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RESEARCH ARTICLE



# Climate resilient development pathways for farmer producer organizations in semi-arid India

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## ABSTRACT

Small and marginal farmers in semi-arid India face vulnerabilities stemming from low agricultural productivity, degraded ecosystems, and market and climate uncertainties. Farmer producer organizations (FPOs) have emerged as collectives to address these challenges and enhance climate resilience. Despite their potential in promoting empowerment and inclusive decision-making, FPOs in India struggle to develop successful business plans and cope with extreme weather events. This study aimed to identify climate resilient development pathways (CRDPs) for FPOs in semi-arid India that can simultaneously address development and climate change concerns. We collaborated with four FPOs in Maharashtra and eight experts to co-create CRDPs for these FPOs. The CRDPs challenged existing visions; when confronted with data on increasing climate risks based on critical climate-stress moments, the FPOs included targeted climate resilience-building measures. The application of critical climate-stress moments for CRDP development is a methodological advancement, particularly in cases of contested goals, ambiguous vision, and multi-stakeholder involvement. Further, depending on their agricultural products and stage of development of climate resilience, FPOs initially prefer incremental adaptation measures over larger transformative changes. We recommend that current policies for promoting FPOs in India carefully consider the differences in types of FPOs and stage of development in climate resilience.

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## KEYWORDS

Climate resilience; climate change adaptation; farmer producer organizations; development pathways; small farmers

## 1. Introduction

Small and marginal farmers constitute over 85% of the farming population in India (Department of Agriculture, 2019). Particularly in semi-arid rainfed regions, these farmers face multiple vulnerabilities, including low agricultural productivity, degraded ecosystems, and uncertainties associated with market fluctuations and weather patterns (Behera & France, 2016; Chand, 2022). The adverse impacts of climate change further exacerbate the challenges faced by these farmers, and projected climate change impacts in these regions include heatwaves, droughts, floods, and irregular rainfall (Aggarwal, 2008; Pathak et al., 2014). In response to many of the challenges of small and marginal farmers, farmer producer organizations (FPOs) are being promoted by the Government of India (Govil & Neti, 2022; Neti et al., 2019; Prasad & Dutta, 2021).

FPOs incentivise collective action and economies of scale and can provide farmers with enhanced market access, improved infrastructure and storage facilities, and investments in building resilience (Govil et al., 2020; Kumari et al., 2021). Nikam et al. (2024) find that FPOs helped farmers better access extension and advisory services and led to an overall

improvement in the income per unit area. Unfortunately, FPOs encounter various challenges. At an institutional level, FPOs struggle to understand climate risks and access human resources, financial and technical support, and market knowledge (Chintala & Mani, 2022; Nikam et al., 2023; Tagat & Tagat, 2016). The primary stakeholders within these FPOs are smallholder farmers and their families, who face an increasingly uncertain future due to the climate-linked yield variability affecting both agricultural productivity and household food security (Mahato, 2014; Ray & Chowdhury, 2015). Furthermore, uncertainties surrounding climate change projections in semi-arid India exacerbate the challenges of adapting to climate change for these smallholder farmers (Singh et al., 2018, 2021). Mourya and Mehta (2021) discuss the potential of FPOs in helping India meet its sustainable development goals and the ability of these institutions to reach a large number of smallholder farmers, while Pallavi et al. (2024) discuss the potential of FPO as “intermediaries of sustainable transition” depending on how they position themselves within the agrarian ecosystem. To address the dual objectives of development and climate action, the concept of climate resilient development

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pathways (CRDPs) has recently gained significance (Schipper et al., 2023; Werners, Sparkes, et al., 2021).

CRDPs integrate adaptation, mitigation, and development decisions to promote sustainable development (Schipper et al., 2023; Sparkes & Werners, 2023). The pathways concept offers decision-focused approaches that incorporate flexibility, enabling adaptation and development planning without becoming locked into maladaptive outcomes (Sparkes et al., 2023; Werners, Sparkes, et al., 2021). The choices to be made along the way will need several stakeholders and explicit discussions around synergies and trade-offs (Schipper et al., 2023; Werners et al., 2018). Werners, Sparkes, et al. (2021) note that there are differences in the way the concept of CRDPs has been applied in related domains of climate action, resilience, development, and pathways, leading to conceptual ambiguity. Some of the early applications of the pathways concepts have been in developed contexts and where the vision or adaptation needs were well defined (e.g. Haasnoot et al., 2013). Empirical evidence of the application of CRDPs remains limited, particularly in developing contexts (Stringer et al., 2022; Taylor et al., 2023). These developing contexts tend to be areas where the number of stakeholders is large, which interferes with setting a clear vision for the pathways (Bhave et al., 2018; Werners, Wise, et al., 2021). Further, the importance of considering the role of politics and power in operationalizing CRDPs is highlighted by Sánchez Rodríguez and Fernández Carril (2024). In a thought provoking commentary on the state of climate change adaptation research, Singh (2024) discusses critical methodological gaps such as, the lack of – (i) quantifiable metrics, (ii) forward looking tools assessing adaptation outcomes over time, and (iii) transdisciplinary approaches. Discussing recent advances around the subject of climate resilient development, Singh (2024) also highlights the need to evaluate if CRDPs “better capture the inequities and path dependencies we must negotiate”. This study seeks to contribute to the empirical evidence concerning CRDPs in developing contexts and presents an approach to address the challenge of creating CRDPs where the vision is ambiguous.

The primary research question for this study is ‘what are climate resilient development pathways for FPOs in semi-arid India?’. Based on the challenges of FPOs in addressing both development and climate concerns, as well as the knowledge gaps around operationalizing CRDPs, specific questions we address in our research are – (i) what are current business plans of FPOs? (ii) what are their challenges (climatic and non-climatic)? (iii) what are current coping strategies? and (iv) what more can the FPOs be doing to improve their future climate resilience?. To address these questions, we collaborated with four FPOs in Maharashtra and eight experts in agricultural and climate aspects. The methodology employed involved initial meetings with each FPO to document their existing business and development plans and challenges and to identify areas for improving climate resilience. The process of documenting challenges included identifying specific risks related to temperature and rainfall within the agriculture season that the FPOs are most concerned about. Such specific, time-bound moments when communities are especially vulnerable to climate-related risks are referred to as critical climate-stress moments (Groot et al., 2017; Shah et al., 2021a).

Findings from our interactions with the FPOs were then discussed with selected experts to generate recommendations of climate resilience-building measures. The recommendations were shared with the FPOs, which then prioritized, selected, and sequenced the interventions in response to the critical climate-stress moments, leading to a co-creation of CRDPs.

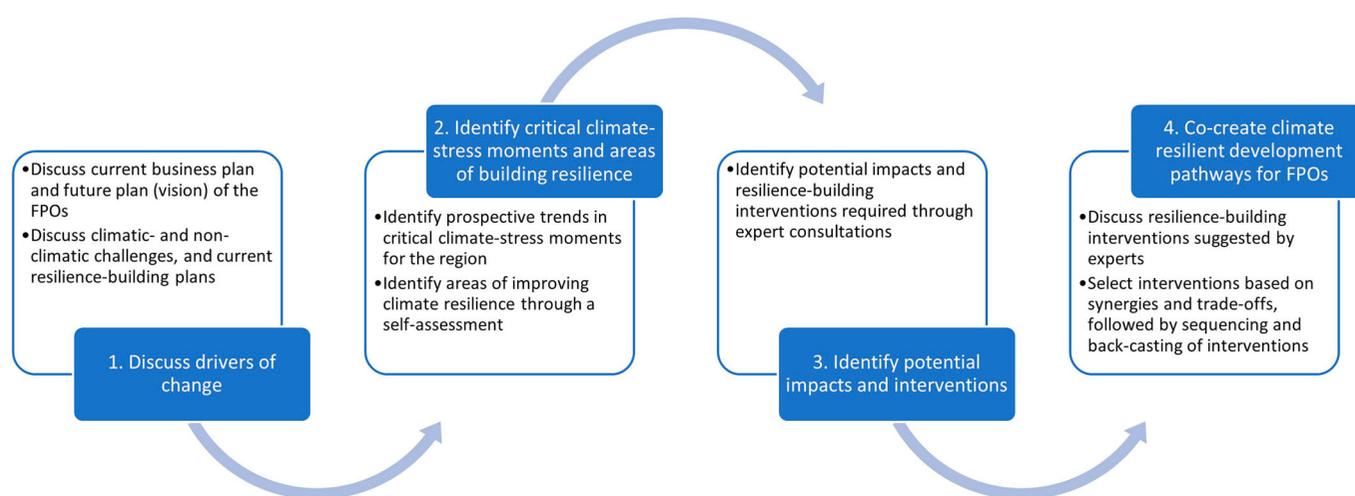
This study generated a set of CRDPs for the individual FPOs, tailored to the products they deal in, their business plan, and stage of development in climate resilience. The CRDPs show a preference for robust and incremental resilience-building interventions, with little inclination towards transformative changes. This research contributes to the empirical application of CRDPs in the context of FPOs in semi-arid India. The use of critical climate-stress moments as the basis to co-create the pathways represents a methodological advancement in cases where there are contested goals or lack of clarity in the vision. The study also highlights the potential of promoting FPOs in India to enhance the climate resilience of its farming systems.

## 2. Methods

Given the synergies between CRDPs and adaptation pathways (Haasnoot et al., 2024; Werners, Sparkes, et al., 2021), we adopted a four-step process to co-create CRDPs for FPOs based on the methodology for developing adaptation pathways suggested by Werners et al. (2018). The four steps and the details that we focused on during each step are shown in Figure 1.

### 2.1. Selecting case studies

Of the four FPOs selected as case studies, two were production-oriented FPOs and two were market-oriented FPOs. The Government of India provides various legal provisions for registering different types of farmer collectives, including the Cooperative Societies Act and the Companies Act (Govil et al., 2020; NAFPO, 2023; Nikam et al., 2024). In this study, we use the term ‘FPOs’ to encompass all such farmer collectives without differentiating between their legal registration forms. Within the emerging landscape of FPOs in India, a clear typology of FPOs that are production oriented or market oriented seems to be emerging (Phadke et al., 2023). Production-oriented FPOs focus on procuring agricultural produce from their shareholders. They typically consist of 300–1,000 members, who are farmers from nearby villages. These FPOs do not engage in much value addition and typically sell their produce at regulated market yards to buyers involved in further value addition and sales to consumers. Meanwhile, market-oriented FPOs are involved in significant value addition and typically, direct sales to consumers. These market-oriented FPOs also tend to be larger in terms of membership and volume of sales. They often include a mix of farmers and occasionally other production-oriented FPOs as a part of the umbrella market-oriented FPOs. Although such a typology is not recognized in policy documents, it aligns with observations made in other studies related to FPOs (Joshi & Prasad, 2023; Phadke et al., 2023). To ensure an equal representation, we selected two case studies of each FPO type in our research.



**Figure 1.** Four-step process for developing climate resilient development pathways for FPOs in semi-arid India (adapted from Werners et al. (2018)).

The selection criteria included FPO location (in semi-arid regions), interest in participating in the study, and consent for sharing data. Krushiyug Farmer Producer Company in Jalna District and Ankur Farmer Producer Company in Ahmednagar District are production-oriented FPOs, while Sahyadri Farmer Producer Company in Nashik District and Abhinav Farmers Club in Pune District are market-oriented FPOs. The four steps involved in co-creating the CRDPs are elaborated below.

## 2.2. Discussing drivers of change for FPOs

The first step involved understanding FPO operations, with details of current business plan, vision (if any), climatic and non-climatic challenges, and any current resilience-building plans. For this, a full-day workshop was organised for each of the four FPOs separately. Before the workshop, we engaged in two rounds of communication with key persons in each FPO to brief them about the study and identify participants representing the FPO for the meeting. In every workshop, the chief executive officer and four or five other key decision makers (e.g. those in charge of procurement, sales and marketing, and logistics, and members of the board of directors) were present. These workshops were held in April and May of 2023.

The workshops started with an introduction to the study from our side. The FPOs then provided an overview of their operations, including their current business plan and future plans (vision). The discussion around future vision included questions about agricultural products that the FPO was keen on dealing with in future, expectations around scale of operations and profits, contribution of the business to the quality of life of FPO members, etc. Subsequent discussions were around challenges, including both climate- and non-climate-related issues, and finally, questions around current resilience-building plans of the FPOs. The overall objective of the discussions was to understand if there were any drivers for change, in terms of strategy or operations. Consent for audio recording the workshops was taken from the participants; the recordings were later transcribed. A detailed session plan is available in Appendix 1.

## 2.3. Identifying critical climate-stress moments for FPOs and areas of resilience building

Step 2 focused on selecting two climate risks that the FPOs are most concerned about, and on identifying areas of improving climate resilience. To understand future climate risks, we relied on the concept of critical climate-stress moments (Groot et al., 2017; Shah et al., 2021a), which are specific, time-bound moments when communities are vulnerable to climate stresses. They result from a combination of socio-economic and biophysical conditions of the farming system and climate-related stresses that the farming system is exposed to (Groot et al., 2017; Shah et al., 2021a). Srinidhi, Smolenaars, et al. (2024) identified five critical climate-stress moments pivotal for semi-arid farming systems in India: (i) increasing volume of late-monsoon (September–October) rainfall, (ii) rising winter temperatures, (iii) increase in the number of days with temperatures exceeding 40°C, (iv) increase in days with heavy rainfall (>25 mm), and (v) increasing rainfall during the dry season (January–March). These critical moments occur when important agronomic decisions need to be taken, such as sowing, harvesting, and irrigating, representing moments of considerable risk.

We provided the FPOs with an overview of the climate data for the region, including trends from our analysis of critical climate-stress moments (Srinidhi, Smolenaars, et al., 2024). The FPOs were shown graphs that included historical data, as well as prospective trends based on the analysis of selected climate models. Based on the trends shown, the FPOs prioritized two critical climate-stress moments that they are most concerned about: one related to temperature and one related to precipitation. These critical moments were used to select and sequence potential resilience-building interventions in the final step. The FPOs also discussed their own experiences around dealing with the critical climate-stress moments and the critical moments that they were most concerned about. These adaptations or climate resilience-building strategies of the FPOs complement the points mentioned in step 1 on challenges and current resilience-building plans.

We also identified areas of improving climate resilience in step 2 through self-assessment of climate resilience attributes

by the FPOs. The climate resilience attributes were taken from the Climate Resilience in Semi-arid India (CRISI) framework, developed specifically for semi-arid farming systems in India (Srinidhi, Werners, et al., 2024). The six-part framework offers an elaborate and comprehensive assessment of a farming system's climate resilience. Here, we used the part of the framework that specifically focuses on identifying areas of improving climate resilience through an assessment of 16 resilience attributes. These resilience attributes are competencies such as self-organization, diversity, and reflectivity, which enhance the system's resilience. During the workshop, participants were asked to consider each attribute and state whether it was relevant or not for their FPO. For the attributes they considered relevant, they were asked to give the FPO a score of 1–5, reflecting their views of the worst to the best condition for that attribute. The attributes that received the lowest scores were identified as areas for improving climate resilience for the FPOs. A detailed session plan is available in appendix 1, along with the list of climate resilience attributes from the CRISI framework in Appendix 2.

#### 2.4. Identifying potential impacts and interventions

The objective of the third step was to understand the potential impacts of the critical climate-stress moments and identify targeted climate resilience–building interventions. To do this, we collaborated with experts to identify potential impacts of climate change on the FPOs and necessary interventions for building resilience. The criteria for the selection of the experts included expertise in various segments of the agricultural value chain and willingness to participate in the study. The areas of expertise were (i) finance, (ii) social inclusion, (iii) agriculture policy, (iv) livestock, (v) agronomy, (vi) agri-goods purchasing, (vii) FPO logistics, and (viii) climate science. All the expert meetings were conducted in May 2023. During the interaction with experts, we shared (i) basic details of the FPOs' business plan and challenges (from step 1), (ii) details of the climate resilience self-assessment of the FPOs (from step 2), and (iii) critical climate-stress moments prioritized by the FPOs (from step 2). Based on these inputs, the experts discussed the potential impacts of climate change on the FPOs and suggested a number of resilience-building measures that could be adopted by the FPOs in the future (step 3). A detailed session plan of the expert interviews is provided in appendix 1.

#### 2.5. Co-creating climate resilient development pathways for FPOs

The co-creation of CRDPs in step 4 of our research was done in half-day workshops for each FPO in June 2023. During the meetings, we started with a recap of the key takeaways from the first meeting, including the FPO's vision, challenges, and current plans; critical climate-stress moments; and climate resilience self-assessment. We then introduced the resilience-building interventions suggested by the experts. We did not undertake a formal appraisal or ranking of the potential interventions. However, the FPOs were asked to consider all the potential resilience-building interventions and select and sequence interventions based on a qualitative understanding

of (i) the areas of improvement identified by the climate resilience self-assessment, (ii) perceived climate risk from the increasing temperature or rainfall trends (critical climate-stress moments), (iii) their existing adaptation interventions or plans, and (iv) potential synergies and trade-offs between interventions. We prepared charts with the prospective trends in critical climate-stress moments and an overview of the climate resilience self-assessment scores. These prompts served as useful motivators to select and sequence future interventions. The sequencing led to the creation of CRDPs for each FPO. The initial pathways were hand drawn on white boards during the workshop. Later, these were transformed into digital figures and shared with workshop participants for verification.

### 3. Results

#### 3.1. Drivers of change

Both production-oriented FPOs face challenges to establish a viable business plan for their agricultural products. While Krushiyug is struggling to generate profits through maize and soybean, Ankur has had similar challenges with onions. Both FPOs are also involved in procuring agricultural inputs in bulk and retail sales to farmers. The FPOs do not have a clear vision or business strategy for the future, but they anecdotally stated a desire to grow in multiple orders of magnitude, 5- to 100-fold growth, in revenue by 2050 and to maintain reasonable profitability. The two FPOs see potential in diversifying existing cropping patterns to include vegetables and integrating livestock and dairy. In terms of climate-related challenges, both the FPOs cite the increasing incidence of heavy rainfall towards the end of the monsoon (Kharif) cropping season (i.e. during September and October) and increasing temperatures in April and May as impacting the yield of the winter (Rabi) cropping season. Due to the lack of profitability and struggles with establishing a robust business plan, the immediate needs of these FPOs revolve around the need for storage facilities, better access to irrigation, and simple value-addition practices like grading and sorting equipment.

The two market-oriented FPOs have distinct business models and different visions and report dissimilar challenges. Sahyadri is one of the largest FPOs in India, catering to both domestic and international markets. Sahyadri is keen to become the largest horticulture producer across India. With grapes being one of its primary products, Sahyadri mentions increasing incidence of precipitation (rain and hail) between January and March as a key climatic challenge that affects harvest-ready grapes. Rising temperature during April and May is also cited as a climatic stress that affects the sprouting of the next batch of grapes. Sahyadri has a detailed climate change adaptation plan, with a diversified portfolio including 27 different grape varieties (a mix of drought-tolerant varieties and others that are better adapted to wet conditions), as well as other horticulture crops such as tomato, banana, mango, pomegranate, sweetcorn, cashew, and citrus fruits. Sahyadri is also investing in a dense network of automated weather stations on all its farms and has contingency plans to shift procurement to other parts of Maharashtra should the climate conditions become unfavourable in the current areas.

However, Sahyadri is quite clear that horticulture is its competitive niche, and it does not see the need to diversify beyond this niche even until 2050.

Abhinav is an informal farmers' collective of over 350 farmer groups, each with over 100 members, and is based in Pune. Its operation is similar to that of an FPO under the direction of core management and marketing teams. Abhinav focuses on growing organic vegetables in small polyhouses and supplying them to urban consumers under a common brand name. It is keen to remain an informal farmers' club and does not see value in going through the formal registration process of an FPO and complying with various legal and administrative reporting needs. Abhinav does not see itself doing anything drastically different in future and mentions that it would like to see its business model of informal farmer collectives replicated in other parts of the country. As most of the production is from protected polyhouses, Abhinav farmers claim that they do not face any climate-related stresses and are not too concerned about climate change. In fact, they see an opportunity in climate change, with some of the projections for areas around Pune showing increasing rainfall. We summarize the drivers of change gathered from the initial workshop with the FPOs in Table 1.

### 3.2. Critical climate-stress moments for FPOs and areas for building resilience

Based on locale-specific data on critical climate-stress moments that were shared with the FPOs, including historical data and prospective trends, increasing April and May temperature was found to be a critical climate-stress moment common to all the FPOs. In terms of precipitation-related risks, Krushiyug and Ankur were concerned about increasing late-monsoon rainfall, while Sahyadri was concerned about an increase in unseasonal January–March rainfall. Ankur saw any increase in precipitation as an opportunity rather than a risk, stating that the overall annual rise in precipitation was a climate parameter of interest to them. Prospective trends in these climate parameters, based on the analysis of both historical and future climate data, are available in Srinidhi, Smolenaars, et al. (2024).

The results of the self-assessment of the climate resilience attributes of the FPOs are shown in Table 2. A broad range of scores can be seen for the attributes for each case study. All the FPOs scored themselves highly on *social self-regulation* and *reflective and shared learning*. They also felt that *exposure to disturbances* (climate or market) has helped the FPOs develop more resilient businesses. Some of the attributes on which the FPOs scored most poorly were *access to credit, insurance, and other financial safety nets*; support from *diverse policies*; and the presence of *governance arrangements that support transformation*. On the *spatial and temporal heterogeneity* and *optimally redundant* attributes, the FPOs had diverging opinions, ranging from very high (in the case of production-oriented FPOs) to not being relevant at all (in the case of market-oriented FPOs). This suggests that the market-oriented FPOs may be neglecting an important area of building resilience, or they might have alternate ways of compensating for the poor scores here.

### 3.3. Potential interventions for FPOs

The experts agreed with the critical climate-stress moments selected by the FPOs, i.e. increasing volume of late-monsoon (September–October) rainfall, rising summer temperatures, and increasing likelihood of precipitation between January and March. However, the experts also pointed out that the increasing late-monsoon rainfall is likely to be accompanied by other risks, such as an increased frequency of dry spells during the monsoon season. The experts also suggested a number of general resilience-building options such as diversification and increase in insurance coverage to address the interdependence and complexity of climate risk occurrence. The inputs from the experts with regard to specific climate risks and general risks are shown in Table 3.

### 3.4. Climate resilient development pathways for FPOs

The suggestions of the experts (Table 3) served as inputs for the final workshops with the FPOs, where the CRDPs were co-created. The production-oriented FPOs – Krushiyug and Ankur – identified the same critical climate-stress moments and had broadly similar resulting CRDPs. Therefore, the results for both these FPOs are treated together in section 3.4.1, while the results for the market-oriented FPOs are presented separately section 3.4.2 and section 3.4.3, respectively.

#### 3.4.1. Production-oriented FPOs: Krushiyug and Ankur

Increasing volume of rainfall in September and October is a key threat for these FPOs. Most of the farms where the FPOs are located have already witnessed an increase from about 150–200 mm of cumulative rainfall in these two months. The trend of increasing rainfall is expected to continue, nearly doubling by the middle of the century (Srinidhi, Smolenaars, et al., 2024). Similarly, the number of days with >40°C (typically in April and May) and the average summer temperatures are both expected to continue to rise (Srinidhi, Smolenaars, et al., 2024).

The scores of the climate resilience assessment (Table 2) for both the production-oriented FPOs show that the primary areas of building climate resilience are profitability, human capital, infrastructure, and effective support from policies. Other areas of building resilience are access to credit, insurance and other financial safety nets, and governance arrangements supporting transformation. Therefore, interventions like grain storage facilities, increased irrigation access, and mechanical harvesters were preferred by the FPOs over customized insurance products (see Figure 2). While the FPOs showed an interest in engaging in value-addition activities and also diversifying to livelihoods to include dairy, these were areas where they also felt the need for further capacity-building and support from appropriate government policies. The FPOs also prioritized interventions such as broad-bed furrows, soil health management, and pest management, which can bolster the FPOs' response to high rainfall, drought-like conditions, and heat stress. Shifting to crops with a shorter growing season was another key adaptation measure recognized by experts and FPOs. While these are included within the co-created pathway, both experts and FPOs recognized

**Table 1.** Drivers of change of FPOs – business model, vision, challenges, and current adaptation strategies

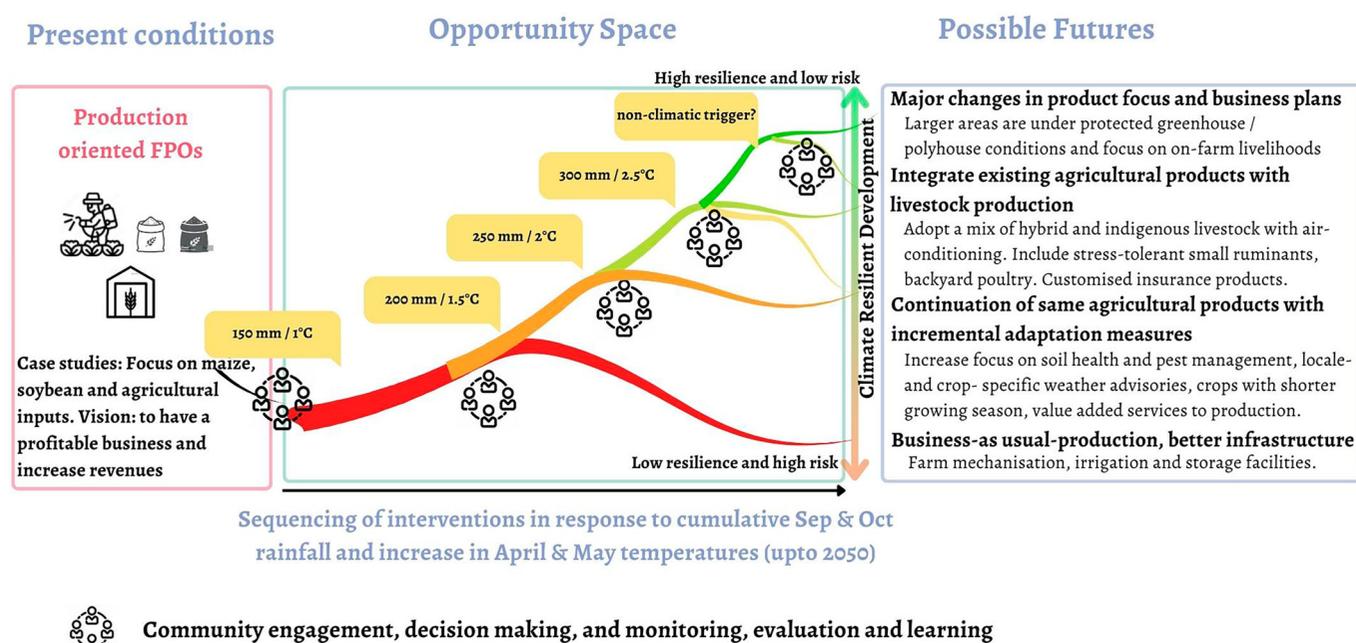
|  | Krushiyug  | Ankur  | Sahyadri   | Abhinav  |
|--|--|--|--|--|
| Category   | Production-oriented  | Production-oriented  | Market-oriented  | Market-oriented  |
| Basic profile, including location and membership | <ul style="list-style-type: none"> <li>512 members.</li> <li>Based in Goshegaon village of Bhokardan taluka, Jalna District. Registered as a Farmer Producer Company in 2018.</li> <li>Members are from 12 villages – 6 nearby and 6 slightly distant villages.</li> </ul>   | <ul style="list-style-type: none"> <li>1,000 members.</li> <li>Based in Parner taluka, Ahmednagar District.</li> <li>Registered as a Farmer Producer Company in 2016.</li> </ul>   | <ul style="list-style-type: none"> <li>Complex structure of 726 farmer members and other shareholder FPOs with over 16,000 farmers linked indirectly to the parent FPO.</li> <li>Based in Nasik, Maharashtra.</li> <li>Registered as a Farmer Producer Company in 2011.</li> </ul>   | <ul style="list-style-type: none"> <li>Informal farmers' club that is a federation of 357 farmer groups (smaller clubs) and estimated to have over 150,000 members across Maharashtra and neighbouring states.</li> <li>Head office in Pune, Maharashtra.</li> <li>Set up in 2004.</li> </ul>  |
| Business model                                   | <ul style="list-style-type: none"> <li>Deals in maize, soyabean, and agricultural inputs.</li> <li>2022 revenue estimated at about 0.5 Cr* rupees.</li> </ul>  | <ul style="list-style-type: none"> <li>Deals in agricultural inputs. Has attempted onion procurement but not very successful.</li> <li>2022 revenue estimated at about 2 Cr* rupees.</li> </ul>  | <ul style="list-style-type: none"> <li>Deals in horticulture: largest exporter of grapes from India; also produces tomatoes, bananas, and six other horticulture crops.</li> <li>Consists of a 3-tier structure of producer, supply-chain, and retail companies.</li> <li>2022 revenue estimated to be around 1,000 Cr* rupees.</li> </ul>   | <ul style="list-style-type: none"> <li>Deals in organic vegetables.</li> <li>Promotes small farms and farming under controlled conditions in polyhouses.</li> <li>As an informal club, does not have a central accounting system.</li> <li>2022 revenue estimated at around 400 Cr* rupees.</li> </ul>   |
| Future plans (vision)                            | <ul style="list-style-type: none"> <li>No clear vision or business plan.</li> <li>Anecdotally states a desire to grow in revenue to at least 50 Cr* rupees and remain reasonably profitable by 2050.</li> <li>Believes that such increase in revenue requires diversification of products to include vegetables and possibly also dairy.</li> <li>Would like to see a larger number of farmer shareholders and share capital.</li> </ul> | <ul style="list-style-type: none"> <li>No clear vision or business plan.</li> <li>Anecdotally states a desire to grow in revenue to at least 12 Cr* rupees and remain reasonably profitable by 2050.</li> <li>Believes that such increase in revenue requires diversification of products to include vegetables and possibly also dairy.</li> </ul>  | <ul style="list-style-type: none"> <li>Would like to be the largest horticulture producer in India.</li> <li>Keen to increase exports, diversify into retail shops and e-commerce platform, and contribute to the sustainable and equitable development of the local area.</li> <li>Believes that hot, dry weather and cheap labour in central India are suited for horticulture and wants to remain in this niche.</li> </ul> | <ul style="list-style-type: none"> <li>Does not see the need to do anything different in future.</li> <li>Would like to see its model of informal farmer clubs replicated in other parts of India.</li> </ul>  |
| Challenges (including climate-related)           | <ul style="list-style-type: none"> <li>Increasing late monsoon rain, leading to losses in harvest-ready crops.</li> <li>Rising April and May temperatures.</li> <li>Access to credit is a challenge</li> <li>Marketing of goods is an issue. Currently stuck with dead stock of about 5000 kg of maize procured at prices higher than current market rate.</li> </ul>  | <ul style="list-style-type: none"> <li>Increasing late-monsoon rainfall is a problem for harvest-ready Kharif crops (e.g. green gram).</li> <li>Increasing April temperature affects Rabi onions and other vegetables.</li> <li>No clear business plan, e.g. what products to focus on. Need help with market research.</li> </ul>   | <ul style="list-style-type: none"> <li>Increasing rain between January and March, affecting harvest-ready grapes.</li> <li>Increasing temperatures in April and May affect sprouting for the next batch.</li> <li>Market fluctuations and risks because of dependence on one or few horticulture crops.</li> </ul>   | <ul style="list-style-type: none"> <li>Making agriculture profitable was a major challenge. Being engaged in agriculture year-round to increase productivity and income was important.</li> <li>Believes this has been sorted in its business model.</li> <li>Key challenge is to have an assured supply of vegetables to meet growing demand.</li> <li>Does not believe that climate change poses much risk, as operations are in controlled polyhouses.</li> </ul> |
| Current adaptation strategies                    | <p>Currently, none. But sees the need for some interventions:</p> <ul style="list-style-type: none"> <li>Rainfall-related strategies – getting mechanical harvest machines and storage facilities.</li> <li>Temperature-related strategies – air-conditioned rooms for livestock, cold storage facilities, more vaccinations for livestock.</li> </ul>   | <p>Currently, none. But sees the need for some interventions:</p> <ul style="list-style-type: none"> <li>Rainfall-related strategies – Mechanical harvesting to reduce time for harvesting in September/October. Further increase may require investment in polyhouses.</li> <li>Temperature-related strategies – early sowing, mechanical crop covers if further changes occur</li> </ul> | <p>Has a detailed plan that includes the following:</p> <ul style="list-style-type: none"> <li>Rainfall-related strategies – use rain-resistant varieties, rent patent-protected varieties. Further increase in rain may require crop covers. More severe rain might warrant a shift in grape procurement to other farms – e.g. in Solapur.</li> </ul>   | <p>Does not see the immediate need for any adaptation interventions. In future, it may require some additional investments to manage logistics (vehicles) and marketing (pack houses) with access to credit or subsidies.</p>  |

*(Continued)*

Table 1. Continued.

| Krushiyug  | Ankur | Sahyadri  | Abhinav |
|--|-------|---|---------|
| <ul style="list-style-type: none"> <li>Credit-related strategies – no individual loans. Try to increase paid-up capital through increased membership.</li> </ul> |       | <ul style="list-style-type: none"> <li>Temperature-related strategies – initial management with increased irrigation. Further increase will require mechanical crop covers. Third level of adaptation would be to opt for other citrus fruits or shift grape cultivation to other farms – e.g. in Solapur.</li> <li>Non climate-related strategies: need for easier access to insurance.</li> <li>Diversified portfolio of 27 grape varieties and other horticulture crops – tomato, banana, mango, pomegranate, sweetcorn, cashew, and citrus fruits.</li> </ul> |         |

\*Cr – Crore denotes ten million in Indian numbering system.



**Figure 2.** Climate resilient development pathways for production-oriented FPOs – Krushiyug and Ankur. Four possible futures (in bold) and potential resilience-building interventions leading to each are shown in the box on the right.

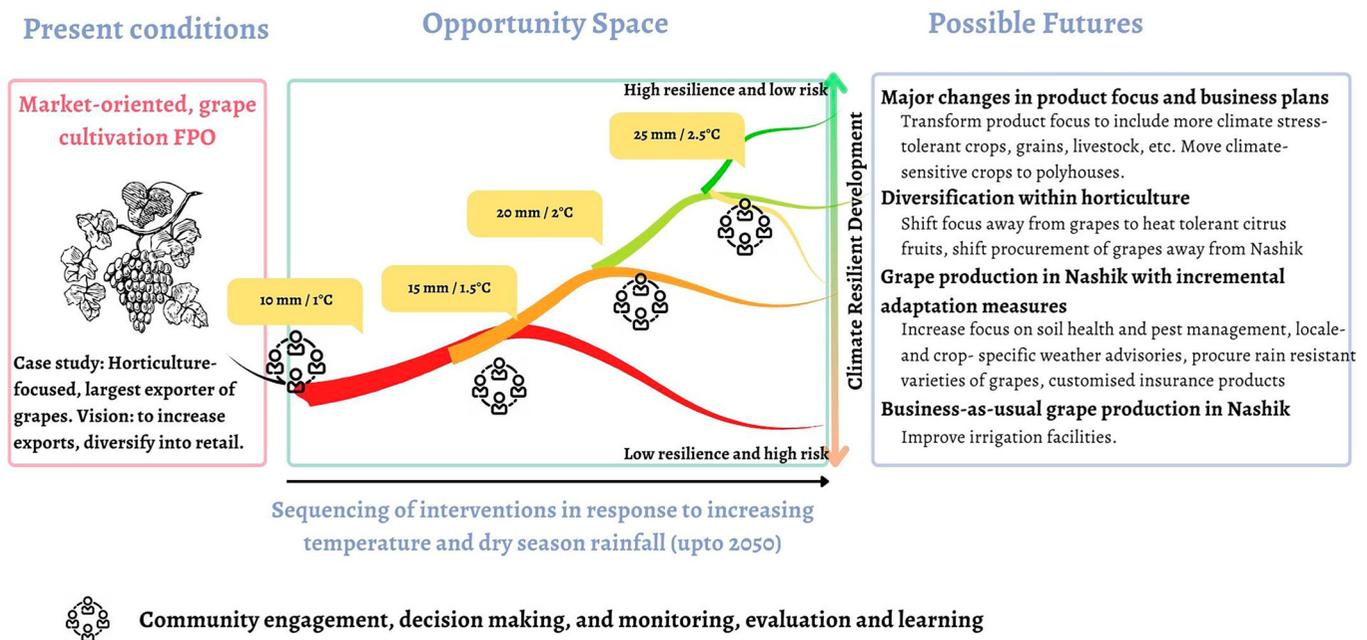
that this adaptation is not without liabilities, such as susceptibility to dry spells or sudden heavy rain during the growing season.

The CRDPs that were constructed for the FPOs (Figure 2) show four possible futures – (i) business-as-usual production with better infrastructure; (ii) continuation of the existing product focus, with incremental adaptation measures; (iii) integration of existing agricultural products with livestock production; and (iv) major changes in product focus and business plans. Irrespective of future risks, there is a primary need to improve infrastructure. With an increase in September and October rainfall from 150 mm to about 200 mm, there is already a need for incremental adaptation measures such as pest management, access to locale-specific weather advisories, and improved soil health measures. Increased rainfall will necessitate customized insurance products and other financial

safety nets (such as compensation for loss and damage). Based on the trends in the critical climate-stress moments, more transformative changes to the production system (e.g. shift from field crops to growing crops under greenhouse conditions/polyhouses) would be necessary by 2050. Indicative pathways are shown in Figure 2. FPOs and experts agree that the exact trajectory adopted and the timing of the decisions would be contingent on factors such as an enabling policy environment, perceived benefit–cost ratios, etc.

### 3.4.2. Market-oriented FPO: Sahyadri

Sahyadri has a well-established business plan that accounts for adaptation (Table 1). Increasing precipitation (rain and hail) from January to March has been identified as a key threat by FPOs. The grape farms of Sahyadri have already seen a change from negligible precipitation in this dry period to a higher



**Figure 3.** Climate resilient development pathways for a market-oriented FPO – Sahyadri. Four possible futures (in bold) and potential resilience-building interventions leading to each are shown in the box on the right.

frequency of years with 5–10 mm of rain. This is expected to rise in the coming years, along with an increase in April and May temperatures. The areas of improvement highlighted by the climate resilience assessment were ecological self-regulation and access to insurance (see Table 2).

The CRDPs constructed for the FPO (Figure 3) show four possible futures – (i) business-as-usual production in Nashik, (ii) grape production in Nashik with incremental adaptation measures, (iii) diversification within horticulture, and (iv) major changes in product focus and business plans. Sahyadri is already setting up a dense network of automated weather stations on its farms. Data from these stations will be used to generate early warning messages to farmers, as well as inputs to agri-insurance providers to design customized products in future, both of which are already being done by Sahyadri. Experts suggested the need for some transformative interventions to diversify their product line to include dairy, vegetables, or grains in future, especially under the higher climate change scenarios, and also consider options like price insurance for their high-value horticulture produce. Sahyadri believes that it has a competitive advantage in its horticulture business and was not keen to divert from this primary business strategy. However, it accepts that some of the transformative interventions would be necessary towards the end of the discussed timeframe (up to 2050). Sahyadri's low score for ecological self-regulation shows the need for improving soil health and pest management through nature-based solutions.

### 3.4.3. Market-oriented FPO: Abhinav

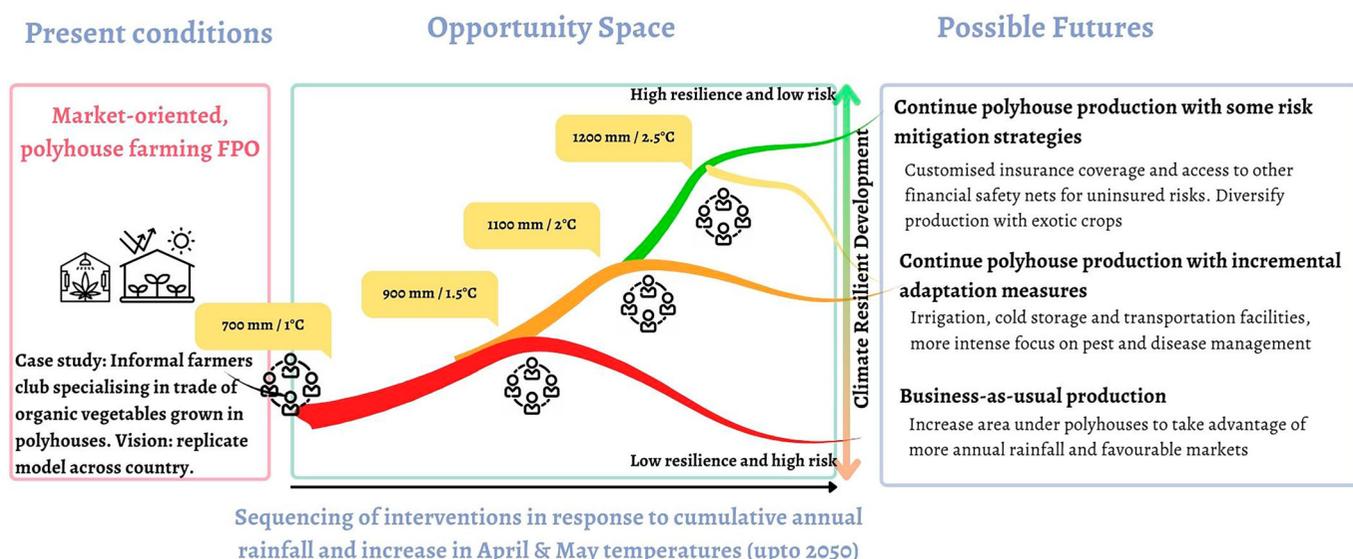
Given the focus of Abhinav on polyhouse cultivation, it does not perceive increased or unseasonal rainfall as an issue. In fact, Abhinav sees the increase in rainfall as an opportunity to increase the area under polyhouses and continue focusing on organic vegetables. However, it acknowledges that

cultivation within polyhouses has a high risk of losses from pests and diseases, which can increase under hotter and more humid conditions. It perceives the need for more intensive care against pests and diseases in future, which could also lead to higher costs of production. The rising temperatures would also require more irrigation, investments in cold storage, and air-conditioned transportation in future.

The CRDPs constructed for this FPO (Figure 4) show three possible futures – (i) business-as-usual production, (ii) continued polyhouse production with incremental adaptation measures, and (iii) continued polyhouse production with some risk mitigation strategies. Experts also agreed that production under polyhouses insulates Abhinav from many climate risks, and the potential interventions applicable to Abhinav were minimal. However, based on the areas of improvement highlighted by the climate resilience assessment, we can see that equity in decision-making and support from policies is poor. The FPO believes that the equity issue could be addressed by greater transparency and effective communication to all members through customized mobile phone-based applications that also help in logistical decisions of managing demand, supply, quality, and dynamic pricing. The FPO has made a conscious decision to not get registered as a formal entity, thereby also forgoing access to any government policy support. Having already made a transformative change in setting up cultivation in polyhouses, the FPOs and experts did not see the need for further transformative changes in the foreseeable future. Some incremental adaptation measures were identified, particularly for temperature-related risks.

## 4. Discussion

The CRDPs for each of the FPOs challenge their existing visions. Alternate crop choices, investments in infrastructure,



#### Community engagement, decision making, and monitoring, evaluation and learning

**Figure 4.** Climate resilient development pathways for market-oriented FPO – Abhinav. Three possible futures (in bold) and potential resilience-building interventions leading to each are show in the box on the right.

and other adaptation strategies were recognized by the FPOs as important in light of increasing climate risks. While there is a preference for incremental adaptation measures to begin with, larger transformative changes were acknowledged as necessary towards the end of the given timeframe of up to 2050.

#### 4.1. Pathways that challenge status quo

The first step in co-creating the CRDPs involved understanding the FPOs' operations, including their current business plan, vision, and challenges. With the exception of Sahyadri, the other FPOs in our study did not articulate a clear vision or business plan accounting for potential challenges in the future. The futures of the two production-oriented FPOs represent a significant shift from the original anecdotal future plans of the FPOs, underscoring the need for numerous resilience-building interventions, such as immediate investments in infrastructure, and larger changes, such as alternate crop choices and diversification through livestock and non-farm livelihoods. The market-related FPOs seem to have taken climate change into consideration, with Abhinav investing in polyhouses and Sahyadri having a clear vision and climate change adaptation plan. However, other climate resilience-building measures were included in their CRDPs when they were provided with data on increasing climate risks through critical climate-stress moments.

Such a re-think around what the potential futures could look like under climate change and what resilience-building actions are required highlights the value of the CRDPs. Especially in contexts where the vision is ambiguous or there are goals that have not yet explicitly considered climate risks, the application of critical climate-stress moments can be very useful to trigger the consideration of more robust climate resilience-building interventions for stakeholders. Werners, Wise,

et al. (2021) discuss the application of the pathways concept in several different contexts, from those that are data-rich and involve expert-driven processes (e.g. Haasnoot et al., 2013; Kwakkel et al., 2016) to those with relatively less data, contested goals, and multi-stakeholder involvement (Bhave et al., 2018; Bosomworth et al., 2015). Our experience of co-creating CRDPs with FPOs, and experts in agricultural and climate aspects, presents an approach to address the challenge of creating CRDPs where the vision is not defined or the goals have not yet specifically considered climate risks. By providing empirical evidence on CRDPs within multi-stakeholder and developing contexts, this research contributes to addressing the research gaps identified by Taylor et al. (2023), and Favretto and Stringer (2024).

The CRDPs were co-created in response to the increasing intensity of specific climate risks such as September and October rainfall, high temperatures in April and May, and unseasonal rainfall between January and March (referred to earlier as critical climate-stress moments). While FPOs build resilience to these risks, it must be noted that temperature- or rainfall-related risks are not going to occur in isolation. They will most likely occur in combination with other climate change-related risks in the year (Krishnan et al., 2020). In such a scenario, activities that improve resilience to multiple risks would be preferable. This was a point cogently considered by experts while recommending interventions such as broad-bed furrows in open fields and improving soil health, as they help fortify protection from the effects of excess rain and heat stress/dry spells. Such robust adaptation and resilience-building approaches, also called no- or low-regret approaches (see Phadtare et al., 2019), are considered useful in contexts with a high degree of uncertainty (Dittrich et al., 2016). By focusing on the impact of specific climate risks on the farming system and motivating the inclusion of appropriate and diverse

**Table 2.** Self-assessment of climate resilience attributes by FPOs.

|    | Resilience attributes  | Indicators in local context/What to look for   | Krushiyug                    |                                     | Ankur           |                        | Sahyadri           |                        | Abhinav         |                        |
|----|--|--|------------------------------|-------------------------------------|-----------------|------------------------|--------------------|------------------------|-----------------|------------------------|
|    |  |  | Relevance (Y/N) <sup>#</sup> | Current score (1 to 5) <sup>#</sup> | Relevance (Y/N) | Current score (1 to 5) | Relevance (1 to 5) | Current score (1 to 5) | Relevance (Y/N) | Current score (1 to 5) |
| 1  | Reasonably profitable  | Profit margins, ability to repay loans quickly, credit rating  | Y                            | 3                                   | Y               | 2                      | Y                  | 5                      | Y               | 4                      |
| 2  | Socially self-organised                                      | Ability to make own decisions as opposed to being reliant on outside support, like an NGO, for decision-making   | Y                            | 5                                   | Y               | 4                      | Y                  | 5                      | Y               | 5                      |
| 3  | Ecologically self-regulated                                  | Reliance of FPO on ecosystem services and common property resources in place of external inputs  | Y                            | 2                                   | Y               | 4                      | Y                  | 2.5                    | Y               | 4                      |
| 4  | Appropriately connected                                      | Connectivity between members and non-members of FPO, support from local community, connected with other local businesses for inputs and services   | Y                            | 4                                   | Y               | 4                      | Y                  | 3.5                    | Y               | 5                      |
| 5  | Functional diversity   | Diversity in sources of water and any other inputs for FPO, diversity in farm outputs (e.g. different grape varieties, other horticulture products, vegetables)  | Y                            | 4                                   | Y               | 4                      | Y                  | 4.5                    | N               | -                      |
| 6  | Optimally redundant  | Alternate sources of income (besides horticulture, e.g. dealing in agricultural inputs, dairy business, processed/ packaged foods)   | Y                            | 4                                   | Y               | 2                      | N                  | -                      | N               | -                      |
| 7  | Spatial and temporal heterogeneity                           | Spatial – geographical spread. Temporal – crop rotation for soil health (from one season/year to another)  | Y                            | 5                                   | N               | -                      | N                  | -                      | N               | -                      |
| 8  | Exposed to disturbance                                       | Small disturbances that test and increase the resilience of a system, such as exposure to droughts, leading to a shift to drought-resistant crops  | Y                            | 4                                   | Y               | 4                      | Y                  | 5                      | Y               | 5                      |
| 9  | Reflective and shared learning                               | People and institutions that learn from past experiences and each other, specific changes, or new practices introduced after significant shocks  | Y                            | 5                                   | Y               | 4                      | Y                  | 5                      | Y               | 5                      |
| 10 | Builds human capital   | Education, diversified skills in FPO members, adopting new practices and technology  | Y                            | 3                                   | Y               | 2                      | Y                  | 4.5                    | Y               | 5                      |
| 11 | Diverse policies   | Appropriate state and national policies that help FPOs become more resilient by enhancing any of the four resilience capacities  | Y                            | 2                                   | Y               | 2                      | Y                  | 2.5                    | Y               | 2                      |
| 12 | Infrastructure for innovation                                | Existing infrastructure, adoption of new knowledge and cutting-edge technologies such as weather-based advisories through smartphone apps  | Y                            | 1                                   | Y               | 2                      | Y                  | 5                      | Y               | 4                      |
| 13 | Supports rural life  | FPO leads to attractive livelihoods to all age groups and sections of the community and a lifestyle that is deemed as dignified by the community   | Y                            | 2                                   | Y               | 2                      | Y                  | 3.5                    | Y               | 5                      |
| 14 | Access to credit, insurance, and other financial safety nets | Access to credit from institutional lenders; viable terms and conditions, such as reasonable interest rates, awareness and access to insurance, compensation from the state for damages not covered by insurance | Y                            | 2                                   | Y               | 3                      | Y                  | 3*                     | N               | -                      |

(Continued)

Table 2. Continued.

| Resilience attributes | Indicators in local context/What to look for                                | Krushiug         |                         | Ankur           |                        | Sahyadri           |                        | Abhinav         |                        |
|-----------------------|---|------------------|-------------------------|-----------------|------------------------|--------------------|------------------------|-----------------|------------------------|
|                       |   | Relevance (Y/N)* | Current score (1 to 5)# | Relevance (Y/N) | Current score (1 to 5) | Relevance (1 to 5) | Current score (1 to 5) | Relevance (Y/N) | Current score (1 to 5) |
| 15                    | Equity in terms of decision-making (and power dynamics in local governance) | Y                | 4                       | Y               | 4                      | Y                  | 5                      | Y               | 3                      |
| 16                    | Governance arrangements that support transformation                         | Y                | 2                       | Y               | 3                      | Y                  | 5                      | N               | -                      |

Note: #An attribute that the FPO considered relevant is marked with a Yes (Y), while an attribute that was not considered relevant is marked with a No (N). Among the attributes considered relevant, FPOs gave a score of 1–5, reflecting their view of the worst to the best condition for that attribute. For attributes considered not relevant, no further scoring of the resilience attribute was carried out (marked with a '-').

\*Participants mentioned that access to credit was not an issue, but access to insurance and other financial safety nets was very poor. Thus, while an average score of 3 has been provided in the table, it could be interpreted as 5 for access to credit and 1 for access to insurance and financial safety nets.

resilience-building measures, the concept of critical climate moments can help bridge disciplinary silos. The focus on the appropriateness of the response (whether it is a business-as-usual response or something additional) for a given set of climate conditions can also help bridge the divide between questions of what is considered 'development' and what is considered 'adaptation', leading to a more holistic response of climate resilient development (see Schipper et al., 2020; Singh, 2024).

Given the state of distress in India's agriculture sector and rising farmer protests in recent years, there have been several

calls for transformative changes (Gulati et al., 2020; Shah et al., 2021b). However, in our case studies, transformative changes that might involve a change in the main agricultural product are invoked only towards the end of the co-created pathways. Such robust and no-regret approaches are consistent with the literature on the risk-averse nature of smallholder farmers (BIRTHAL et al., 2021), which also pervades farmer collectives with a large representation of smallholder farmers (Molla et al., 2020). To incentivise larger transformational changes in agriculture, Huang (2021) discusses the role of market and regulatory reforms in the case of China. In the Indian

Table 3. Potential resilience-building interventions based on critical climate-stress moments.

| September and October rainfall   | April and May temperatures   | January to March precipitation   | General resilience-building measures   |
|--|--|--|--|
| <ul style="list-style-type: none"> <li>Mechanical harvesters</li> <li>Storage facilities</li> <li>Cultivation of shorter duration crops (risky when there are dry spells)</li> <li>Broad-bed furrows</li> <li>Improved soil health and pest management</li> <li>Investment in mechanical drying units</li> <li>Linkage with custom hiring centres</li> <li>Extension services to advise on rain tolerant varieties of maize and soybean</li> <li>Cultivation of fodder crops like super Napier, which can also support more livestock</li> </ul> | <ul style="list-style-type: none"> <li>Broad-bed furrows and other technological solutions to reduce soil moisture loss</li> <li>Water budgeting and crop planning in every season</li> <li>Improved soil health and pest management</li> <li>Cultivation of shorter duration crops (risky if there is excess rain in Jan-Mar)</li> <li>Extension services to advise on drought-tolerant varieties of sorghum, millets</li> <li>Investment in polyhouses</li> <li>Increased ownership of small ruminants and backyard poultry</li> <li>Shift of some areas to horticulture, particularly citrus fruits</li> <li>Innovations in drip irrigation for field crops</li> <li>Expensive solutions like crop covers over entire plantation</li> </ul> | <ul style="list-style-type: none"> <li>Diversification in varieties and business model (horticulture is more sensitive to this risk than traditional grains)</li> <li>Dairy as a good high-value alternative for diversification and a source of organic manure for the rest of crop mix</li> <li>Protection of high-value horticulture crops using cones or more expensive crop covers</li> <li>Higher density of weather stations to provide more accurate forecasts</li> <li>Fungicide sprays to protect produce just harvested</li> <li>Conversion of some areas to partially or fully protected poly/greenhouses</li> </ul> | <ul style="list-style-type: none"> <li>Two- or multi-tiered model of FPOs to be promoted by government policies with differentiated incentives based on business model and risk appetite</li> <li>Capacity-building targeting financial literacy, logistics, and marketing training rather than only farming practices</li> <li>Diversification of risk with a focus on traditional food grains that are less sensitive to rain and temperature variations</li> <li>Compensation of drop in productivity through value addition</li> <li>Adoption of climate-resilient agriculture practices like efficient water use, improving soil health, and integrated pest and nutrient management</li> <li>Reorganization of the Board of Directors to ensure good lending rates from banks</li> <li>Innovation in better long- and medium-range forecasting</li> <li>Customised insurance coverage and facilitation of faster claim settlement through FPOs</li> <li>Focus on improving member engagement to cover at least 80%</li> <li>Trying out price insurance, especially for market-oriented FPOs</li> <li>Apps for transparent communication and logistics</li> </ul> |

context, Gulati and Juneja (2022) and Srinidhi, Werners, et al. (2024) have highlighted the need for similar reforms for investments in irrigation, agricultural technology, rural market infrastructure, soil health improvement, and diversifying income sources by promoting non-agrarian livelihoods.

#### **4.2. Synergies and trade-offs between interventions for building climate resilience and climate resilient development pathways**

The climate resilience self-assessment showed some generic areas of improvement for all the FPOs, such as improving *access to credit, insurance, and other financial safety nets*; support from *diverse policies*; and *governance arrangements that support transformation. Infrastructure for innovation, reasonable profitability, and builds human capital* were identified as areas of improvement for the production-oriented FPOs. We find some synergies and trade-offs between these areas of improvement and the co-created CRDPs. The two production-related FPOs, Ankur and Krushiyug, are both in urgent need of basic infrastructure such as storage facilities, increased irrigation access, and mechanical harvesters to reduce costs, prevent losses, and reduce the time to get their produce to markets. Among the two market-oriented FPOs, Sahyadri already has a detailed adaptation plan. However, with all its production still exposed to increasing weather variability, additional adaptation interventions in anticipation of more extreme weather changes will be required in the future. The need for customized insurance products highlighted in its CRDPs also emerges as an area of concern in its climate resilience assessment. Given its well established presence in the horticulture market, the incentives to diversify to other dryland agricultural produce typical to the region, like maize, soybean, vegetables, and dairy, is minimal, although an increase in diversity can help increase climate resilience. The case of Abhinav, with its specific focus on organic vegetables, also shows an apparent trade-off between the increased risk of specializing in certain agriculture produce versus diversifying products and improving climate resilience.

The findings from our case studies suggest that the synergies between interventions for building climate resilience and CRDPs are stronger when there are clear and obvious development deficits to be fulfilled. As mentioned by Schipper et al. (2023), ‘the principles of climate-resilient development emphasize not simply reducing climate risk, but rather making development process resilient to changing climate’, and that ‘institutions are most effective when taking a development-first approach to adaptation’. In this context, it is interesting that trade-offs between interventions for building climate resilience and CRDPs become more apparent with the two market-oriented FPOs that had a relatively well-established business plan and vision. The co-created pathways seek to maintain their high level of profitability despite having limited heterogeneity or redundancy in the system to an extent where these attributes were even considered ‘not relevant’ (see Table 2). Critiques of resilience theory point out issues such as limited attention given to social, economic, and political processes in the normative framing of resilience (Moser et al., 2019; Redman, 2014). We believe that this normative

understanding of resilience, including climate resilience, is a reason for the apparent trade-offs when the CRDPs were no longer about basic development deficits but rather about increasing profits or aiming for a higher level of development. Srinidhi et al. (2023) discuss the need for a more holistic understanding of climate resilience while developing the CRISI framework. Several development-oriented indicators related to economic viability, profitability, and equity are already included within the functions and attributes of the framework. The added value of the CRDPs, we believe, is in helping communicate the synergies and trade-offs between different choices related to climate action and development more explicitly to stakeholders. Taylor et al. (2023) similarly emphasize that while a pathways map is an important output of the co-creation exercise, the primary intended outcome is the processes, governance, and capacities for “inclusively and equitably assessing, negotiating, sequencing and enacting options along pathways”.

In-depth consideration and analyzes of such synergies and trade-offs can also nudge policy makers towards creating appropriate incentives. For instance, promoting sorghum and millets in the Government of India’s public procurement or increasing the demand for these grains through campaigns like the ongoing Millet Mission could motivate farmers to shift away from water-intensive rice and wheat to drought-friendly crops across large parts of the country.

#### **4.3. Reflections on the methodology used in co-creating CRDPs**

The guidance document on pathways development by Werners et al. (2018) lists several possible approaches for co-creating CRDPs. Some are better suited for data-rich contexts (e.g. using scenarios and turning points) and others, where the vision is clear (e.g. visioning and back-casting). In our co-creation experience, we encountered issues with both ambiguous vision and a lack of data with the production-related FPOs. While the market-related FPOs did have a relatively clearer vision and some climate change considerations, data around the critical climate-stress moments did lead them to re-evaluate their strategies and consider new interventions as a part of the CRDPs. Recommendations from experts also played a key role in options that the FPOs were considering in the final workshop, prior to selecting and sequencing the interventions into pathways. Some of the expert recommendations were disregarded. For instance, the recommendation of shifting to drought-tolerant varieties of sorghum and millets (see Table 3) was largely put aside by the FPO stakeholders due to the current low market prices of these crops. Co-creation is considered a ‘joint, collaborative, concurrent, peer-like process of producing new value, both materially and symbolically’ (Galvagno & Dalli, 2014). Here, it is worth noting that a co-creation exercise with a different set of stakeholders, perhaps with people in the Ministry of Agriculture, agricultural economists, investment bankers, and organic farming proponents, could have resulted in different recommendations and perhaps slightly different CRDPs. Due to the synergies and trade-offs between interventions and the different perceptions of risk amongst different stakeholders, there is perhaps no

‘right’ or ‘wrong’ CRDP. Complex problems of climate change and sustainable development have characteristics such as having contested definitions, multiple uncertainties, real-world constraints, and solutions not being ‘true/false’ or being only partial and temporary (Bammer, 2019). Moreover, while there are several reasons for the growing popularity of co-creation as a concept – the chief ones being the ability to break down hierarchies and improve inclusive decision-making – there are also some important concerns, such as failure of accountability, rejection of responsibility, and reinforced inequalities (Leino & Puumala, 2021; Steen et al., 2018).

The case study-based approach followed here presents inherent limitations in terms of generalisability (Kumar, 2018). The findings may also be sensitive to the chosen time-frame; extrapolating them to different temporal contexts requires caution. The diversity in the types of FPOs and experts selected broadens the applicability of the conclusions to an extent, however, building a larger evidence base of CRDPs across semi-arid regions globally, and longitudinal studies that track the effectiveness of the proposed CRDPs are certainly potential avenues for future research.

## 5. Conclusion

Considering the need to simultaneously address both development and climate change concerns of smallholder farmers in semi-arid India, we specifically asked the question of what the potential CRDPs could be for FPOs in semi-arid India. We collaborated with four FPOs in Maharashtra and eight experts from different backgrounds and co-created CRDPs for the FPOs. The methodology employed involved initial meetings with each FPO to document their existing business, development plans, and challenges, and to identify areas of improving climate resilience. Specific climate-related risks were identified by using the concept of critical climate-stress moments. The findings from our interactions with the FPOs were subsequently discussed with the selected experts to generate recommendations for climate resilience-building measures. These recommendations were then shared with the FPOs, who prioritized, selected, and sequenced interventions in response to critical climate-stress moments, resulting in the co-creation of CRDPs.

The CRDPs for each of the FPOs challenge their existing visions. The futures of the two production-oriented FPOs represent a significant shift from the original anecdotal future plans of the FPOs and highlight the need for several resilience-building interventions, such as immediate investments in infrastructure, and larger changes such as alternate crop choices and diversification through livestock and non-farm livelihoods. In the case of the two market-oriented FPOs, despite them having accounted for climate change, several other climate resilience-building measures were included in their CRDPs when exposed to data on increasing climate risks through critical climate-stress moments. These included interventions such as a shift in procurement areas, transforming the product line to include more climate stress-tolerant crops, and developing customized insurance products. The value of co-created CRDPs lies in connecting the vision and business plans of the FPOs to prospective climate risks.

They help in clearly communicating and discussing timing, associations, and compromises associated with these interventions. Depending on the agricultural products of the FPO and the stage of development of its climate resilience attributes, there may be a preference for incremental adaptation measures to begin with or a desire for larger transformative changes. Policies supporting FPOs must recognize these differences and have a multi-layered approach to incentivise building infrastructure, incremental adaptation, or more transformative changes. This approach would recognize varying technology levels, social organization, and financial capacities of diverse FPOs across India, facilitating the transition towards more climate-resilient farming systems in India. A key recommendation that arises from our research is to revise the existing uniform policy for promoting FPOs to adopt a differentiated model, incorporating tailored provisions based on the types of FPOs and their respective stages of development in climate resilience. Based on the potential for CRDPs to provide such an integrated response, we also recommend that state action plans on climate change (see Jogesh & Paul, 2020) and other regional climate resilient development planning be formulated using such a pathways approach.

Applying the concept of critical climate-stress moments to develop CRDPs represents a methodological advancement, particularly in cases characterized by contested goals, an ambiguous vision, and multi-stakeholder process involvement. Introducing climate change projections and prospective critical climate-stress moments into the discussion allowed us to present stakeholders with triggers necessitating concrete responses in terms of adaptation or development-related interventions. By concretely considering future risks, mediated by the concept of critical climate-stress moments, our approach to co-create CRDPs facilitates the prevention of lock-ins and minimizes the risk of maladaptation. Further research and evidence from various stakeholder groups and contexts would enhance the adoption of climate-resilient development pathways in policymaking across different geographical scales.

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No potential conflict of interest was reported by the author(s).

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