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Enhancing Resilience or Exacerbating Inequity? Revisiting Irrigation Investments in India

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ABSTRACT: There is an increasing emphasis in India on building climate resilience through public investments in irrigation. Maharashtra's Project on Climate Resilient Agriculture is a first such state implementation. Although resilience is a systems concept, the project targets individual farm-level investments. Our aim is to evaluate how these investments reshape water access amongst all farmers and how they impact resilience. In our study area in Jalna district, we evaluate the proposed interventions by combining field data with a modelling approach. Two indices are developed to indicate resilience: Irrigation Risk Index and Lock-in Index. We find that though the project increases the volume of water harvested, farmers are incentivized to use most of it through agricultural intensification with no buffer to deal with shocks. Despite an apparent focus on the resilience, the implementation prioritises increasing productivity of the irrigators over addressing vulnerability of rainfed agriculture. Moreover, the promotion of multiyear orchards creates a lock-in and reduces the adaptive capacity of irrigators. At the same time, due to the common-pool-resource property of water, less is available for the supplemental irrigation needs of other farmers. We conclude that the programme not only reduces resilience but also exacerbates inequity in water access. The research contributes to debates on investments for productive versus supplemental irrigation in rainfed areas. It also highlights the need for incorporating an equity lens when designing for resilience.

KEYWORDS: Climate resilience, agriculture, equity, supplemental irrigation, Maharashtra, PoCRA, India

INTRODUCTION

About 55% of India's gross cropped area is rainfed. The majority of it comprises arid and semi-arid upland terrains with eroded soil. The dryland rainfed areas face recurring droughts and their populations experience high levels of poverty. Even so, this terrain makes an important contribution to agriculture, producing a variety of millets, pulses, oilseeds and cotton (Rao et al., 2015), in addition to supporting a large livestock economy (Revitalizing Rainfed Agriculture Network, 2017). The high variability in rainfall has been exacerbated by climate change, and ensuring food and livelihood security requires enhanced resilience to changes in rainfall patterns including long dry spells. Vulnerability to this increasing variability in rainfall patterns is highly unequal and is affected by socio-economic and biophysical attributes (Prasad et al., 2023). How interventions for resilience may lead to more equitable outcomes is thus an important question. It is the focus of this paper.

Rainfed areas have been defined in different ways (Revitalizing Rainfed Agriculture Network, 2017; Kumar et al., 2017; Pal et al., 2019). In general, the designation of 'rainfed' implies a lack of irrigation access that results in a dependence on monsoon rains; these rains may or may not fully meet crop water needs, depending upon whether the potential evapotranspiration demand is more or less than precipitation levels. The distinction between rainfed and irrigated regions has been questioned (Kumar et al., 2017), since some irrigation is common even in dryland rainfed areas, usually using groundwater or seasonal local surface water sources. This may be in the form of full irrigation of seasonal crops on small landholdings and/or supplemental irrigation of rainfed crops to overcome dry spells. Farmers engaging in a combination of rainfed and irrigated agriculture are in a minority, however, and most farmers cultivate rainfed crops without access to any supplemental irrigation; these crops generally include millets, oilseeds, pulses and cotton.

In India, historically, public investment supporting rainfed farming has been very limited, as most government programmes have supported paddy-wheat irrigation (Mishra et al., 2013; Revitalizing Rainfed Agriculture Network, 2017). It is estimated that, of the total expenditure on agricultural subsidies between 1997 and 2012, only 1% was spent on rainfed farming, while the rest was spent on intensive agriculture (Mishra et al., 2013). Government programmes in rainfed agriculture have largely been in the form of watershed management through soil and water conservation. While such efforts may recharge blue and green water within the watershed, they do not target specific beneficiaries. A large body of literature also shows that the benefits of watershed works are not shared equally (Shah, 2001; Calder et al., 2008; Shah et al., 2009), and that they are known to disproportionately benefit landowning farmers who have access to irrigation through their proximity to water harvesting structures (Shah, 2001). In India, the Integrated Watershed Management (IWM) programme has been widely taken up by different government and non-government actors. It involves participation from local stakeholders in planning for the watershed as a whole, but has a limited focus on equity or on enhancing water access by the vulnerable population within the watershed (Shah et al., 2009). The state of Maharashtra has been a pioneer in these efforts, and over time it has championed several flagship programmes devoted to the theme of making the state 'drought-proof' (Tiwale and Sankar, 2025). Over time, these programmes moved away from integrated watershed development and towards demand-driven interventions that included subsidies for private irrigation infrastructure that were given to specific beneficiaries. The types of investment that are subsidised include private farm ponds and drip irrigation systems; their goal is to enhance the productivity, irrigation efficiency and economic development of the irrigating farmers, especially the progressive farmers. Needless to say, this 'success to the successful' mode of beneficiary targeting further worsens the inequity in access to irrigation (Shah et al., 2021; Pritchard et al., 2024). This is especially problematic since public funds are being invested to facilitate private access to water; furthermore, as water is itself a common pool resource (Prasad et al., 2022), other users of the same resource are thereby negatively impacted.

Programmes on climate resilient agriculture are a relatively new phenomenon. Given that a large share of the Indian population is dependent on agriculture and that Indian agriculture is highly dependent on monsoon rains, there is recognition that building adaptive capacity to monsoon variability is essential (Sikka et al., 2018). In 2011, the Indian Council of Agricultural Research initiated its network project on National Innovations on Climate Resilient Agriculture (NICRA); its aim was to conduct research on, and demonstrations of, technology and innovations in land and water management in different contexts. The World Bank has partnered with several states to support specific packages promoting climate resilient agriculture. Maharashtra’s Project on Climate Resilient Agriculture (PoCRA) is the first of these; having started in 2017, it targets the 15 most vulnerable districts of the state. While the driver for these programmes is to build adaptive capacities and resilience of farmers, the set of land and water interventions is essentially a repackaging of the interventions that were implemented in previous flagship programmes (Prasad et al., 2023). One of these, the Jalyukta Shivar Abhiyan, was launched in 2014 with the objectives of expanding rainwater harvesting, increasing the irrigated area, and improving water use efficiency and groundwater levels (Tiwale and Sankar, 2025). However, compared to previous flagship programmes, PoCRA has an increased focus on interventions at the farm level rather than at the landscape or watershed level.

The origin of the concept of resilience is attributed to Holling (1973). In the context of climate change, the Intergovernmental Panel on Climate Change (IPCC) has defined resilience as the capacity of a system and its component parts to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner. The 'capacity' that is being referred to here is predominantly of three types: absorptive, adaptive and transformative (Douxchamps et al., 2017). In the context of smallholder agricultural systems, the absorptive capacity is the amount of change that the system can undergo while still retaining its function. It refers to, for example, the extent of yield losses that may be withstood in the case of a dry spell or drought year, while still being able to continue agricultural practices post-shock. Absorptive capacity can be gained through, for instance, savings, insurance schemes, and disaster planning. Adaptive capacity refers to the changes that farmers are able to make through their learning and experiences in response to shocks; they may opt, for example, to change cropping patterns, or to invest in irrigation, technology, or new institutional arrangements. The third form of resilience is transformative capacity. This may take the form of switching to a completely new way of farming such as agro-ecological farming, or exiting farming altogether when continuing becomes untenable.

Resilience refers to a system as a whole; the entities within the system, however, are typically not homogenous. Williams et al. (2020) invoke the question of equity in resilience by asking whether increasing resilience at the aggregate level can leave vulnerable populations behind. They argue that evaluating resilience-enhancing strategies requires assessing the distribution of potential effects over the system's entire population, instead of seeing only the overall effect on the system. Miller et al. (2010) discuss the epistemological challenges of bringing together the concept of resilience and vulnerability. Resilience is a systems concept with its roots in social-ecological systems, while vulnerability is understood at the level of actors or of specific social units of analysis such as communities, districts, and sectors. They call for the development of integrated approaches that incorporate social-ecological relations as well as matters of social differentiation, equity and power. In programmes for climate resilient agriculture that target specific beneficiaries, it is therefore important to evaluate not only the overall resilience of the social-ecological system, but also the distribution of impacts within its different components.

We study the case of the World-Bank-funded Government of Maharashtra Project on Climate Resilient Agriculture (PoCRA). PoCRA has the twin programme objectives of enhancing climate resilience and improving farm productivity of small holders in the 15 most vulnerable districts of the state, primarily in the rainfed regions of Marathwada and Vidarbha. In order to achieve the stated objectives, the programme funds or subsidises a number of public and private investments. Our study area is based in Jalna district of Maharashtra, which was included in the first phase of PoCRA implementation. After a microplanning exercise in June 2018, the PoCRA team developed the Detailed Project Report (DPR) for our study area (PoCRA Project Management Unit, 2018) with a list of interventions to be implemented as part of the programme. Our objective is to analyse how the proposed interventions would reshape water access among different types of farmers, and if this would lead to an increase in the system's resilience. To do this, we use a mixed methods approach that combines field insights from the study of irrigation practices with a water-budget-based quantitative analysis.

The paper is structured as follows. In the following section, we first provide the background of PoCRA and its conceptualisation and operationalisation of 'resilience'. We then describe our case study area, followed by our approach for computing the potential (re)distribution of irrigation water as a result of the proposed interventions in the project; here we introduce two indices to capture the resilience of the system. We then share the results of our comparison of the baseline scenario with the scenario that is planned under the PoCRA programme, which includes the proposed investments and new cropping patterns. We then discuss the implications of our findings and end with our conclusions.

BACKGROUND AND METHODOLOGY

PoCRA

The Project on Climate Resilient Agriculture (PoCRA) was launched in the state of Maharashtra in 2017. The rationale for the project was that about 84% of Maharashtra's agricultural area is rainfed and, with increasing climate vulnerability, farmers with small, unirrigated landholdings are especially vulnerable to climate shocks. Reducing distress among farmers and increasing sustainability and profitability thus required addressing issues such as growing water scarcity, degradation of land resources, increasing costs of cultivation, stagnant farm productivity, and impacts of climate change (Government of Maharashtra and World Bank, 2017). The stated project development objective is to enhance the climate resilience and profitability of smallholder farming systems in select districts of Maharashtra.

The climate shocks that call for enhanced resilience include changes in temperature and rainfall, the increasing variability of both, and extreme weather events (World Bank, 2016). The desired project outcomes are improved agricultural productivity and growth, increased household income and food security, and a climate resilient agriculture sector. The project also aims to contribute towards India's climate-related international commitments through a reduction in greenhouse gas (GHG) emissions. Climate resilience is not explicitly defined in the PoCRA concept note or implementation plan; the stated key performance indicators (KPIs) for climate resilience (World Bank, 2025), however, indicate that it is measured as high water productivity, high uniformity and stability in crop yields and a reduction in GHG emissions.

To achieve these outcomes, the project employs a "triple win strategy". This is articulated as: 1) enhanced farm-level water security to overcome intra- and inter-seasonal climate variability; this takes the form of, among other things, increased water storage, enhanced water efficiency, and in situ water conservation; 2) improved soil health through soil nutrient management, promotion of soil carbon sequestration, and the adoption of agricultural practices that enhance soil fertility; and 3) increased farm productivity and crop diversification through the adoption of climate resilient seed varieties (short maturity, drought resistant, salt tolerant) and market oriented crops, and integration of farmers into the corresponding value chains. Horticulture plantations and agroforestry are also promoted to mitigate GHG emissions through carbon sequestration (World Bank, 2016).

Interventions under the programme are selected from a pre-approved list. These include: 1) soil and water conservation works in the catchment area, such as check dams, gabions, continuous contour trenches and bunds; and 2) farm-level interventions with subsidies for structures such as farm ponds, dug wells, pipelines to transfer water, and micro-irrigation systems, and subsidies for planting horticulture crops such as citrus, pomegranate and mango. Additional farm-level interventions include provision of shade nets and polyhouses; assistance with farm mechanisation; support in strengthening value chains; and support for allied activities related to animal husbandry.

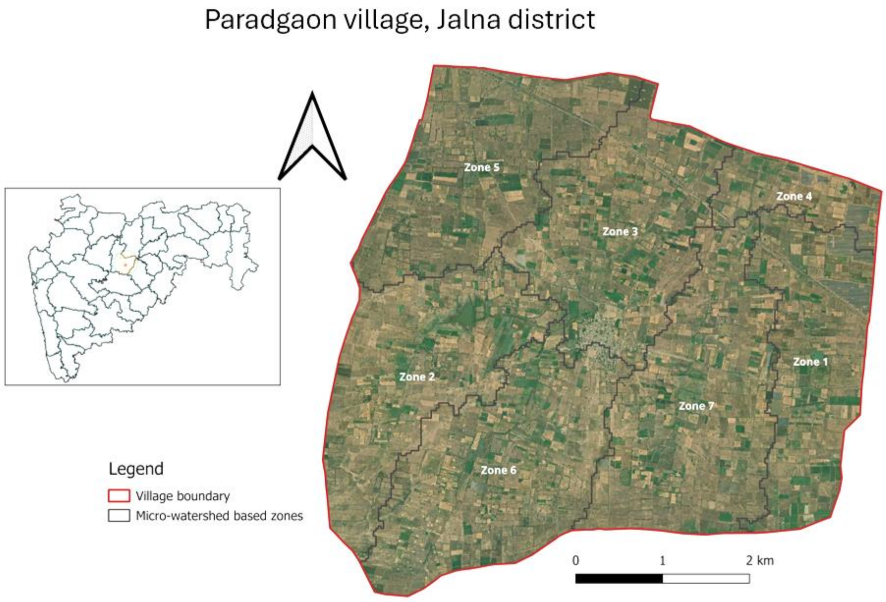
Microplanning is an integral step in the implementation of the programme. This involves the drawing up of participatory integrated village development plans over four to seven days, and then the aggregation of these plans to form a mini-watershed plan for a cluster of villages. Water budgeting is a key component of this exercise. Based on the current water balance for the village and desired changes in water use, scope for further impounding of water is determined. A village-level plan is developed that incorporates the new engineering structures to be created and the desired uses for them, for example, in terms of new cropping patterns. The integrated village development plan is approved by the village *gram sabha*. Post microplanning, the plans approved by the *gram sabha* are vetted by a team of technical experts and eventually approved at the district level. The short microplanning exercise captures only the type and number of interventions; specific details of beneficiaries and intervention locations are then finalised over time, with a key role being played by the Village Climate Resilience Management Committee (VCRMC). This committee is tasked with plan implementation, including recommending beneficiaries based on project guidelines. The VCRMC is a subcommittee of the *gram panchayat* (elected governing council of the village) with representation from marginal farmers as well as from progressive and agribusiness-oriented farmers.

In a departure from previous state programmes, PoCRA explicitly rejects the watershed approach (World Bank, 2016). Although mini-watershed plans and water budgets are developed to guide activities, the majority of the investment is planned to be at the farm level and not at the catchment-level. Given this, the question of equity in programme outcomes becomes especially important. The project has a guiding principle that most vulnerable farm households need to be prioritised for farm-level interventions. These vulnerable households include: farmers from marginalised groups such as Scheduled Castes (SCs) and Scheduled Tribes (STs), women farmers, disabled farmers, and other marginal and smallholder farmers. There is, however, no explicit prioritisation of farmers who do not have access to irrigation, even though the premise of the project is based on the vulnerability of rainfed agriculture. At the same time, we find that many interventions promoted under the programme (such as micro-irrigation, shade nets and horticulture) are such that they self-select beneficiaries who already have access to irrigation.

Study area

Paradgaon village was part of the first phase of the PoCRA implementation. It is in Jalna district of Maharashtra's Marathwada region. The village area is 2927 hectares (ha), and it has a population of 5222. It receives an average annual rainfall of 657 mm. The village is in the hard-rock shallow-aquifer region and its soil is deep and predominantly clayey, with some areas having gravelly clay loam soil. Before the implementation of PoCRA, the village had a total of 245 dug wells of about 20 to 25 metres in depth, 92 borewells that are up to 80 metres deep, and 1 village pond.

Figure 1. Study area.



Farming in Paradgaon is predominantly rainfed and cotton is the primary crop. Other common Kharif (monsoon) crops are pigeon peas, soybeans and mung beans, and intercropping is also practiced in the Kharif season. In Rabi (winter), the main irrigated crop is wheat, while other Rabi crops are sorghum (*jowar*) and green gram. No crop is cultivated in the summer months due to water scarcity. There are 514 farm-owning families, of which 42% have landholdings of less than 1 hectare and 74% have less than 2 hectares (PoCRA Project Management Unit, 2018.

Primary field surveys found that the predominant cropping patterns in the village include: 1) cotton (rainfed or irrigated), 2) cotton intercropped with pigeon peas (rainfed or irrigated), 3) pigeon peas intercropped with soybeans in Kharif followed by intercropping with wheat in Rabi (irrigated), 4) soybeans in Kharif followed by wheat in Rabi (irrigated), 5) green (*mung*) or black (*udid*) lentils in Kharif, followed by sorghum in Rabi (all rainfed), 6) soybeans in Kharif, followed by green gram in Rabi, and 7) annually irrigated crops such as sugarcane, citrus, sweet lime and grapes.

The PoCRA microplanning exercise led to the development of the village micro plan. This plan advocates a reduction in the area under rainfed crops and an increase in the area under seasonal and annual irrigated crops (PoCRA Project Management Unit, 2018). These recommendations are part of the effort to improve land and water productivity and to encourage crop diversification that is driven by emerging market opportunities for increasing smallholder income. In order to shift towards crops that are relatively less water intensive, a reduction in area under sugarcane and grapes is proposed, combined with an increase in citrus trees and pomegranate orchards. To increase cropping intensity, there is a planned reduction in long-duration crops such as cotton and pigeon peas and an increase in short-duration crops such as soybeans and vegetables. This acts only as a guideline, however, since each farmer ultimately decides what to grow; however, the programme incentivises this shift by providing subsidies for the new horticulture crops. New watershed interventions are also planned, including installation of check dams and farm ponds, deepening of streams, and expansion of farm compartment bunding; as per the PoCRA Detailed Project Report (DPR), these are expected to increase the runoff impounding capacity by an estimated 374,000 m^3 (PoCRA Project Management Unit, 2018). Our aim is to evaluate how the proposed intervention plan would modify water availability and irrigation water use for different types of farmers and in what way these interventions operationalise climate resilience.

Approach

In June 2018, the PoCRA project team completed a participatory microplanning exercise in Paradgaon and prepared a Detailed Project Report (DPR) on the planned interventions. The following month, the author conducted field work and conducted surveys of farmers in different zones of the village in order to understand crop choice, irrigation decisions, and the perceived impact of irrigation access on yield and income in good and poor rainfall years (Prasad, 2019). The water budget is computed using baseline data, and the planned PoCRA interventions are available in the DPR. The water budget computation and water distribution figures are based on data gathered by the author on irrigation practices and norms in the study area.

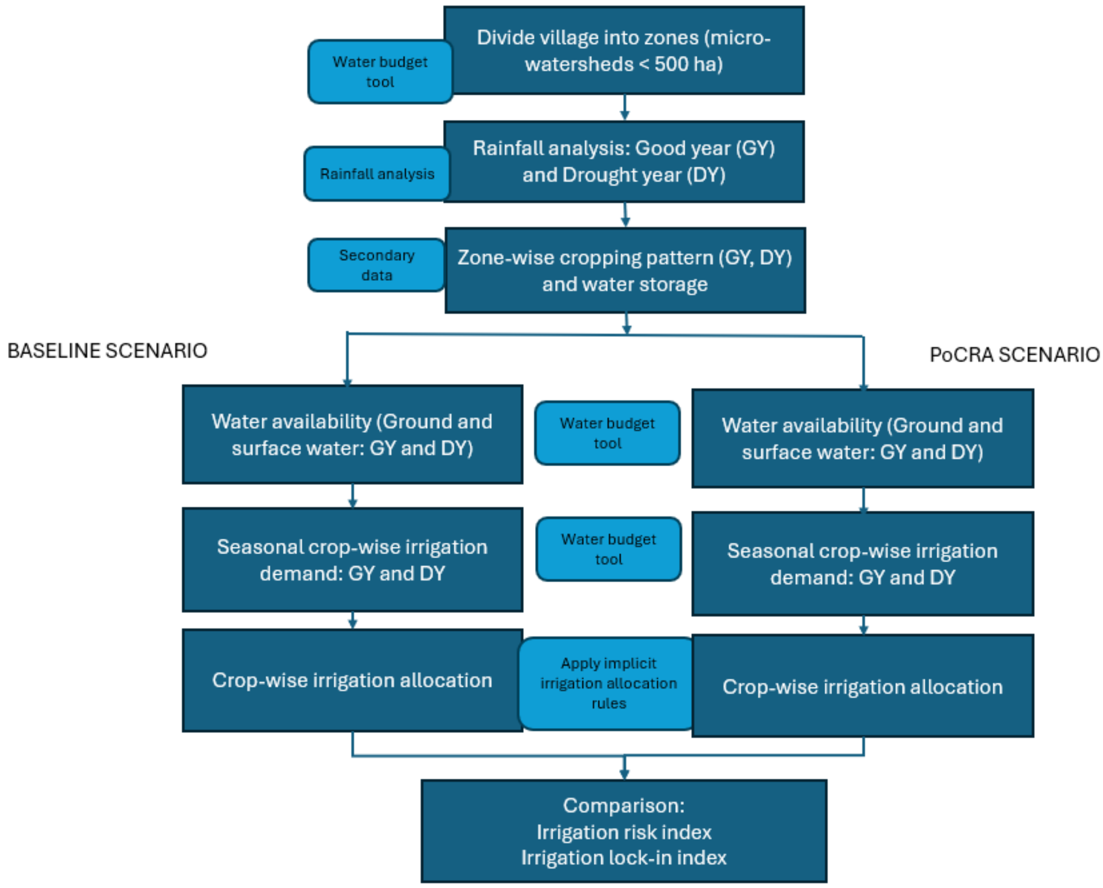
There are two scenarios, that is, the baseline case and the PoCRA planned scenario. The two scenarios differ in the assumed cropping pattern and in the type of water harvesting structures available. We compare the two scenarios in terms of the total water available in the form of soil moisture, harvested surface water and groundwater; we also look at the allocation of this available water to different types of crops based on the irrigation practices of farmers. We make this comparison for a good-rainfall year, and separately for a drought-year rainfall pattern. It is important to make this distinction of good-rainfall year and drought year, rather than comparing across an 'average' rainfall year because: 1) the objective of the programme is to build resilience to droughts and dry spells, and 2) farmers adapt their cropping intensity based on their assessment of the monsoon rainfall; that is to say, during a drought year they reduce the sown area of the irrigated (Rabi) crop and when rainfall has been good they sow crops with relatively higher water intensity. Comparison across good-rainfall and drought years thus allows incorporation of this adaptation strategy.

Computation of water availability and demand

Given the rainfall pattern, cropping pattern, and capacity of the water harvesting structures, we compute the water availability and the seasonal crop water deficit. This is done using the water budget tool developed by the PoCRA-IITB team (Belsare et al., 2022). The computation is done at the micro-watershed (or 'zone') scale, that is, an area of less than 500 ha (Figure 1). The water budget tool used by PoCRA (and in this work) is a spatially resolved rainfall partition model that computes seasonal zone-wise availability of surface water, groundwater and soil moisture, in addition to the share of rainfall that is taken up by crops (the actual evapotranspiration, or AET). The model also shows the crop water deficit, that is, the amount of crop water needed which would not be met from rainfall alone (Prasad et al., 2023). This crop water deficit is the volume of externally applied water that would prevent crop yield loss; in effect, it is the irrigation requirement. For each cropping season, the model thus estimates the water available for irrigation and the total crop water deficit at the micro-watershed scale.

Once the aggregate water availability and the crop water deficit are known at the zonal level, we apply implicit water allocation rules that are practiced by farmers to determine the distribution of water use among different types of crops, for both the baseline and the planned cases. We then compare the baseline and planned scenarios using two indicators that allow us to understand the implications of the water use distribution on farmer resilience (Figure 2 summarises this approach).

Figure 2. Approach.



Norms for irrigation allocation under scarcity

There are three cropping seasons. The Kharif crop is largely rainfed, and those who have access to irrigation may apply supplemental irrigation during dry spells within the rainy season. Before the start of the second cropping season of Rabi, farmers know how good the rainfall has been and those with access to shallow wells make a judgement on how long their wells will have water before the aquifer goes dry. Their expectation of how much they will be able to irrigate guides their cropping decision; for example, if farmers are confident of irrigation access through the Rabi season, they may cultivate higher-value crops such as vegetables or wheat, while if they are not assured of full irrigation they may grow millets, gram, or fodder crops. Some Kharif crops such as cotton and pigeon pea are long-duration crops that are sown in Kharif and may be irrigated after the end of the rainy season if a farmer has access to irrigation; alternatively, they may be cultivated as rainfed crops with a reduced yield. Orchard crops are multiyear and require year-round irrigation; farmers cultivate them only when they have invested in assured access to irrigation.

Even if a farmer's intent to irrigate is reflected in their crop choice, they may not actually irrigate when the need arises. This may occur when the farmer is unable to compete with other farmers who have greater ability to draw the limited water. The farmer may adapt by deciding to prioritise the irrigation of a high value crop over other crops; available water may then be rationed according to the crop intensification hierarchy (Prasad and Sohoni, 2020). Because of their large investment cost, orchards have the highest priority for irrigation, and farmers go to great lengths to meet their crop water demand even if it requires purchasing tanker water in times of scarcity. At the other end of the spectrum, rainfed farmers who grow cotton or pigeon peas (*tur*) have no access to irrigation or intent to irrigate and have significantly lower yields, depending on rainfall and soil moisture availability.

Table 1. Crop classification and farmer strategies for adaptation to monsoon variability

Crop Classification	Description	Example of crops	Farmer adaptation to monsoon variability	
			Sowing decisions: what and how much to sow	Irrigation decisions: what and how much to irrigate
F3	No irrigated crops, only rainfed	*Kharif*: pearl millet, green beans, soybeans *Rabi*: fodder, sorghum, green gram *Long Kharif:* cotton, pigeon peas	Intercropping with long-Kharif crops; Vary Rabi crop choice and sown area based on monsoon-end soil moisture	N/A
F2	Only seasonal irrigated crops (no orchards)	*Kharif*: soybeans, vegetables *Rabi*: vegetables, wheat, onion *Long Kharif:* cotton, pigeon peas	Rabi sown area increased in good-rainfall years and reduced in drought years	Prioritise high value crops for irrigation Long-Kharif crops are irrigated in good years and left unirrigated when water is insufficient Do not irrigate up to full crop water requirement (practice deficit irrigation)
F1	Annual irrigated orchards	Sugarcane, orchards (pomegranate, citrus fruit, guava)	Sown area and crop locked in for multiple years	Irrigation needs are locked in; sacrifice other crops to irrigate orchards; buy water if needed

Note: F1 = high value crops.

Based on this understanding, we categorise three types of crops in this smallholder farming system (Table 1): 1) F3: only rainfed crops such as rainfed cotton, pigeon peas and millet; 2) F2: seasonal irrigated crops such as wheat, onions and vegetables; and 3) F1: high value crops such as orchards. When water is scarce, F1 crops get the most irrigation since they are high value and require a dependable source of irrigation.

F2 crops have the next priority, but many of them may not receive the full intended irrigation and thus may suffer a reduced yield. F3 crops do not receive any irrigation. This prioritisation in allocation applies not only at the farm scale; it also applies across different types of farmers, based on the considered assumption that farmers cultivating F1 crops have made this choice because they have the highest means for irrigation.

On the supply side, watershed interventions that enhance soil moisture include compartment bunding or continuous trenching in the upland areas of the watershed. These interventions support purely rainfed crops (F3) by enhancing soil moisture and aiding in groundwater recharge. For farmers with no access to irrigation, interventions such as dug wells, or unlined farm ponds that capture field runoff allow to either access supplementary irrigation for monsoon crops or shift to irrigated crops. Interventions to harvest surface water (which also contributes to groundwater over time) include check dams, gabions, private farm ponds, and pipelines for transferring water to support irrigated crops (F1 and F2). Hence, other than the in situ interventions that enhance soil moisture, all other interventions enhance the local availability of surface and groundwater, which is only accessible to irrigated crops in the vicinity of the interventions.

Using the norms described here, we estimate the water availability resulting from the interventions and how this reshapes water access among three broad types of farmers: those with purely rainfed farms and no access to irrigation (F3 only, no F1 or F2 crops); those with limited access to irrigation who may be able to irrigate seasonally (having F2 and F3 crops, but no F1 crops); and farmers with assured irrigation who have multiyear orchard farms (F1, F2 and possibly F3 crops). Note that most farmers have no, or limited, irrigation access, while those with assured access to irrigation form a minority. According to the model, PoCRA investments would be followed by a number of shifts: some purely rainfed farmers would gain irrigation access, and some with seasonal irrigation access would invest in assured access; this would correlate with shifts in the overall area that would be under F1, F2 and F3 crop types.

Defining indices to compare scenarios

Our estimates of how access to water is reshaped by the interventions indicates the degree of distributional equity within the system. We further develop indicators to evaluate the resilience of the overall system.

Douxchamps et al. (2017) review the literature on the tools and indicators that are available for measuring resilience. They find that most indicators are social in character and that many of them are applied at the household level to determine, for example, which households are more and less resilient. Systems aspects are often not considered. Identifying indicators that measure the health and functioning of systems is more challenging. Where this has been attempted, the identification is largely theoretical and is not easily applied in practice. When there is a clear acknowledgement of their limited scope, indices focused on sub-parts of a system can be useful proxies for helping reduce the complexity of assessing resilience (Douxchamps et al., 2017). According to Constas et al. (2014), the measurement of resilience should include two points in time – an ex-ante and ex-post component – to reflect the process of building resilience into a complex system.

In our context, the focus is on the resilience of agricultural water use to rainfall variability at the systems scale, that is, at the aggregated village level. This resilience is high when the total crop water need in the system is sufficiently lower than the amount of water available to meet crop water demand; in such cases, deviations in water availability due to a system shock cause minimal adverse effect on farmers. Second, system resilience is high if farmers are able to respond quickly in a drought year by reducing their crop water demand, thereby minimising losses. In order to capture these two aspects of resilience in the context of dryland smallholder farming, we propose two indices, namely, Irrigation Risk Index and Irrigation Lock-in Index (as shown in Table 2).

Table 2. Indices for measuring resilience in irrigation water use

Index	Description	Implication
Irrigation Risk Index	(Irrigation demand of crops intended to be irrigated)/(irrigation water available)	Low fraction implies high resilience to water shocks; if close to or more than 1, then the demand for water is equal to, or exceeds, available water, which leaves very little buffer for farmers to depend on in a drought year
Irrigation Lock-in Index	(Irrigation demand for high-value multiyear crops)/(irrigation water available)	A higher fraction indicates higher lock-in of irrigation demand and poor adaptive capacity to monsoon variability

The Irrigation Risk Index may be compared to the index referred to as Days to Day Zero (DDZ), which was developed and applied by Lankford et al. (2023) to measure the resilience of irrigated agriculture to drought. DDZ represents the number of days it would take for the supply of catchment water available to irrigation to be withdrawn down to zero in the face of a prolonged drought. A higher DDZ, as for example more than 300 days, indicates greater resilience, while a DDZ of less than 150 days signals lower resilience. The Irrigation Risk Index, on the other hand, is a ratio of the amount of water needed for irrigation in a specific rainfall year, to the amount of water available for that year. This could be translated to DDZ if the denominator was taken to be the rate of irrigation water application. We find this to be less useful in our context, however, because crops are not irrigated 365 days of the year and the sown crops and area are both dynamic. DDZ as an index would be useful for a year-round irrigated crop, but in the context of rainfed farming – where the irrigated area may adaptively change each season – it is not so useful.

RESULTS

Following the approach shown in Figure 2, we first apply the PoCRA water balance model to obtain the seasonal water availability and crop water demand for our case study area in two extreme rainfall years: the drought year of 2014 (420 mm rainfall) and the good-rainfall year of 2016 (1009 mm). This is done for both the baseline (current state) scenario and the proposed (PoCRA planned) scenario.

Interventions

Table 3 shows the classification of the crops in Paradgaon and the area under each category (PoCRA Project Management Unit, 2018). In reality, the sown area and crop types are dynamic, since farmers are free to decide what crops they want to cultivate and because they respond to different drivers (Prasad and Sohoni, 2019). Similarly, the numbers used in the proposed plan are arrived at by the PoCRA team in discussions with farmers, but they cannot actually be enforced. Orchard cultivation is incentivised through subsidies, however, and subsidies are also provided for private irrigation infrastructure that incentivises rainfed farmers to shift to irrigated crops. As a result, the area under orchards is proposed to be more than doubled (42 to 91 ha), but a shift from more-water-intensive crops (sugarcane and grapes) to less-water-intensive orchards (citrus, pomegranate) is also being incentivised.

In both baseline cases, the irrigated area ranges between 22% (drought year) and 24% (good-rainfall year). In the PoCRA planned scenario, the irrigated area increases to about 30% of the cropped area. Table 4 shows the type of physical interventions proposed, which include stream deepening, gabions, check dams, and farm ponds; these are estimated to harvest 374,000 m^3 of additional water (PoCRA Project Management Unit, 2018) and support the change in cropping pattern.

Table 3. Paradgaon village crop classification.

Classification	Description	Season	Sown area (hectares)	
			Baseline	Proposed
F3	No irrigated crops, only rainfed	Kharif	2264	2068
		Rabi	408	294
F2	Only seasonal irrigated crops	Kharif	588	768
		Rabi	194	160
F1	Irrigated orchards		42	91
Gross cropped area			3496	3381

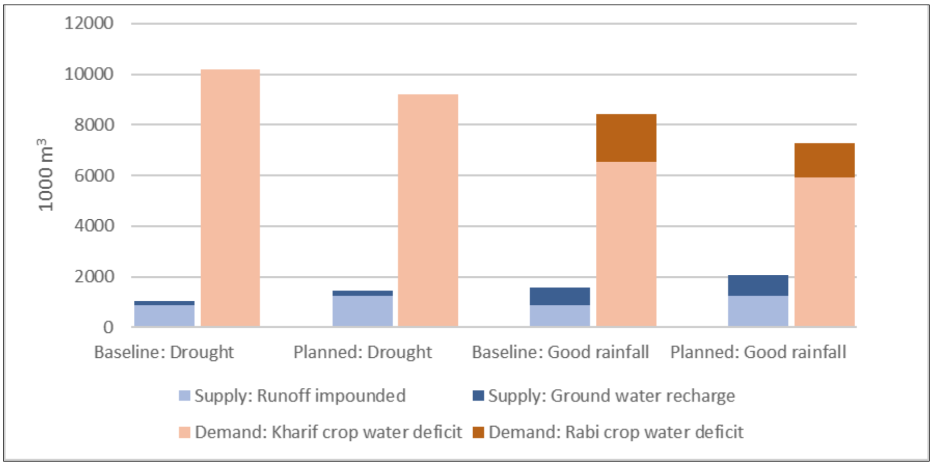
Table 4. Proposed interventions in Paradgaon village as per the microplanning process.

Proposed intervention	Count	Unit	Assumed water harvested as per PoCRA (1000 m^3 per unit)	Total water harvested (in 1000 m^3)
Stream deepening	2785	Metre	0.0075	20.9
Compartment bunding	94	Hectare	0.45	42.3
Gabion, concrete bund	2	Count	8.4	16.8
Farm pond	20	Count	2.2	44.0
Community farm pond	10	Count	25	250.0
Dug well	50	Count	0	0
Total				374

Aggregate water availability vs crop water deficit

The water budget model is applied at the micro-watershed level, with the seven values further aggregated at the village scale (Figure 3). Within each scenario, the amount of runoff arrested is the same in good-rainfall and drought years. This is because even though in a good-rainfall year the runoff created is significantly more than in a drought year, the impounded runoff is limited by the available storage. In the baseline case, the available volume of storage of harvested runoff is limited to 858,000 m^3, but in the planned scenario this increases to 1,232,000 m^3 because of the proposed interventions. The rainfall partition into groundwater, as expected, is low in drought years compared to good-rainfall years, and relatively higher in the proposed scenario compared to the baseline scenario. Over time, part of the harvested surface water recharges the groundwater; the blue bars in Figure 3 thus represent the total available water that can be used for irrigation and other purposes.

Figure 3. Paradgaon village water balance for a good-rainfall year and a drought year.



On the demand side, the model computes the seasonal crop water deficit, which is the difference between the crop's water requirement (ET) and the amount of water that it receives from soil moisture (actual evapotranspiration, or AET) under rainfed conditions. In the baseline scenario, this is computed using the current cropping pattern; in the planned scenario, however, the crop water deficit is for the proposed cropping pattern. In both scenarios, the Kharif crop water deficit is lower in a good-rainfall year than in a drought year (for example, in the baseline case this is 6,517,000 m^3 compared to 10,169,000 m^3) since the rainfall meets a larger share of the crop water need. Since most farmers do not have access to irrigation, the crop water deficit remains largely unmet. Note that, despite a high rainfall of 1009 mm, there is a crop water deficit in Kharif season because of specific biophysical properties; the clayey soil type, for example, results in high runoff and low soil moisture content, impeding its ability to meet the crop water requirement in rainfed conditions. The area sown in Rabi season is much less than in Kharif and the crop water demand is thus significantly lower; this results in low absolute values of crop water deficit despite less green water being available in this season. In a drought year such as 2014, farmers do not sow a Rabi crop at all, hence the Rabi crop water deficit does not apply.

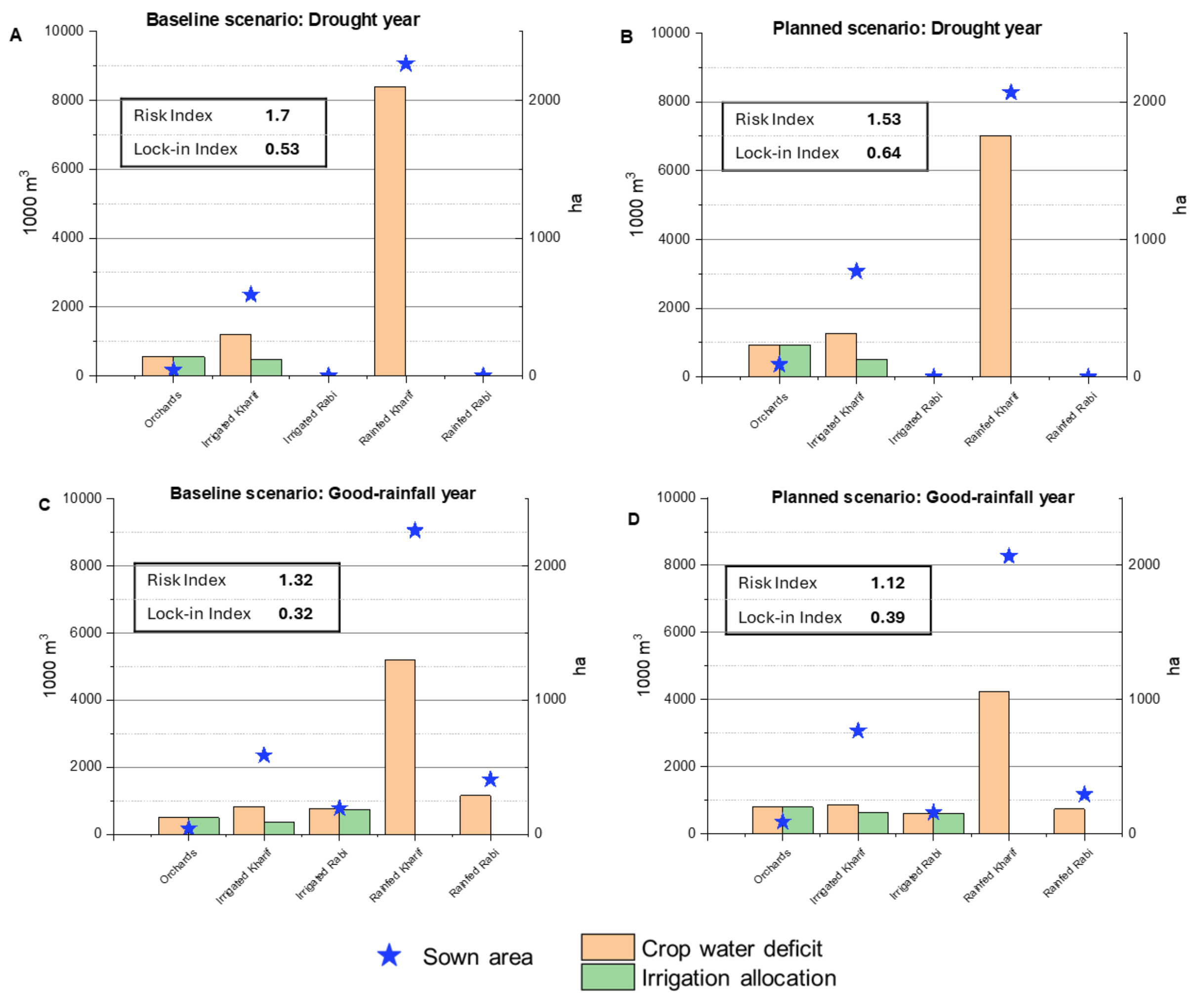
Overall, in both scenarios, the amount of water available (supply) is small compared to the crop water deficit (deficit), hence the water budget is negative. As seen in Figure 3, for the baseline case the total crop water need (including all crops, irrigated and rainfed) is 10 times the amount of water available for irrigation during drought years and 5 times the available volume during good-rainfall years. With the planned changes in cropping patterns and with investments in water harvesting, this is expected to fall to 6 times during drought years and 3 times during good-rainfall years.

Water allocation

Given that the available water is significantly lower than the crop water needs, we now apply the water allocation norms. Figure 4 shows the crop water deficit separately for each type of crop (orange bars) and, against this, it shows how the limited available water is allocated among the different crops. We also compute the Irrigation Risk Index and the Irrigation Lock-in Index to compare the outcomes of the scenarios.

Figure 4 shows that not only is the crop water deficit (for rainfed and irrigated crops together) much higher than the available water, but even the irrigation water demand of crops that are grown with the intention to irrigate is significantly higher than the available water. This shows that the full crop water need of irrigated crops would not be met in any of the scenarios, even in good-rainfall years. This is also reflected in the Irrigation Risk Index. In the baseline case, the index values indicate that the irrigation demand for irrigated crops is 1.7 times more than the available water in a drought year and 1.32 times the available water in a good-rainfall year. This implies that the irrigated crops cannot meet their full yield potential, not only due to rainfall fluctuations and climate uncertainty, but also because the irrigation need of the baseline cropping pattern far exceeds the water budget even when rainfall is good. This is consistent with the situation in most rainfed villages in Maharashtra, where the water budget is seen to be consistently negative. This fact is used as a driver for calling for more water harvesting infrastructure to bridge the demand-supply gap.

Figure 4. Distribution of available irrigation water among different crop types for baseline and proposed scenarios



In the planned scenario, water availability is expected to increase in both good-rainfall and drought years due to investments in rainwater harvesting. At the same time, however, the programme has planned a 230 ha increase in the irrigated area (a 36% increase), which will lead to an increase in irrigation water requirement. As a result, as shown by the Irrigation Risk Index, the irrigation requirement continues to overshoot the available water by 1.53 times in a drought year and 1.12 times in a good-rainfall year.

As seen in Figure 4, of the total water available for irrigation (all the green bars put together), a significant share is used by high value orchards (F1). In the baseline-drought scenario, orchards make up 1.5% of the sown area and use 53% of the available water in drought years. In the planned-drought scenario, the area under orchard is to increase to 3%. The type of horticulture that is planned is less water intensive than the baseline case, for example growing citrus fruit instead of grapes; since they do require irrigation throughout the non-monsoon months, however, 64% of the available water is committed to this 3% of the area. The fully rainfed area, by comparison, constitutes 70% of the gross cropped area and derives no benefit from the irrigation interventions.

Implications of the result

In the baseline case, the amount of water available to support irrigation is significantly lower than the irrigation requirements of the irrigated crops. In the PoCRA planned scenario, water availability is enhanced due to investments in watershed structures and greater water storage. At the same time, however, PoCRA plans to incentivise farmers to increase their irrigated area; because of this, the total irrigation demand continues to be more than the available water, which is expected to trigger competition in access to irrigation (Prasad et al., 2022). A focus on resilience would instead call for bringing the Irrigation Risk Index to a value lower than 1 by implementing water harvesting structures without calling for agricultural intensification. A focus on resilience would also need the development of institutions and practices that would ensure that the Irrigation Risk Index remains below 1 under different risk scenarios.

We also find a high level of inequity in access to irrigation water among the irrigators, which continues in the PoCRA planned scenario. In the baseline case, as indicated by the Irrigation Lock-in Index for drought years, we see that orchards use 53% of the available water even while accounting for only 1.5% of the sown area. In the PoCRA planned scenario, 64% of the available water is committed to 3% of the area, which corresponds to farmers with assured access to irrigation. An alternative approach could have been to have a large area under seasonal and supplemental irrigation (shifting from F1 to F2 crops); this would benefit a large number of farmers who have previously had no or limited irrigation.

Orchards are multiyear crops that require large investment from farmers. They typically have a lifespan of at least 15 to 20 years and the first harvest is not possible until a few years after planting. Unlike seasonal crops, fruit trees have a year-round water demand, and orchard cultivation thus creates an irrigation lock-in for farmers. An investment in an orchard constitutes a long-term commitment to irrigate no matter how good or poor the water availability (Prasad et al., 2022). The lock-in implies that the farmer no longer has the capacity to adapt to a drought year by shifting to a more appropriate cropping pattern or by reducing their cropping intensity to avoid crop loss. Moreover, since orchards require irrigation throughout the long dry season, in dry periods even a small area under orchards uses a significant share of the water that is available in the landscape.

It is important to note that, traditionally, diversification of cropping patterns and cultivation of fruit trees are practices that are known to help smallholding farmers become more resilient to market-related shocks. Even though referred to as "crop diversification", however, the horticulture farming practices currently being promoted entail monocropping of fruit trees with intensive inputs, assured irrigation, and strong market linkages. Such farms have high vulnerability to pest attacks and market price fluctuations; moreover, when this practice is promoted in drought-prone regions, the associated irrigation lock-in reduces the farmer’s capacity to adapt to climate shocks.

In a region that faces high variability in rainfall and groundwater replenishment, being climate resilient implies having the ability to intensify cropping when there is a good-rainfall year and to step back and de-intensify cropping in drought years to prioritise other uses of water such as drinking water for humans and livestock and fodder cultivation. The PoCRA interventions, though expected to enhance water availability, do not lead to enhanced resilience, as farmers are incentivised to use most of the harvested water for agricultural intensification with no buffer to deal with shocks. Moreover, with the promotion of orchards, the programme would lead to a reduced adaptive capacity of farmers by creating an irrigation lock-in in a highly variable environment and at the same time increasing competition to access the limited water among the other irrigating farmers. The proposed interventions will thus reshape water access in a way that exacerbates the current inequity in access to irrigation water.

The above conclusion is supported by a PoCRA post-implementation assessment (Sambodhi et al., 2024). Of the US$600 million project cost, US$498 million was budgeted for the largest component of the project, that of climate resilient agricultural systems. Of this, approximately 82% of the investments have been made in only four types of interventions: drip irrigation (50%), shade nets (16%), sprinklers (10%) and horticulture (5%). Note that these investments can only be useful to farmers who already have access to irrigation and not to farmers who depend on only rainfall. Individual assets approved under PoCRA that may be useful to farmers with no access to irrigation include: farm ponds, community farm ponds, farm pond linings, broad-based furrow technology, well recharge, interventions on saline lands, water pumps, and wells. All of these together accounted for an investment of less than 8% of the expenditure on individual assets. Additionally, about 2% of the US$498 million was spent on soil and water conservation works in the catchments, including bunds, trenches, gabions, small check dams and recharge shafts. This shows that even though the justification of the project is to address the vulnerability of rainfed agriculture to climate change, the programme interventions primarily support a section of those farmers who already have irrigation access and are focused on expanding the area under high value crops. A claim to resilience is made, however, by accounting for the carbon that is sequestered through these interventions. The project estimates that the agroforestry and horticulture activities in the project accounted for about 2 million tonnes of CO_2 sequestration during the project implementation period, by supporting horticulture and agroforestry on 29,270 ha and 613 ha respectively (Sambodhi et al., 2024).

DISCUSSION

Resilience of smallholder agriculture in rainfed regions refers to the capacity of the smallholder farming system to pursue agricultural production and 'bounce back' in the event of shocks such as dry spells and drought years. Resilience is a "systems" concept that originates predominantly from the broad field of social-ecological systems, where interconnections and feedback between the subsystems are key and the system thus becomes more than the sum of its parts. Focusing on only a limited number of irrigated farmers and providing subsidies for private irrigation investments is a fragmented approach (Tiwale and Sankar, 2025) that results in greater inequity due to the common pool resource property of water. Pritchard et al. (2024) show that programmes on climate adaptation can lead to increased inequity when subsidies focus on addressing individual adaptive capacities in a way that does not prioritise the needs of the marginal farmers. This is observed in our case study, where the interventions lead to the concentration of irrigation water use in a small share of the area in order to incentivise high value crop production, with very little emphasis on interventions for supplemental irrigation for farmers practicing rainfed agriculture.

The current thinking around resilience in agricultural water management and in indicators such as DDZ has a bias towards resilience of irrigated systems only. It does not give due consideration to the resilience of rainfed systems. This raises the question of what kind of investments can lead to the increased resilience of rainfed agriculture.

Some scholars have advocated for a paradigm shift in rainfed farming. They call for a move away from soil and water conservation that is focused on green water alone to an approach that combines blue and green water availability for supplemental irrigation of rainfed crops (Rockström, 2003; Rockström et al., 2010). To minimise the risk of dry-spell-induced crop failures and to build resilience in small-scale agricultural systems, Rockström et al. (2010) propose investments in the storage of surface or subsurface runoff and the development of rainfed farming as a blended blue-green system through making provisions for supplemental irrigation. This decentralised small-storage approach also resonates with those who call out the limitations of big infrastructure projects such as large dams and canals (van der Zaag and Gupta, 2008).

Kumar et al. (2017), on the other hand, assert that in semi-arid rainfed regions rainwater harvesting and in situ soil moisture conservation would not help in meeting crop water demand because, by definition, rainfed regions in semi-arid areas have low precipitation levels and high aridity. Runoff, soil moisture and groundwater recharge are thus simply not enough to meet crop water requirements unless only low-water-consuming and short-duration crops are grown during Kharif and a relatively small area is irrigated in Rabi. Obtaining optimum crop yields would require imports of surface water. Large parts of Punjab and Haryana, for example, have low to medium rainfall and high aridity, and they cultivate irrigated crops only because of investments in surface water imports through canals. They claim that unless there is such a water import, access to irrigation would only lead to unsustainable groundwater abstraction; however, they do not consider the practice of deficit irrigation, which is usually followed in water-scarce regions. In fact, it is well established that the highest water productivity (that is, the most crop per drop) is achieved when water is used for supplemental irrigation (or deficit irrigation) rather than full irrigation of crops (Vaidyanathan and Subramaniyan, 2004; Sharma et al., 2010).

Lankford et al. (2024) say that judicious supplementary irrigation may be technically feasible where there is well-regulated access to hydrologically sustainable surface water and groundwater. They argue, however, that this is a simplistic understanding because it does not consider the practical difficulty involved in providing and controlling one or two small doses of irrigation over a large area economically, technically and institutionally. This therefore leads, in practice, to serious unintended consequences of a blue water crisis in water-scarce catchments. Lankford et al'.s context, however, is sub-Saharan Africa, where supplementary irrigation is assumed to be supplied through surface irrigation since groundwater development is limited. In the Indian context, the atomistic system of wells, and more recently farm ponds, addresses the technical and economic challenges of operationalising supplementary irrigation; except in rare cases, however, serious institutional challenges remain, especially with regard to controlling irrigation intensification. Lankford and Agol (2024) argue that when irrigation investments are made on rainfed land the demand for irrigation starts to grow, since it is easy for irrigating farmers to switch more of their land from rainfed to irrigated crops or to increase cropping intensity. This drives up the total water withdrawals and depletion. Hence, what starts as a modest call for supplementary irrigation runs the risk of worsening water scarcity in an already water-scarce catchment. They therefore question if investments should be made in supplemental irrigation at all, as opposed to strengthening the existing irrigated farming.

Although Lankford et al. (2024) largely refer to surface irrigation, similar unintended consequences have been true even in India's context of conjunctive water use. For more than 50 years, India has been making massive investments in enhancing green and blue water availability through programmes on integrated watershed management (IWM). The 1970s saw the early success of isolated experiments with watershed programmes. From the first National Watershed Development Program for Rainfed Areas in 1990, followed by revised guidelines in subsequent phases, IWM has been the flagship approach for the development of India's dryland regions (Kumar et al., 2022). By 2005, nearly 45 million hectares had been covered in the different phases (Sen et al., 2007), and another 39 million hectares were covered in the period between 2009/2010 and 2014/2015 (Government of India, 2017). Since 2014/2015, however, there has been a consistent fall, with the current guidelines of the New Generation Watershed programme of the Pradhan Mantri Krishi Sinchayi Yojna (Prime Minister's Agricultural Irrigation Plan, or PMKSY 2.0) aiming to cover only a modest 4.95 million ha during the 2021 to 2026 period. This reflects the changing policy focus of the past decade, which has shifted from enabling sustainable livelihoods through natural resource conservation to increasing farm income through technologies for on-farm water conservation, enhanced water use efficiency, cultivation of high value crops, and development of market linkages.

Literature on the outcomes of past IWM programmes shows that in several watersheds they have been effective in increasing land productivity, employment generation, and the social upliftment of beneficiaries living in the rural areas; the success has been intermittent, however, as additional risks emerge over time (Government of India, 2008). First, in IWM projects, soil and water conservation measures have the effect of converting surface flow into groundwater and subsurface flow. Surface water, however, is considered to be a common property resource that is relatively easy to access, while in India groundwater is used as private property that is accessed through investments in wells. Public investment in watershed works thus results in shifting water from the public to the private domain and thereby creating inequity (Joy and Paranjape, 2004). Moreover, groundwater availability is not enhanced uniformly over the watershed, but rather in local pockets (Batchelor et al., 2003); this is especially true in the proximity of streams and recharge structures that benefit those who own land in these relatively water-rich zones (Shah et al., 2009).

Second, the gains experienced by those who benefit most can dissipate as competition for water resources increases (Batchelor et al., 2002). This intensified competition accompanies the increase in the number of wells and borewells that occurs in the wake of IWM projects that trigger an increase in irrigated area and cropping intensity (Prasad et al., 2022; Lankford and Agol, 2024). Prasad et al. (2022) show that increasing irrigation investments and agricultural intensification are initially driven by aspiration as more and more farmers are influenced by the success of early adopters, but that they eventually come to be driven by vulnerability as the landscape becomes more water scarce due to increasing withdrawals. The zero sum nature of water availability implies that greater withdrawal by some irrigators results in insufficient water for supplementary irrigation by others; this forces them to also invest more in water infrastructure in order to stay viable or be forced to quit agriculture. Most importantly, the increased cropping intensity comes at the expense of drinking water security, especially for the landless and asset-poor farmers who depend on shallow public drinking water wells (Prasad and Sohoni, 2020; Joy and Paranjape, 2004).

Thirdly, another well-documented unintended consequence of increased rainwater harvesting in the upper reaches of a catchment is the reduced stream flow to the downstream areas. This can result in the drying up of tanks and other downstream structures, and in some cases can even lead to basin closure (Batchelor et al., 2003; Calder et al., 2008). This happens when the amount of storage created does not consider the runoff potential and the existing storage in the catchment. The impact is highest in drought years, since planning is often done on the basis of mean rainfall figures. Programmes that aim to "capture every drop of rain" or "saturate" target villages with water harvesting structures without having a systems view of the entire catchment run the risk of this unintended consequence.

There are examples of successful cases where soil and water conservation, together with strong community norms for water governance (such as restrictions on water intensive crops, water budgeting and monitoring of water availability) have ensured that these externalities are avoided. In such cases, the irrigation water demand stays within the seasonal water availability and communities are able to successfully adapt to drought years (Foster et al., 2009). There are also examples of grassroots organisations that have demonstrated creative ways of assuring supplemental irrigation; among these is the borewell pooling programme, whereby hundreds of farmer collectives have been formed in which borewell-owning farmers share water from their wells with the non-borewell-owning farmers to allow them to irrigate up to three times during monsoon dry spells. This is a part of their agreement that also mandates that no new borewells would be dug within the collective (Ravindra and Raina, 2012). Another approach has been the provisioning of tanker water during dry spells. These strategies can serve as lessons in intervention to enhance resilience of rainfed farmers. The past decade, however, has witnessed a shift in the central policy with a decreased focus on supporting rainfed farming. Instead, agricultural intensification is promoted as a means to enhance farm income, and large investments in micro-irrigation are seen as the pathway to increasing water use efficiency and reducing irrigation demand. At the basin scale, however, the water-saving potential of micro-irrigation is questionable due to the 'rebound effect' that leads farmers to increase their irrigated area and shift to crops with higher evapotranspiration (van der Kooij et al., 2013, 2017).

A similar transition played out in Maharashtra leading up to PoCRA. Between 2012 and 2015, the state reeled under severe droughts. In 2015, soon after the new state government came into power, the Jalyukta Shivar Abhiyan (JSA) was kicked off as a flagship programme, with the goal of making the state "drought-free" within the next five years. The scheme advocated capturing every drop of rain, and investments were made in treating drainage lines, desilting ponds, widening streams and creating rainwater harvesting structures such as farm ponds. The success of the JSA programme was questionable (Bhadbhade et al., 2019; Shah et al., 2021). In 2016, however, it was supplemented with the Magel Tyala Shettale (Farm Pond On-Demand) scheme. This was initiated in response to demands from farmers in drought-affected villages and was funded by the state’s budget for drought mitigation measures. Private farm ponds had first come up in the state after the 1990s, through experimentation by farmers and non-government agencies. Farmers found that channelling the runoff generated within the farm into an on-farm pond was very successful, especially in the many parts of the state that have deep clayey soil with poor drainage and in regions with saline groundwater. Over time, the practice evolved and became problematic, as farm ponds started to be used as storage structures for groundwater and canal water that supported year-round irrigation of high value crops (Kale, 2017). As the success stories of farm pond users emerged in the media, they came to be considered the silver bullet solution, not only for addressing the water scarcity problem but also for increasing farmers’ incomes by providing assured irrigation for high value crops. Promotion of farm ponds, along with micro-irrigation and horticulture, became the winning combination that apparently could achieve the conflicting goals of 1) harvesting water to address water scarcity (through farm ponds), 2) arresting high withdrawals by irrigators (through the presumed water savings from micro-irrigation), and at the same time, 3) achieving agricultural intensification and high farm incomes through horticulture cultivation. This technological solution appeared to elegantly solve the distributional dilemma by suggesting that more water would be created which will satisfy increased demand without taking water away from others or reducing groundwater availability (van der Kooij et al., 2017). No one would need to limit agricultural production, and farm incomes would rise. Many scholars and practitioners have pointed out the unsustainability and inequity inherent in these assumptions (Kale, 2017; van der Kooij et al., 2017, Prasad et al., 2022), and this is also illustrated in our results. This combination, however, gained popularity among implementing agencies and farmers alike. As Argade and Narayanan (2019) find, this aspiration is linked to the imaginary of a 'better life' and a notion of 'development' that is associated with cultivation of 'better crops’ even if it is self-defeating in nature.

It was in this context that PoCRA was initiated in 2017. Despite an apparent emphasis on resilience and the need to address the vulnerability of rainfed agriculture, the project promoted the same combination of investments. In fact, it went a step further in explicitly rejecting[1] the watershed approach. Of its US$498 million budget for building climate resilient systems, PoCRA invested only 2% on public assets within the catchment, and 97% on individual assets. Micro-irrigation, horticulture, and farm ponds together add up to more than 82% of the amount invested in individual assets (Sambodhi et al., 2024). There is only a sprinkling of expenditure on other practices, even though there is copious discussion in the project planning documents of concepts such as soil fertility, nutrient management, improved drought-tolerant seeds, animal husbandry and capacity development. PoCRA implementation ended in 2024, and there is yet to be an extensive study of its impact. The World Bank’s project-closing report cites the assessment report commissioned by PoCRA itself (Sambodhi et al., 2024) and awards the project an overall satisfactory outcome rating. Within the government, the programme is considered to be a big success, and a second phase of PoCRA was approved in 2025.

[1] According to the World Bank (2016: 6), "a watershed-based approach was considered for the project, with a stronger focus on natural resources management. This approach was eventually discarded since it would not sufficiently focus on farm-level adaptation and mitigation issues nor would it provide the support for value chain development, a key part of the comprehensive approach needed to provide the market outlets and input supplies required to incentivize farmers to adopt resilient crops and agronomic practices."

The objective of enhancing resilience comes from a place of addressing vulnerability; implementation, however, follows a utilitarian approach that is focused on the most productive entities and individuals. Moreover, the current focus on promoting irrigated agriculture instead of supporting rainfed agriculture does not prevent further intensification of agricultural water use in the future (Prasad et al., 2022; Lankford et al., 2024); indeed, it sets up the target regions for a further reduction in resilience to droughts and dry spells.

CONCLUSION

The objective of the study was to evaluate how interventions for climate resilient agriculture in dryland rainfed regions operationalise resilience, and for whom. We use a case study of the Government of Maharashtra's Project on Climate Resilience Agriculture, where planned interventions include investments in rainwater harvesting and irrigation infrastructure, as well as incentives for shifting cropping patterns to high value crops in order to enhance farm income. By using a modelling approach based on water budgeting, we assess how the new interventions reshape access to water among different types of farmers. We find that while the interventions would increase water availability in the target village, the majority of the available water would be used for irrigating a fraction of the cultivable land, thus benefiting farmers who already have assured access to irrigation. The incentivisation of year-round irrigated orchards in a drought-prone region not only worsens inequity in access to irrigation; it also reduces the adaptive capacity of irrigators by locking a large share of water into irrigating multiyear crops for decades to come. The resilience of the vast majority of the farmers with no irrigation access – those who are most vulnerable to dry spells during the rainfall season – remains largely unaddressed in the programme. This is despite the fact that the justification for initiating projects on climate resilience stems from the high vulnerability of farmers practicing rainfed agriculture. We argue that the concept of resilience does not inherently capture the distribution of outcomes within the system, and hence it is important to use the equity lens to evaluate the distributional effects of interventions. In public programmes on irrigation investments, there is a bias towards supporting existing irrigators; we thus argue for a greater focus on investing in solutions for supplemental irrigation of rainfed crops in order to help make farmers more resilient to changing rainfall patterns.

The state of Maharashtra has a long history of implementation of watershed management programmes to enhance water availability and agricultural productivity. PoCRA was introduced in Maharashtra in 2017 on the heels of the Jalyukta Shivar Abhiyan, which itself aimed to make the state 'drought-free'. While the previous programmes were critiqued for being iniquitous in terms of benefit sharing, there are examples of successful grassroots-level attempts that have institutionalised benefit sharing and implemented supplementary irrigation for rainfed farms. PoCRA marks a shift away from previous approaches that aimed to enable sustainable livelihoods through natural resource conservation; the shift is towards the utilitarian approach of increasing farm income through technologies for on-farm water conservation, enhanced water use efficiency, cultivation of high value crops, and development of market linkages. It rejects the integrated watershed approach and instead focuses primarily on funding private assets for those who already have access to irrigation. We call for more attention to the impact of this approach, especially as the second phase of PoCRA begins and as there are ongoing reductions of the national allocation to support rainfed agriculture through integrated watershed management.

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