices to improve soil health, water budgeting and crop planning.

Together with the community and other stakeholders involved in the assessment, we decided that the time frame used in the assessment of Kalamkarwadi would cover 25 years, from the start of WSD in 1996 to 2020. The resilience of the system was evaluated for five specific time slices within the assessment period: 1996, 2001, 2009, 2018 and 2020. These five time slices correspond to the start of the WSD project, the completion of the WSD project, a year of normal rain, a drought year and the year of most recent available data, respectively.

Step 2: Challenges. Before implementation of WSD activities, poor agriculture and livestock productivity meant that a large proportion of the limited household income was used for purchasing food, grain and fodder. Migration for work was common, with at least one person from each household seeking work in larger villages and towns. Drinking water was a perpetual challenge during the summer months, and the village had to rely on water supply by tankers.

Interactions with the local community during our field visits and a comparison of geographic information system images show that from 2001 to 2020, the WSD's positive impacts have largely been sustained. However, an analysis of local rainfall data shows significant challenges of drier conditions and an increasing frequency of droughts. Further, the annual average rainfall has declined from about 580 mm in 1986 to about 480 mm in 2020 (Department of Agriculture, 2021). Such a shift toward drier and more arid conditions is corroborated by local experiences and climate change impact assessments across central India (Ramarao *et al.*, 2019; Krishnan *et al.*, 2020).

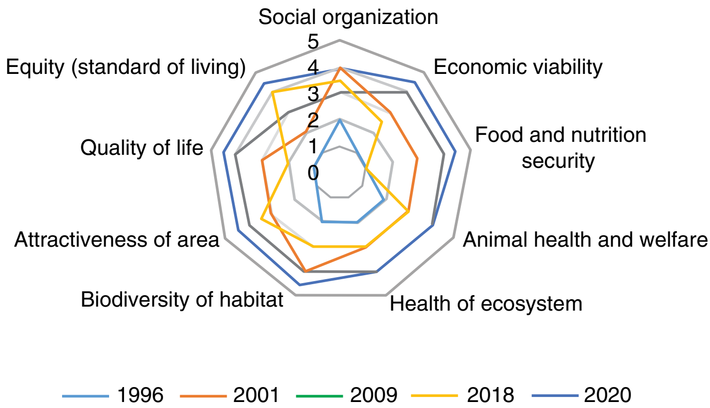
Although soil health and access to water resources have improved, many farmers have lands in upper parts of the watershed that are unproductive. Most WSD activities focus on common lands in the village and haven't led to investments in private lands, like land levelling. The PRA exercise also highlighted challenges in managing the watershed resources due to differences between the watershed's geographical boundaries and the administrative boundaries of the two villages and the village council (*gram panchayat*).

Step 3: Functions of the watershed. To assess the watershed functions, the stakeholders in the PRA rated the indicators in Table 15.2 on a scale of 1 (poor) to 5 (excellent), indicating their relative performance over the assessment period. The scoring considers data from different sources for the list of indicators for each function (Table 15.2) and the consensus of the group involved in the PRA. The scoring was grounded in available information that included both qualitative and quantitative data. Qualitative data on indicators such as readiness for voluntary labor, diversity in diet, perception of village youth, waste management system and migration scenario were sought on the basis of recall. Quantitative data on indicators such as community-based institutions, total crop and livestock production, income, soil quality, malnutrition and BPL cards were obtained from project completion reports and from information available with the village council. Such data were discussed in the multi-stakeholder group before arriving at the final score for each function.

Although the absolute value of the scores may be contested, we believe the direction of the scores over time provides the most value. The discussions during the appraisal exercise showed a significant improvement in the number of community-based organizations – like the VDC and women's SHGs – and community engagement since the initiation of WSD activities. Assessment results for each of the functions at the five time slices are shown in Fig. 15.3. No significant quantities of other bio-based resources were reported in Kalamkarwadi (and hence they are excluded from Fig. 15.3).

An overall improvement across all indicators is observed from 1996 to 2020, driven by improved natural resources and better agricultural productivity after the WSD interventions. However, a dip in performance can be observed during the drought year 2018 for all indicators except social organization and equity (standard of living) – which increased even in 2018. Social organization increased because the challenges of the drought motivated the community to collaborate and find solutions such as purchasing water through tankers. The factors that led to an increase in equity (standard of living) are discussed in Step 6.

Step 4: Resilience capacities. We started the assessment of the resilience capacities by first defining anticipation, robustness, adaptability and transformability in the local context and discussing relevant indicators for each (Table 15.3). Given their experiences of frequent droughts and the recent COVID-19 pandemic, anticipation was a capacity that farmers could quickly relate to and helped validate its inclusion. We then referred to the performance of the watershed functions (Fig. 15.3) and sought the stories behind the performance. For instance, we explored why food and nutrition security dropped during the drought in 2018 but bounced back rapidly during the good rains of 2020. The appraisal exercise showed that although water-intensive cash crops have brought in better profits, they have



Source: Primary data collected in this study.

Fig. 15.3. Perceived performance of the watershed functions in Kalamkarwadi.

increased the farmers' vulnerability to droughts – an indicator of the system's lack of robustness.

Based on the indicators mentioned in Fig. 15.3, we sought evidence for each resilience capacity in Kalamkarwadi. Several WSD interventions had a positive influence on robustness and anticipation. For instance, we saw a positive influence on anticipation through: (i) the establishment of the VDC, SHGs, dairy cooperative and youth groups providing forums to discuss risks; and (ii) the exposure, training and capacity-building measures in the recent climate-proofing project contributing to an improved understanding of the increasing frequency of extreme weather events and the need to take proactive actions. A positive influence on robustness was seen through: (i) the WSD interventions such as drainage line treatments and area treatments that decreased soil erosion and improved the water table; and (ii) the introduction of borewells for drinking water, which helped the community during droughts. There were, however, some unintended consequences – such as the shift toward water-intensive cash crops and cross-bred cattle, which have increased the risk of heat stress and droughts. Although the community coped with buying tanker water and fodder during the 2018 drought, there is recognition that these changes have reduced its adaptability to a drier and more variable local climate. We found limited evidence that contributed to transformability. The introduction of biogas units linked to toilets was transformative in the behavioral changes it brought about (through its contribution to improvement in quality of life and a more integrated farm–livestock system), but the current lack of alternatives to the dominant crop–livestock farming system suggests that the capacity for transformability is not very strong yet.

STEP 5: RESILIENCE ATTRIBUTES. A list of resilience attributes derived from literature on the resilience of farming systems served as a starting point for discussions on unforeseen stresses that went beyond the commonly experienced climate risks like droughts and unseasonal rain. The appraisal exercise helped refine the list of attributes to the semi-arid context, as discussed in Section 15.2 (Table 15.3). The attributes were then rated on a scale of 1–5, indicating the degree to which each attribute was present during the assessment period. Appraisal participants were asked to give a score of 1 to the poorest form of the attribute they could imagine, such as relying on a single crop on a small piece of land (indicating the lack of diversity or redundancy), and to give a score of 5 to the best possible form of the attribute, such as multi-cropping and a mixed crop and livestock system. The scores as well as comments from stakeholders that support the relative scores of the attributes are presented in Table 15.4.

STEP 6: REFLECTION. The final step involved reflecting on the results of the resilience assessment from earlier steps, making revisions where required

Table 15.4. Performance of the resilience attributes of Kalamkarwadi. (Source: Primary data collected in this study.)

	Resilience attributes	Scores (1–5: low–high)	Indicators that support the relative score assigned
1	Reasonable profitability	3	Income from crops and livestock has increased, but so have input costs and losses due to extreme weather events.
2	Social self-organization	4	The VDC and the SHGs have sustained even after projects that initiated them have been completed.
3	Ecological self-regulation	3	Water resources are very sensitive to rainfall and suffer during a drought, such as in 2018. Needed to be supplemented with purchased water.
4	Appropriate connectedness	5	Success of the biogas linked to toilets has brought about a lot of connectedness between crops, livestock and community household needs.
5	Functional diversity	4	Mixed crop–livestock systems and inter or mixed cropping provide diversity as well as some redundancy.
6	Optimal redundancy	4	In addition to the points under functional diversity, increased sowing area and some non-farm income for smallholders have helped.
7	Spatial and temporal heterogeneity	5	Farmers often have fragmented land holdings and leave some of the less productive land parcels fallow. In years of good rainfall, these provide the opportunity for additional yield. Crop rotation provides temporal heterogeneity.
8	Exposure to disturbance	3	Exposed to recurrent droughts but has not to led to major changes in the crop choices or the predominant crop–livestock system in the village.
9	Reflectivity and shared learning	4	The success of all the watershed work has involved many demonstrations and learning from each other's experiences.
10	Human capital building	3	Farmers see the need for training related to higher value chain agricultural produce, marketing and diversifying livelihoods, as these skills are currently inadequate.
11	Diverse policies	3	Do not find the current policies very supportive of agriculture, especially regarding market access and minimum support price during public procurement.
12	Infrastructure and information for innovation	2	New technology like weather-based apps for farmers have been introduced but not yet very widely adopted.
13	Support for rural life	3	Moderately happy with rural life and would prefer if children got a better education and went to cities.
14	Access to credit, insurance and other financial safety nets	2	When institutional credit was not available, farmers did have access to informal sources of credit but at much higher interest rates.
15	Equity (decision-making and power dynamics)	4	The efforts to make the VDC participatory and inclusive have been sustained even after the completion of the watershed activities.
16	Governance arrangements that support transformation	1	Governance arrangements for business-as-usual scenarios (like purchasing water through tankers during a drought or digging a borewell) seem adequate. However, no specific vision for long-term planning or major transformational actions was observed (like investing in other areas of the agri-value chain or non-farm livelihoods).

and reflecting on the adequacy of the climate resilience-building measures. For instance, while discussing the performance of the function of equity (standard of living), the appraisal exercise had initially suggested a dip in the score during the 2018 drought, in line with the overall reduction in income and increased losses during the year. However, while reviewing the results, the multi-stakeholder group realized that the losses sustained by the better-off farmers with higher investments were much more significant than those sustained by the marginal farmers. Some of the marginal farmers depended on income from other sources – such as non-farm labor – and suffered relatively lower losses. Therefore, equity (standard of living) had gone up during 2018 while the performance of most other functions had decreased. This insight also shows that an alternate source of income contributes to functional diversity and optimal redundancy in the system (Table 15.4), leading to improved resilience for smallholder farmers.

Reflecting on the adequacy of the resilience-building measures, the appraisal stakeholders agreed that WSD interventions had contributed to several important gains – like improvements in soil quality, water table, vegetative cover, agriculture and livestock productivity, community engagement and equity in access to employment and quality of life. These have contributed to an increase in resilience capacities like robustness and anticipation. However, there were limits to focusing on WSD interventions alone as a development strategy. Over the years, cropping patterns in Kalamkarwadi have changed to include more cash crops that are also water intensive. Although they have led to better income levels in years of good rainfall, the losses during drought years – such as in 2018 – were substantial. In terms of livestock, the type and quantity of assets have changed, from 92 cross-bred and 59 indigenous cows in 1996 to 304 cross-bred and 41 indigenous cows in 2020 and a significant increase in milk production over the years.

Here again, the low rainfall in 2018 impacted the milk output and led to the distress sale of cattle in some cases. These experiences highlight that focusing on WSD interventions alone is not adequate and there is an urgent need to focus on the resilience capacities of adaptability and transformability while also improving resilience attributes like access to credit, insurance and other financial safety nets; infrastructure and information for innovation; and governance arrangements that support transformation. Exposure, training and capacity-building measures in recent years have improved understanding about the limits of WSD in the local community. These measures are also slowly motivating the adoption of innovative practices like locale-specific and weather-based agro-advisories, water budgeting and crop planning in the ongoing climate-proofing project.

15.4 Evaluating the Relevance of the CRISI Framework

In this section, we evaluate the framework's relevance for assessing farming systems' climate resilience in the context of semi-arid India. Similar questions about the relevance of frameworks and indicators have been asked in the domain of climate change adaptation (Dinshaw *et al*., 2014; Pringle and Leiter, 2018; Hallegatte and Engle, 2019). Considering the similarities in challenges between assessing adaptation and assessing resilience to climate change, we draw inspiration from the Adaptation Metrics Mapping Evaluation (AMME) Programme (see IPAM, 2021) and identify the following three criteria to evaluate the CRISI framework: (i) identifying all relevant stakeholders and their needs; (ii) following a systems perspective while assessing resilience (as opposed to a disciplinary/sectoral perspective); and (iii) providing information for decision-making processes. We find that the CRISI framework adequately meets these three criteria, as discussed below.

15.4.1 Identifying all relevant stakeholders and their needs

Step 1 of the CRISI framework explicitly focuses on identifying stakeholders, governance structures and power dynamics within the farming system, and Step 2 seeks to identify stakeholders' views on existing stresses and vulnerabilities and what they expect, including short-term and long-term views. Identifying the relevant stakeholders was also done in a participatory manner with the involvement of the local community as a part of the first step. The appraisal exercise then consisted of a diverse group that included large farmers, small farmers, women, youth and elderly members of the local community; development professionals who have been working with the WOTR for several years; and experts in the areas of agriculture, land and water resource management. Although the effort was to try to reach a consensus on various aspects of the assessment, differing opinions, especially from the marginalized sections of the group, were separately recorded and appropriately captured in the final scores. For instance, the smallholder farmers were concerned about risks during shorter time frames like an agricultural season (3 months–1 year) and dissatisfied with access to credit, insurance and other financial safety nets (low score in Table 15.4). The CRISI framework thus enables identification of the needs of a diverse and relevant set of stakeholders.

15.4.2 Following a systems perspective while assessing resilience

Step 1 of the CRISI framework begins with a discussion about the stakeholders' views of the farming system, including what they value and why. Using such a participatory process to define the system, as opposed to an expert-driven identification of the system and its sub-components, is key to adopting a systems perspective (Darnhofer *et al.*, 2012; Sriskandarajah *et al.*, 2016). Another key characteristic of a systems perspective is adopting an inter- and transdisciplinary approach as opposed to a disciplinary approach (Gibbon, 2012). The CRISI framework is based on the frameworks by Meuwissen *et al.* (2019) and the RAPTA, which are both embedded in a systems perspective.

This can be seen in the comprehensive list of functions, capacities and attributes used in CRISI that cover all five types of capital (physical, natural, social, human and financial) that are often cited to demonstrate a holistic systems approach to sustainability (DFID, 1999; Porritt, 2007). Therefore, the CRISI framework is not restricted to assessing the impact of issues related only to irrigation, agricultural productivity or income but rather looks at the resilience of the farming system from a much more holistic and interconnected perspective. The final step on reflection is also important from a systems perspective as it gave the opportunity to reflect on backward and forward linkages of interventions and their consequences. For instance, some of the unintended consequences discussed in Step 4 of the case study, such as WSD prompting the shift to water-intensive cash crops and cross-bred cattle, came to light during this step.

15.4.3 Providing information for decision-making processes

Applying the CRISI framework to assess the Kalamkarwadi watershed provided numerous insights for decision-making, such as farmers' current preferences for water-intensive cash crops and hybrid livestock breeds and the lack of incentives to change. Also, given the vulnerability of current livelihoods to changing rainfall patterns, the need for diversifying livelihoods and investing in other areas of the agricultural value chain was an important insight. In addition, a very practical aspect of CRISI from a decision-making perspective is its spatial scale of application. Participants in the appraisal found the selection of the micro-watershed a useful unit for analysis as this is also the scale at which WSD projects are typically implemented (Symle *et al.*, 2014). Another aspect important to decision-making is one of timescales. Applying the CRISI in Kalamkarwadi shows the value of considering longer timescales during assessments, since issues such as changing rainfall patterns and the need for additional land management interventions became explicit only when the discussions covered a timescale of more than 20 years.

15.5 Discussion and Conclusion

To arrive at a framework for assessing the climate resilience of semi-arid farming systems in India, we developed the CRISI framework based on existing literature on resilience assessments, the local knowledge and experience of the research team and insights from application of the framework to a case study. We also evaluated the framework's relevance against three criteria – identifying all relevant stakeholders and their needs, following a systems perspective while assessing resilience and providing information for decision-making processes – and found that the framework adequately meets them. The CRISI framework's strengths lie in its holistic understanding of resilience, its focus on participatory approaches and its customized lists of functions, indicators and attributes that help operationalize it for assessing the resilience of farming systems in semi-arid India.

The framework assesses the farming system's resilience to specific climate stresses and other forms of uncertainty, risk and externalities. Droughts are a recurrent and specific climate stress faced by communities in semi-arid India, but other forms of uncertainty in weather – like a delayed onset of the monsoon, dry spells, unseasonal rains at different times of the year and heat waves – and market fluctuations are being experienced with increasing frequency (Kuchimanchi *et al.*, 2019; Singh *et al.*, 2019). The CRISI framework factors in the drivers of vulnerability such as income, food security, the health of the ecosystem, equity and quality of life. It also factors in the need to anticipate challenges and transform the system through appropriate resilience capacities, resilience attributes and a focus on reflective learning.

In assessing the resilience of semi-arid farming systems in India, the CRISI framework makes several improvements over other resilience assessment frameworks. It goes beyond impact assessments that rely on biophysical and economic indicators, focusing on issues such as equity and prompting discussions around what would enhance resilience in the future. It broadens the range of resilience-building activities that can be assessed, highlights the need for a diverse set of stakeholders and encourages assessments over longer time frames. The bias toward focusing on the status quo during the assessment is reduced by referring to quantitative data from earlier years, such as geographic information system images and information on crop sown areas, during the PRA exercises to bring more objectivity into the assessment of the earlier time period. Step 6 of the framework also brings in critical reflection about the system's resilience vis-à-vis emerging challenges, such as climate change, and the need to build the resilience capacities of adaptability and transformability of the farming system.

Through the case study, we demonstrated the application of the CRISI framework at the micro-watershed scale, and we believe that it has potential to be used in the work of government agencies, non-governmental organizations and research institutes that focus on semi-arid farming systems in India. Several government programs in India are aimed at improving natural resources to reduce the impact of droughts in semi-arid regions, such as the Integrated Watershed Management Projects (IWMP) under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) scheme and the soil and water conservation work carried out under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). The CRISI framework has application potential in generating evidence-based insights that can guide such programs in the planning, monitoring and evaluation stages and in turn contribute to shaping future agriculture policy in India.

In applying the CRISI framework, one limitation that we encountered was that this process was data-intensive and some participants in the appraisal exercises found the framework, with its ten system functions, four resilience capacities and 16 resilience attributes, quite cumbersome and time-consuming. However, there was consensus among the participants that its usefulness for decision-making would be lost by trying to simplify the framework. In the case of Kalamkarwadi, we had the benefit of existing baseline and endline data, such as geographic information system images and surveys on agriculture and livestock production. We were able to supplement this quantitative data with three meetings for additional qualitative data. If such extensive baseline and endline data were not available, applying the CRISI framework would require additional time for the primary data collection. A workaround for this could be relying on secondary data from local administrative offices, with checks on the quality and reliability of the data. It also must be noted that although applying the CRISI framework identifies interventions that have contributed to the current resilience of the farming system, it cannot establish a more certain attribution. Considering the complexity of issues that farming systems face, several other socio-economic factors likely also contribute to the system's resilience.

We see two specific areas of further research related to the CRISI framework – in socio-ecological systems of larger or smaller scales and in different development contexts. Although the CRISI framework has some scale-independent indicators (i.e. they do not depend on the geographical size or population) such as soil quality, water table depth and per capita income, other indicators, such as the number of institutions and total food production, are very specific to the size of the micro-watershed and its population. Challenges related to smallholder farmers in India, including the specific challenges faced in semi-arid contexts, apply in other types of farming systems in India as well as in other developing countries (Behera and France, 2016). The COVID-19 pandemic has further shown that issues around equity, the resilience capacity of anticipation and attributes such as reflective and shared learning, access to financial safety nets and governance arrangements that support transformation apply even in developed societies.

While assessing case studies from different contexts, it would be important to keep in mind that the ratings of the indicators might not be directly comparable. However, we believe it is still possible to use the CRISI framework for such comparative assessments by focusing on the direction of change (for indicators of the functions, capacities and attributes) rather than the absolute values, and by focusing on the stories behind the performance of the indicators. In an upcoming publication, Srinidhi *et al.* (2023) demonstrate the application of the CRISI framework in such comparative assessments by focusing on the direction of change (increasing or decreasing) and the relative change over the time period of the assessment (comparing the difference between the performance of indicators before and after intervention).

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