TRIGGERS AND TRAJECTORIES OF SUSTAINABLE GROUNDWATER MANAGEMENT IN SEMI-ARID REGIONS OF MAHARASHTRA, INDIA

A MENTAL MODEL APPROACH

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Abstract

This paper is an exploration of the mental models of groundwater sustainability in the semi-arid regions of Maharashtra and aims to understand the behavioral aspects of groundwater management; in particular the challenges and actions from the past and present that inhibit or enable sustainable groundwater management in rural areas; the processes and structures that influence groundwater use and management over time, and the psychological beliefs, values, and norms regarding water resources and its security. The study forms a qualitative assessment of the mental models of 43 farmers in three districts in Maharashtra based on agro-climatic and institutional contexts that shape their beliefs, perceptions and behavioral aspects of sustainable water management and conservation. The results of the study show three key insights: one, water scarcity is a complex problem that requires a systems approach for understanding the feedbacks and interrelations between the various elements of the groundwater use and management, especially the long-term and short-term impacts of water initiatives. Second, despite higher water-related distress, farmers in the scarcity zone people showed higher sustainability consciousness than assured rainfall or transition zones in their desire to conserve groundwater for future generations. Third, the success of watershed development works in the past were largely due to collective mobilization and active participation of village members towards a common goal of conserving groundwater resource. Future interventions and policy nudges that harness the strength of collective community action will likely be more effective in increasing the sustainability consciousness of rural farmers in the long run. Fourth, water policies need to incorporate the underrepresented dimensions of social and environmental sustainability for a more balanced approach.

Introduction

Water is a critical element in arid and semi-arid landscapes (Burmil, Daniel and Hetherington, 1999), especially since it forms a limited resource tied deeply to human livelihoods, growth, and development. Changes in water regimes in such climatic fragile landscapes can alter the entire biophysical, environmental, and social ecosystems. As such, water (presence or lack of) holds critical meaning and significance to individuals and communities living in these regions. The Sustainable Development Goals SDG 6 calls for clean water and sanitation to 'ensure availability and sustainable management of water and sanitation for all'. According to Hermanowicz (2005), the meaning of water sustainability has changed over time from solely maintaining a balance of water demand and supply to incorporating elements of water quality, and their social and environmental impacts on natural systems. This trend in the discourse around water issues in India can be seen in a similar light. While earlier works on water issues in India often focused on water availability (as a function of water demand and supply) (see Dhawan (1989); Singh et al. (1993); Moench (1994; 1996); , the recent focus on inter and intra generational iniquities (Narain (2006); Kumar & Saleth, 2018) as well as the environmental effects of water extraction have highlighted the sustainability aspects in water management (Kumar & Saleth, 2018; Nair, 2007; Srikanth, 2009;).

According to Corral-verdugo and Fr (2006), an individual's ability to anticipate future events is based on cognitive processes based on their past and present experience and is called the 'time perspective' of individuals that determines their sustainable behavior. There is evidence that people with a future perspective display more sustainable behavior towards natural resource conservation while past or present perspectives are indicators of behavior opposing sustainability (Arnocky et al., 2014; López-ridaura, Masera and Astier, 2002). Furthermore, as highlighted by Rogers et al. (2004), sustainability is not static and the actions we take now influence the sustainability of the future. The time perspective aspect of sustainability is an important but overlooked concept, which calls for not only envisioning how our actions in the present would affect the future but also, how our actions in the past have affected our present.

This study seeks to fulfill this gap by eliciting the mental models of groundwater related issues by people in the semi-arid regions of Maharashtra who face its scarcity the most and asks foundational questions like:

1. What is the meaning and importance of water security to people in the semi-arid regions of Maharashtra?
2. What are the actions and challenges people face with respect to the sustainable use of groundwater?
3. What are the factors that influenced the actions around groundwater management over time?
4. What are the policy and intervention triggers that can nudge people towards more sustainable management of groundwater in the future?

This knowledge contribution is essential for developing and adapting water policies in ways that expand the framing of water security beyond availability but are inclusive to aspects of access, utilization, and long-term sustainability. It would also fill in the gaps in knowledge on individual level behavioral and cognitive aspects of groundwater management that is often lacking in the water discourses in India and elsewhere (Pahl-Wostl et.al. 2007).

Dysfunctional water structure in Pimpri Pathar

Conceptual Framework

Jones et al., (2014) defined mental models as the "internal, cognitive representations of people's interaction with the world". Mental models have been particularly useful methodology to understand the 'environmental cognition' of individuals which means understanding how humans structure their thoughts about environmental issues, how do such cognitions form, how do cognitions change over time and how do they influence behavior and actions (Henry and Dietz, 2016) . In the mental modelling methodology, individuals verbally or visually express their thoughts, beliefs and understanding about an issue which are then converted into visual diagrams/models that highlight these cognitive processes. The mental models act as a "boundary objects" to highlight the diverse ways in which different social, cultural and socio-economic identities of individuals influence their behavior and decision-making, in this case, around ground water use and management.

In this study, we aim to understand the time perspective (past, present and future) of beliefs, perceptions and actions around groundwater security and management. Thus, the mental models trace a temporal dimension towards beliefs, challenges, actions and perceptions and behavior around groundwater. This is illustrated in the conceptual framework of the study (Fig 1).

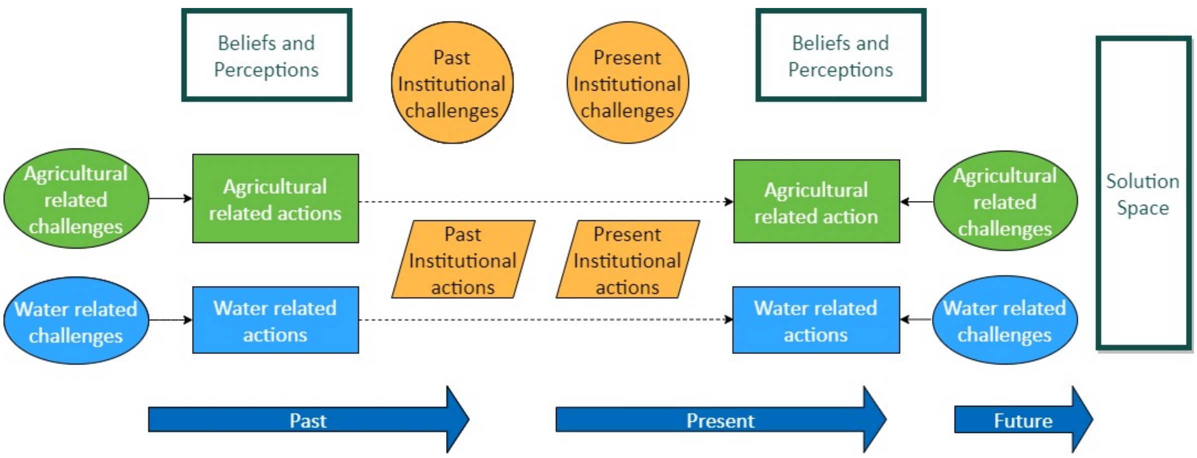

Fig. 1: Conceptual framework of the study; the x-axis represents data dimensions of perceptions of components of water security; y-axis represents the temporal dimension of perception

As illustrated in the Figure, we explore the individual cognitive perceptions of groundwater related issues (Biaggi and Ferro, 2011) and behavioral aspects of groundwater conservation actions. Further, the representation, values, and perceptions of groundwater both shape and are shaped by specific social and cultural contexts. These factors and perceptions are often dismissed as unquantifiable. The objective of this study is to specifically uncover the heterogeneity in perceptions, beliefs, values, and actions among different populations based on the agro-climatic and institutional contexts that shape their experiences around groundwater resources.

Study Area

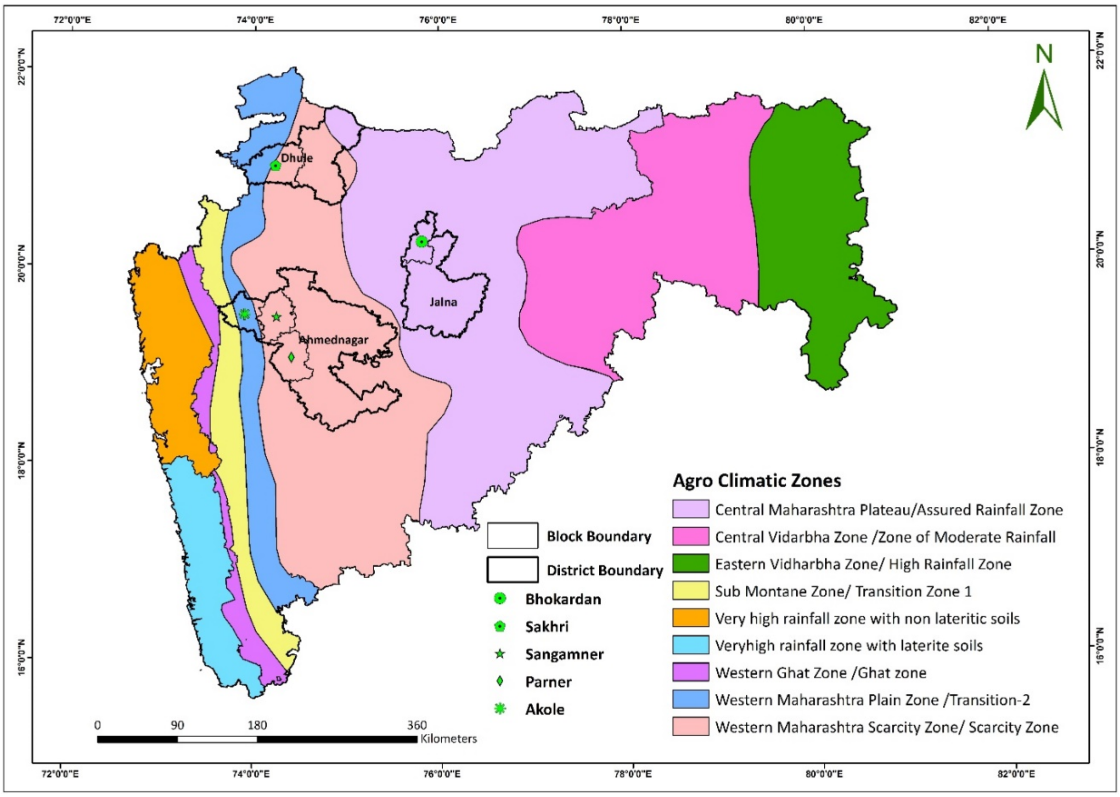

Fig. 2: Agro-climatic Divisions and study areas in Maharashtra

The Western semi-arid regions of India are emblematic of water struggles in the way water forms the root of political and social conflict and strife (Wagle et al. 2012; Brunner et. al., 2010; Pangare et. al., 2004). Maharashtra covers almost 9.4 percent of the total geographical area of the country which can be divided into nine agro-climatic zones (see Fig. 2). The Western Ghats across the coastline of Maharashtra forms an intercept to the Westerly monsoon winds from the Arabian Sea, resulting in higher rainfall (annual average: 3000 mm) in the windward regions west of the Ghat Mountains, while the leeward areas east of the Ghats form the transition and drought-prone zones which receive only about 500-700 mm annual rainfall. The state has been divided into nine agro-climatic zones based on rainfall patterns, soil characteristics and cropping patterns as south Konkan coastal belt, north Konkan coastal belt, western ghat, transition zone 1, transition zone 2, scarcity zone, assured rainfall zone, moderate rainfall zone and eastern Vidharba region (GoM, 2010). The selected villages in this study; fall under the scarcity, transition zone 2, and assured-rainfall agro-climatic zones (see Figure 2).

Methodology

4.1. Data collection

The sample villages (Table 1) were selected based on two criteria: the agro-climatic zone and whether any watershed-related work had been conducted in the village. Selection based on agro-climatological zones ensured a diverse coverage of geographical contexts with varying degrees of groundwater availability in each zone. Selection of villages with both prior watershed development intervention and comparative villages with no watershed development ensured a wide coverage of beliefs and perceptions of people based on their past experiences and observations of watershed development and conservation initiatives.

Agro-Climatic Zone	District	Village	Number of interviews
Scarcity Zone	Ahmednagar	Hivare Korda	8
	Parner	Pimpri Pathar	9
Transition zone 2	Akola	Wanjulshet	8
	Akola	Mogras	4
Assured rainfall zone	Jalna	Kolegaon	8
	Jalna	Kadwanchi	6

Table 1: Sample villages and number of interviews

In each village, the research team, along with the village sarpanch (village head/chief) and key village representatives, conducted a participatory mapping exercise to identify the key landmarks (school, temple), water resources (farm ponds, rivers, community wells), and layouts of houses, streets, and community hamlets within the village. Four or more respondents were selected in each village for the interviews.

The selection of respondents for the interviews was made based on gender, and socio-economic characteristics of the farmers represented by caste, land size, and access to water infrastructure (such as private borewells, dug wells and farm ponds). The interviews from each village included representation from diverse perspectives of females and males and landless, small, medium, and large farmers. The number of interviews in villages in each agro-climatic zone was determined when the team reached a saturation point when no new insights were being generated with additional interviews. The distribution of interviews based on gender, farmer type, and access to water infrastructure is outlined in Table 2 for reference.

Data, in the form of extensive narratives, were collected from 43 respondents in six villages across three districts in Maharashtra. The interviews were conducted in Marathi or Hindi by the research team. A set of core open-ended questions was systematically asked to each respondent; with follow up questions where needed. The average length of the interviews was about 60

Agro- Climatic Zone		Scarcity Zone	Transition Zone	Assured Rainfall zone
Gender	Male	10	7	5
	Female	7	5	9
Farmer type	Landless	4	-	3
	Marginal	2	1	4
	Medium	3	2	2
	Small	1	4	1
	Large	7	2	3
	Women's group	-	1	-
Access to water infra-structure	Borewell	3	-	1
	Borewell + Farm-pond	1	-	-
	Borewell + Farm-pond + Well	1	-	1
	Community well	3	3	5
	Farmpond	-	1	2
	Own well	1	2	2
	Pipeline	3	-	1
	Rainfed	2	1	-
	Shared water pump	-	1	-
	Not mentioned	3	4	2

Table 2: Distribution of interviews based on gender, farmer type and access to water infrastructure

to 75 minutes and the respondents were asked open-ended questions like: "What are your past memories regarding water?", "Is there any change in these past experiences with water compared to now?", "What is the situation of water at present?", "What will be the status of water and its problems in the future? What do you think", "What could be possible solutions to water problems and issues?"

The questions covered aspects of people's past experiences with water starting with their memories from childhood on availability, access, and utilization of water, past challenges associated with water as well as the actions they took to cope with the water situation. The respondents were also asked to describe the present experiences, challenges, and actions associated with water and agriculture. Interviewees were also asked about their perception of climate, beliefs regarding the status of water in the future, motivations, and solutions that can be implemented to secure a better future for their children. Additional questions included but were not limited to conflicts regarding water management, institutional actions and challenges, and perspectives of future generations on sustainability issues.

4.2. Interview coding

Out of 43 interviews, 38 interviews were transcribed from audio to Marathi script by a team of transcribers who had observed the interview process and hence knew the context and were less prone to make interpretive errors. The transcribed interviews were then translated to English by professional translators to ensure good quality of translations such that contexts and meanings were not lost. The translations were cross-checked and reviewed by the core research members to ensure consistency and accuracy. 5 interviews could not be translated properly to English due to issues with unavailability of transcribers and hence were excluded from the coding analysis.

Grounded theory (Strauss, 1987) is a methodological approach which forms focus on the development of theory without any preconceived hypothesis. It involves the use of analyzing raw qualitative data and using an iterative coding paradigm to develop themes, concepts, and patterns within-case comparisons (Glaser and Strauss, 1967). The key purpose of the analysis is to assess 'what' the data says and identify patterns in the data. The interview data is coded into concepts and themes where the analyst reads the data and identifies segments within the text that fits a particular theme or concept. The selected segments, also referred henceforth as excerpts, are then labeled with the coding rubric or in other words the identified theme or concept. The resulting code counts and excerpts can then

Primary Codes	Sub-codes	Code # 1	Coder # 2	Coder # 3
Past Agriculture	Actions	57	79	73
	Challenges	39	77	40
Past Water	Actions	71	175	92
	Challenges	63	231	124
Past Climate	Adaptation Actions	6	1	3
	Challenges	10	58	11
Past Livelihoods	Actions	37	111	115
	Challenges	15	43	49
Past Institutions	Actions	26	175	36
	Challenges	8	53	4
Present Agriculture	Actions	149	266	239
	Challenges	80	119	109
Present Water	Actions	168	166	192
	Challenges	94	201	206
Present Climate	Actions	13	7	6
	Challenges	18	59	30
Present Livelihoods	Actions	61	172	164
	Challenges	26	63	61
Present Institutions	Actions	115	97	32
	Challenges	75	126	24
Future agricultural beliefs		25	57	35
Future water beliefs		64	99	83
Future climate beliefs		21	38	27
Motivations		53	102	16
Solutions		50	150	49

Table 3: Primary coding rubrics

be analyzed further, compared based on cases or summarized to identify patterns across the data. We used Dedoose content analysis software to code the interviews. Coding can be either open or closed: which means that either the coding rubrics can be predetermined or generated during the process of coding. In this study, we conducted two rounds of coding by a team of coders who coded the interviews separately to ensure intercoder reliability.

The first round of coding was conducted by three coders using a closed coding rubric composed of 25 codes and sub-codes. Table 3 indicates the specific coding rubrics and the count of the excerpts regarding each rubric by the coder (Sources), and how often each sub-code was coded across the interviews by each coder (References). For example, as shown in table 3, the primary code of 'Past Agriculture' has two sub-codes i.e. actions and challenges. These codes label all text which is related to past agricultural actions and challenges mentioned by the interview respondents. The table also highlights the count of references for each code by each of the three coders: Coder # 1, Coder # 2, and Coder # 3. The count of the references by the three coders varied, as the coding style varied between each coder. Some coders selected smaller chunks of text while others coded in larger chunks of text (Campbell et al., 2013). However, Dedoose is a collaborative qualitative analysis software that ensures blind coding as well as document closing. This allowed us to check the codes on a case by case basis to help cover as much relevant information as possible and ensure intercoder reliability.

The second round of coding of excerpts from the first round of coding was conducted separately by two coders to identify further themes within the aforementioned codes using open-ended coding. The excerpts of the primary codes from the first round of coding were categorized based on agroclimatic zones and coded for secondary codes and sub-codes. For example, of the total 1539 excerpts from the primary round of coding, 37 percent of the excerpts belonged to interview respondents from the assured rainfall zone, 26 percent belonged to interview respondents from the transition zone and the remaining 38 percent belonged to the interview respondents from the scarcity zone.

The excerpts from different agro-climatic zones had different secondary codes and sub-codes that emerged from the open-ended coding process. For example, past agricultural actions and challenges were sub-coded for recurrent themes and concepts that arose in the excerpts such as irregular water supply or low water quality etc. The secondary coding rubrics consists of 16 secondary codes and 320 secondary sub-codes. Details of secondary coding rubrics (codes and sub-codes) for past water-related challenges and actions are highlighted in Table4. The frequency percentage distribution of each code count from the secondary coding was used to compare the different agroclimatic zones. The percentage frequency is calculated by identifying the total count of coding instances for a particular code by agro-climatic zone; and dividing the code count per zone by the total number of code counts for all zones.

Primary code	Secondary code	Secondary sub-code
Past Water Challenges	Irregular water supply	
	Lack of water structures	No farm pond
		No pipeline
		No tap water system
		No wells
	Low groundwater due to geological features	
	Low water quality	
	Socio-economic issues in water	Caste-based water issues
		Social issues (non-sharing)
		Water-based conflicts
		Water Scarcity
		Water available for drinking only
		Water shortage due to excessive irrigation
		Water wastage (running tap, pump water flow, etc.)
Past Water Actions	Irrigation	Flow irrigation as per water availability
		Borewell irrigation
		Irrigation through open channels
	Construction of water infrastructure	Construction of KTs
		Construction of borewells
		Construction of dams
		Construction of dug wells
		Construction of percolation tank
		Construction of water channels
	Use of water infrastructure	Use of wells
		Use of farm pond
		Use of moat/pulley
		Use of pipeline water supply
		Use of water tankers
	Manual water collection	
	Excessive extraction of groundwater	
	Took loans to construct water infrastructures	
	Accessing water through multiple sources	

Table 4: Secondary coding rubrics for past water challenges and actions

4.3. Model development

Three collective mental models were constructed to represent the three agro-climatic zones, namely scarcity, transition zone 2, and assured rainfall zone. The mental models, as mentioned in the previous sections, were developed to identify and highlight the key processes or mechanisms that influenced the past, present trajectories of groundwater sustainability among agriculturalists in the study area as well as identify solutions that may trigger people to navigate towards a more sustainable water future. The mental models trace the perception of farmers on the institutional mechanisms that influenced the change in agricultural actions and challenges from the past to the present and their proposed solutions for the future for each of three agro-climatic zones. The models were constructed through an iterative process by incorporating the key concepts that emerged from the second round of coding by using the count frequency percentages in each agro-climatic zone. The secondary codes with the higher percentages were picked to show a representation of the high-frequency mentions made by farmers about the particular theme and concept.

The mental model diagram was developed using diagrams.net which is an open-source diagramming software. The first mental model represents the collective model for the scarcity zone, the second model represents the collective mental model for the transition zone and the third model represents the collective mental model for the assured rainfall zone. The models are split into four sections: past agricultural and water challenges and actions; past and present institutional actions; present agricultural and water challenges and actions; and future solutions. Each of these sections outlines the key secondary codes relevant to the themes and traces the mechanisms or processes that created the trajectories from the past to the present.

Results

As readers may recall, the objective of this study was three-fold: one; understanding the behavioral aspects of groundwater management; in particular the challenges and actions from the past and present that inhibit or enable sustainable groundwater management in rural areas; second, understanding the processes and structures that influence groundwater use and management over time, and third, understanding the beliefs, values, and norms regarding groundwater resources and its security. In the following subsections, we elaborate on the insights gained from this study towards these objectives. Section 5.1. elaborates on the analysis of the codes and identifies the key actions and challenges in the past and the present with regards to agriculture and water as well as the various behavioral aspects of agricultural and water-related beliefs, motivations, and perceptions of farmers in the study area. Section 5.2. identifies the institutional factors and processes that influenced the trajectories of groundwater management over time through mental models and discusses the future aspirations and solutions of farmers in the area.

5.1. Actions and challenges to the sustainable use of water and agriculture

5.1.1. Past agricultural challenges and actions

Overall, the analysis of code counts for agricultural challenges in the past shows that the main challenges faced by farmers in the past across all agro-climatic zones were: water scarcity, low income, low crop production, food insecurity, low rainfall, rainfall uncertainty, and low crop diversity.

Water scarcity had the highest code frequency percentage in the assured rainfall zone (43%) followed by scarcity zone (36%) and transition zone (21%). Low rainfall was a challenge mentioned by all agro-climatic zones equally (33%), whereas uncertain rainfall as a challenge was perceived mostly by the scarcity zone (60%) followed by transition and assured rainfall zones (20% each). In the assured rainfall zone, respondents mentioned they were unable to do multiple cropping in the past (75%code frequency) due to water scarcity and had no choice but to cultivate only one major cash or food crop per season as per water availability. Consider the following quotation from one of the farmers, who shared his inability to diversify crops in the past due to water availability.

"Earlier, only maize and cotton were cultivated. The crops have changed due to the availability of water. Chili and maize are being cultivated twice. Earlier, irrigation could not be done. There were no wells, so only one crop could be grown"

In the scarcity zone, the farmers mentioned doing subsistence farming (40% code frequency) of only food crops (35%) that were mainly dependent on rains (40%). Like assured rainfall zone, they also were unable to expand their crop choices (25% of low crop diversity) and mentioned facing low crop production (43%) due to less water availability. Consider the following quote of a respondent from this zone in support of this state of the past.

"[Respondent] Earlier, we used to have Potato crop when there was drought. It was not so that we earned a lot, but we could make a living. Later, in the 80's, we started taking the crop of peas. But it was like, if it rained in the beginning, well and good... or otherwise, it burned. [Interviewer] Has this been like that since childhood? [Respondent] Yes. All of it is like this since my childhood. When it started raining in Mumbai, it started raining here as well in July. And once it stops then we cannot say whether it will return or not. It is a very low or no rainfall region... This is the environment for the last fifty years. We never had irrigated crops, so the farmer has always been poor."

The challenges of the farmers in the transition zone were almost similar to those of the assured rainfall and scarcity zones. However, an additional challenge mentioned by farmers in the transition zone was food insecurity (100% code frequency). Subsistence farming (60%) of food crops (45%) that were highly rainfall dependent (50%) did not deliver enough food for survival, therefore rendering people food insecure. The following quote expresses an instance of food insecurity of a respondent belonging to this zone.

"Due to water scarcity, food was not enough for us. The agriculture production was very low and was difficult to fulfill our food requirement."

Apart from all the above challenges, the farmers also indicated low income from sales of agriculture production as a major agricultural challenge. It was a challenge mostly in the assured rainfall zone (50%) followed by transition zone (33%) and then the scarcity zone (17%) (Fig 3).

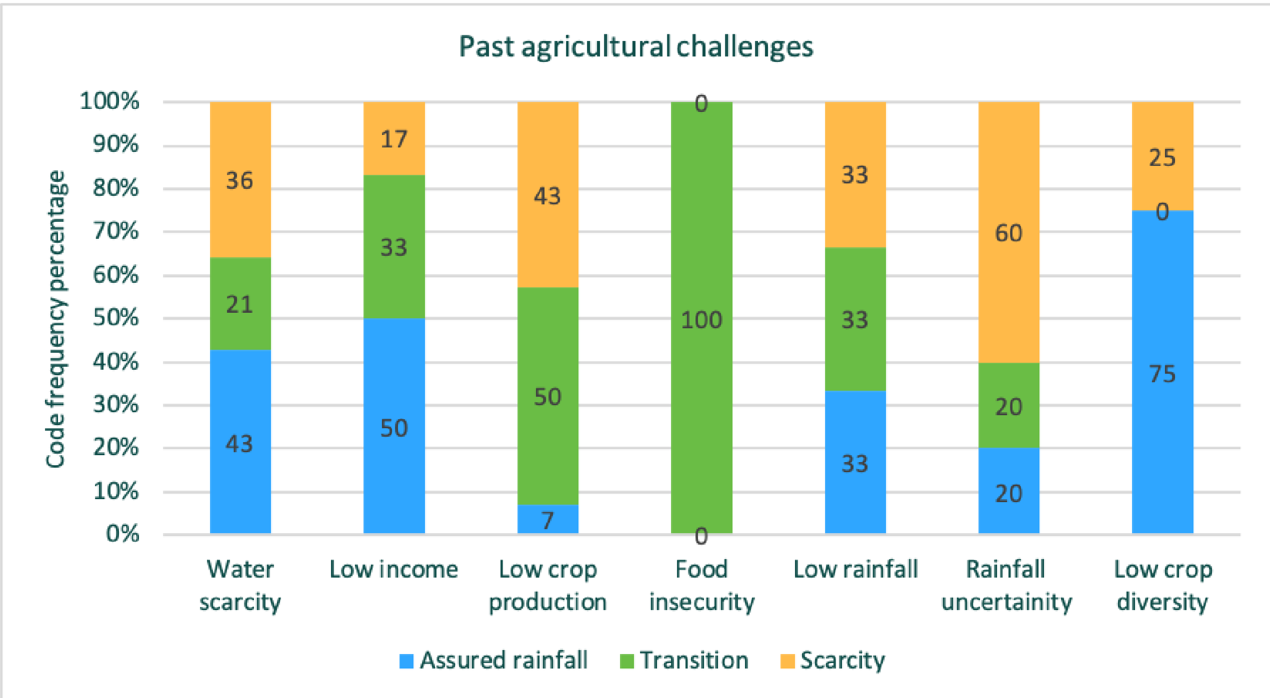

Fig 3: Code frequency percentage of mentions of past agricultural challenges

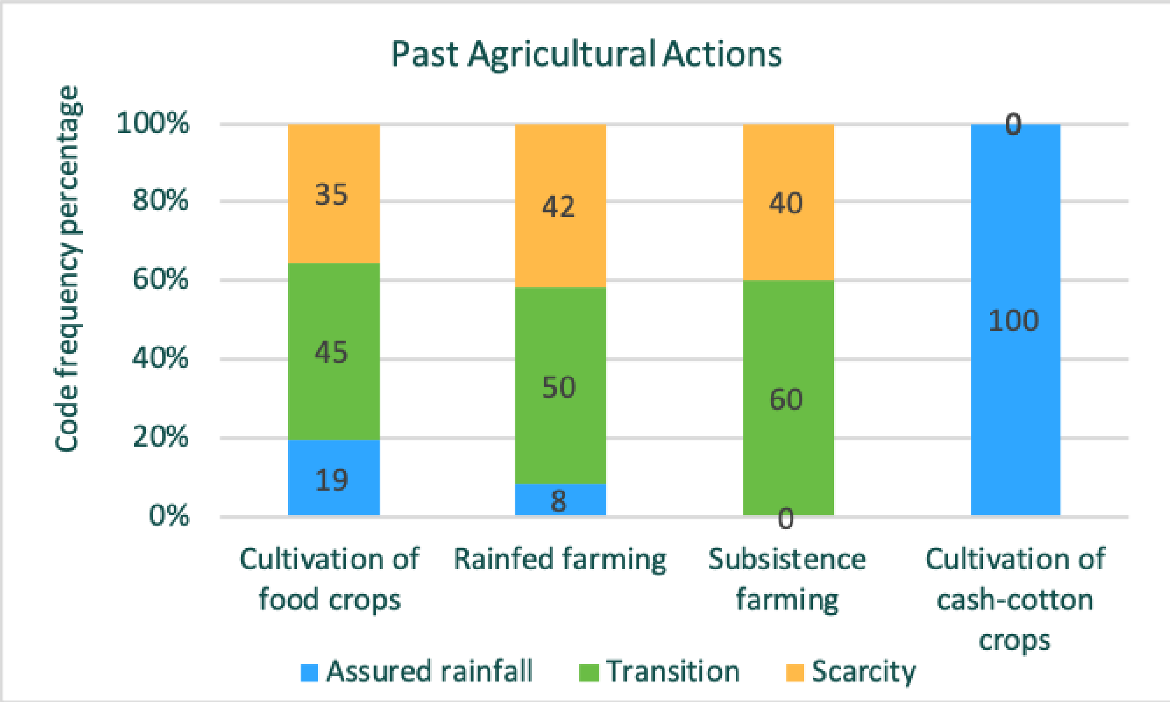

Fig 4: Code frequency percentage of mentions of past agricultural actions

5.1.2. Past water-related actions and challenges

The analysis of code counts for water-related challenges in the past shows that the main challenges faced by farmers in the past across all agro-climatic zones were: water scarcity, lack of water infrastructures, low water quality and water availability for drinking only and not for irrigation and livestock.

The most recalled problem in the assured rainfall zone was lack of water infrastructures (60%). Water scarcity (45%) was so prevalent in the zone that there was enough water available only for drinking than for irrigation and livestock (17%). Water for drinking and household purpose was brought manually (41%) by the members of the family mostly from wells (26%) located at distant places; often the quality of the water being very low to be used immediately (40%). Consider the following quotation which shows the difficulties one had to experience to fulfill their water requirement in the past.

"There was no tap water then. I used to go to the well to fetch water. The well is about a kilometer away. From there, we carried water-filled pots on the head. If we went at four o'clock in the morning, we would get five to ten utensils full of water and if it was late, there would be no water."

Farmers also availed water from the supply of water tankers (35%) and pipelines to fill the water gap brought from the wells. They also constructed more borewells (38%) and dug wells (38%). The extraction from these sources was done so excessively (46%) that it gave rise to other challenges such as the decrease in groundwater levels and social conflicts as we will see in the present water-related challenges in the following sections.

Farmers in the scarcity zone faced similar challenges of water scarcity (34%) due to lack of water infrastructure (20%). This challenge became even more pronounced due to over-extraction of groundwater (38%). Water through pipelines (67%) was also being supplied in the past, however, there were issues of insufficient water reaching the villages and broken pipelines that further reduced the availability of water. There was an enormous use of water tankers (59%) in the village to mitigate the challenge of water which was available for drinking purposes (67%)

only. Along with collecting water manually from wells (42%), farmers in the scarcity zone increased the number of borewells (63%) and dug wells (25%) to increase water availability for drinking, irrigation, and livestock use. As water demand increased; demand for borewells and dug wells also increased; further lowering the groundwater levels. Consider the following quotation that explains the rise of the construction of borewells.

"Now the numbers of bore wells have been increased. It had a more negative impact on groundwater. Now there are about 150 to 175 bore well in the village. The first bore well was drilled in the year 1995. Then till the year 2000, the percentage of bore wells increased. The expectation of the farmers increased. We expect that more 5 acres of land should be brought under irrigation. Such expectation would not be possible to fulfill through one well. Therefore, we had to drill bore well. In one day, I drilled four bore wells of 300 ft. deep each in my field."

Farmers in the transition zone were dependent on wells (32%) and a river located near their villages for water. Like the other two zones, they also brought water manually (23%) from the wells; and when the wells did not have sufficient water, then it was brought from the river which was already running less due to lack of rainfall. They increased the construction of wells (38%) in the hope to get more water, however they did not indulge in excessive extraction (15%) as was the case in the other zones. Water was also being supplied through pipelines (11%) and water tankers (6%), but they were not reported to be used extensively.

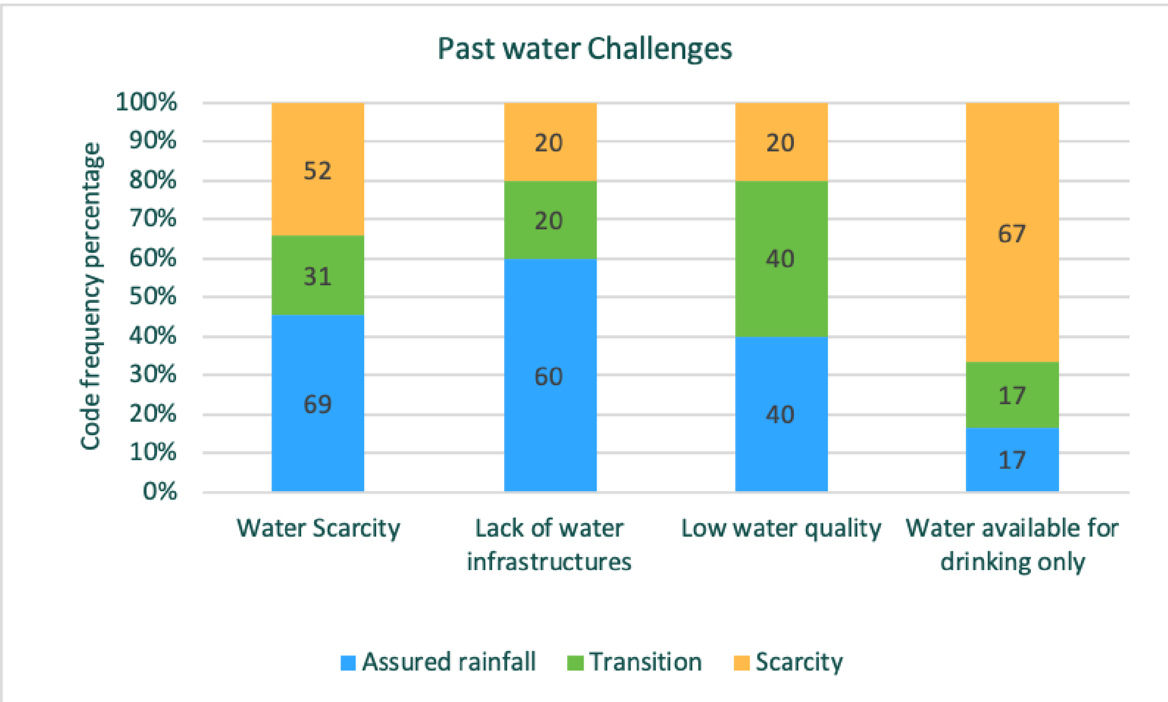

Fig 5: Code frequency percentage of mentions of past water challenges

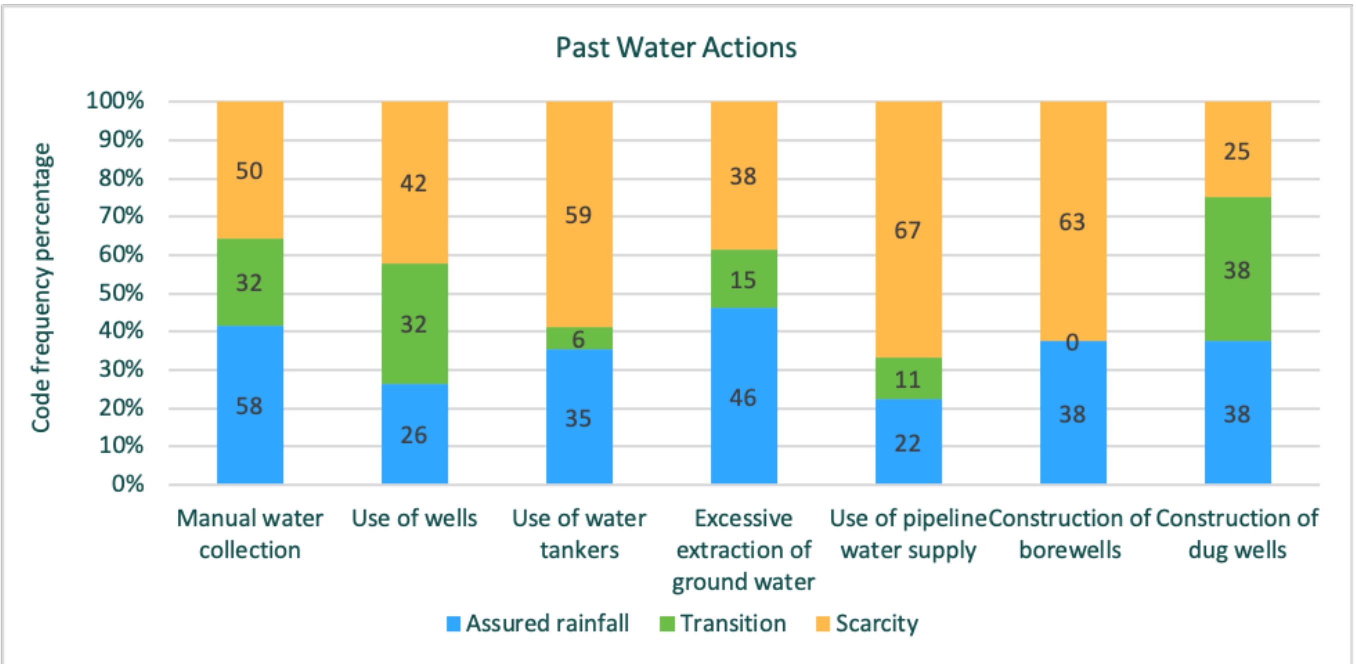

Fig 6: Code frequency percentage of mentions of past water actions

5.1.3. Present agricultural challenges and actions

The analysis of code excerpts for present agricultural challenges shows that low crop production, excessive rainfall, low rainfall, and water scarcity are still challenges faced by farmers as in the past. In addition to these challenges, farmers also reported facing low income, pest and wildlife crop destruction, and excessive use of chemical fertilizer (Fig 7).

Agriculture in the assured rainfall zone improved with the adoption of new techniques such as drip and sprinkler irrigation (43%), improved crop varieties (33%), farm machineries (43%), and crop inputs (fertilizers and pesticides) (33%). Though the challenge of water scarcity (46%) due to low rainfall (38%) and losses due to excessive rainfall (44%) have persisted, farmers started to cultivate a diversity of food (23%) and cash (60%) crops. Farmers attributed this change to the introduction of new agricultural techniques as highlighted in the following quote from a respondent.

"Now people use drip. Rainwater is preserved and given to crops by drip. Earlier, irrigation was done through open channels. It is not like that anymore. Now, everyone uses drip and sprinklers for irrigation. It was not like that earlier, once the motor was turned on, no one cared where the water went. Earlier, people did not know the importance of water. There was no guidance. Agriculture developed due to guidance and information."

However, farmers also reported other newer challenges of market price fluctuation (17%), low production (13%) due to attack of pests and wildlife (20%) and excessive use of chemical fertilizers (10%) that prevents them from reaping the benefits of crop diversification (Fig 7).

In the scarcity zone, farmers also adopted improved agricultural techniques (Fig. 8) such as farm machineries (14 %), crop inputs (Fertilizers and Pesticides) (17%) and improved crop varieties (17%), however, compared to the assured rainfall and transition zone, adoption and use rates were low. The use of open channels irrigation is still dominating (67%) despite the introduction of irrigation through drips and sprinklers (43%). Due to this improvement in the agricultural practice, they were able to shift from only rainfed and subsistence farming to commercialized farming by cultivating more diversified food (48%) and cash crops (19%).

Despite these improvements, the farmers still face the problem of water scarcity (46%), pest attack (50%), and the use of excessive chemical fertilizers (30%). Also, fluctuation in the market rates and production (63%) has not been able to provide the farmers with a consistent income (83%). Following is an instance a farmer shared about the fluctuation in production and market price in this year.

"I: What else is cultivated in the field? R: Some onions were planted; the market rate was good but there was no good production. In the place where every year we got 100 sacks onions, at the same place this year we only got 50 sacks of onion. Last year, 100 sacks gave only 50 thousand rupees but this year 50 sacks helped us to earn 1.5 lac rupees."

Similar to the assured rainfall and scarcity zone, farmers in the transition zone shifted from traditional agricultural practices by bringing farm machineries, crop inputs (fertilizers and pesticides), and improved crop varieties into their current agricultural practices. The use of drip irrigation (14%) facilitated continued production of food (29%) and cash (21%) crops for a longer duration.

However, this zone also has similar problems of water scarcity (31%) prompted by low rainfall (25%). Also, crop production was mentioned to be low (25%) due to damages caused by excessive rainfall (44%) on some days and pests attacks (30%). Farmers reported increased instances of pest and disease attacks (30%) as compared to the past, despite excessive utilization of chemical fertilizers and pesticides. Consider the following quotation that shows how a farmer feels disappointed with the excessive use of chemical fertilizers on crops.

"The next generation is educated so they will go for jobs. I think they should go for job. If there is rainfall, there is no market and if there is market, it does not rain. Earlier there was less attack of diseases and now as use of chemicals is increasing, there is an increase in attack of diseases. If tomatoes are cultivated, a lot of pesticides are required to be sprayed."

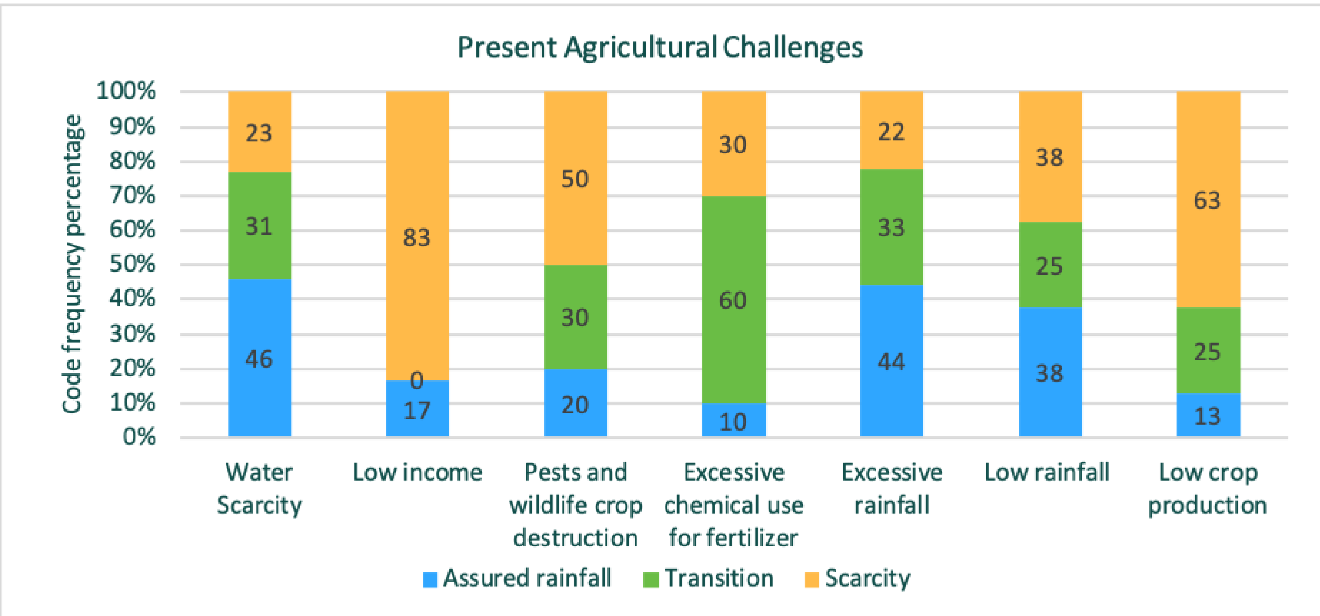

Fig 7: Code frequency percentage of mentions of present agriculture challenges

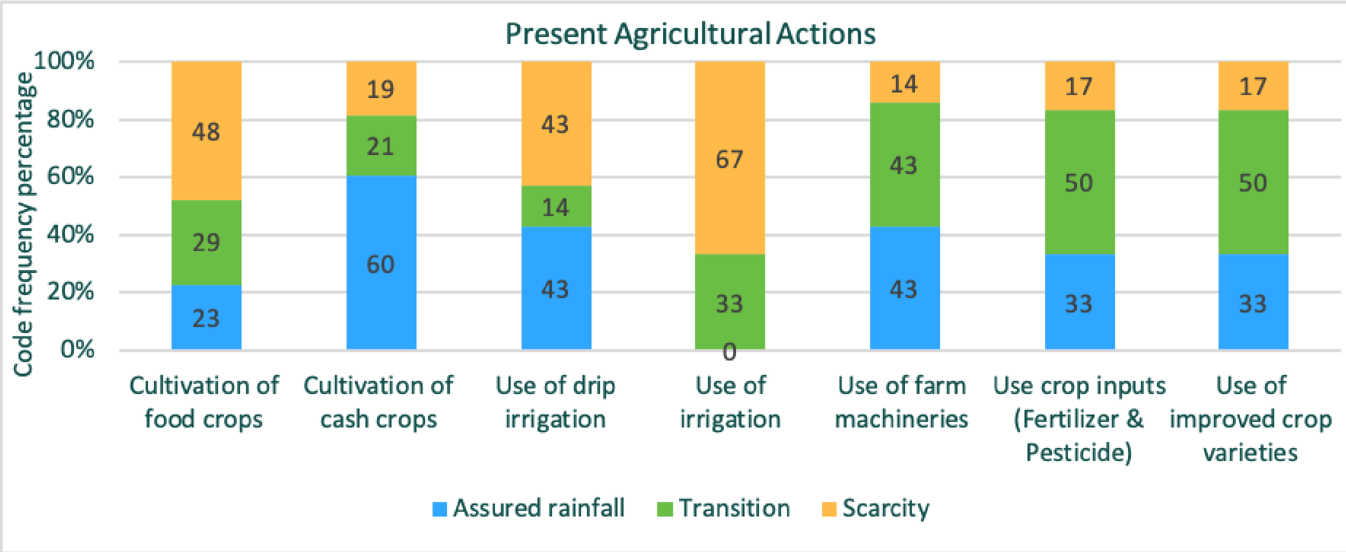

Fig 8: Code frequency percentage of mentions of present agricultural actions

5.1.4. Present water-related challenges and actions

The analysis of code excerpts for present water challenges shows farmers are currently facing the challenges of water scarcity, low water quality, lack of income, dysfunctional water systems, excessive rainwater run-off, and social conflicts in water sharing.

In the assured rainfall zone, to have a sustained supply of water for agriculture, the farmers installed water storage structures such as farm ponds (66%) and separate water tanks (64%) in their farms and villages. The water storage structures are filled through rainwater as well as borewells (25%). As crop production increased in the assured rainfall zone; the demand for groundwater has also increased. Farmers reported having water supplied from water tankers (8%) as well. Farmers also mentioned having drip (50%) and sprinklers (67%) installed in their farms to ensure the conservation of water for irrigation. However, farmers still reported collecting water manually (60%) from common water sources (wells, rivers, tankers, etc.) for household purposes and also agriculture. Farmers highlighted challenges in reduced groundwater levels (27%) due to its unregulated extraction (38%). In one of the villages in the assured rainfall zone, the following plan was implemented to regulate water usage:

"We built a structure on the nallah, no matter under what scheme it be. WOTR also gave us CNB. Now also, if you look at it, it will have a lot of water. We use it with drip and they put a direct motor into it. Then we took a Gram Sabha and passed a resolution that no one would lift water from public water sources without permission."

Apart from the above challenge, they also mentioned experiencing challenges of low income (50%) from market sales, low water quality (40%), excessive rainwater runoff (20%), and social conflicts in water sharing (75%).

In the scarcity zone, farmers reported being still highly dependent on water tankers (85%) and borewells (75%) as was the case in the past. Low rainfall and rainwater run-off (80%) have caused water scarcity (57%) in this zone. As agricultural production increased, the water demand too increased, therefore increasing the need for the purchase of water through water tankers and extraction from borewells. Further, farmers also reported dysfunctional water structures and systems (71%) as a problem in the present. Water for agriculture was reported to either being manually collected (40%) from common water sources or transferred to storage structures such as tanks (18%), wells, and farm ponds (17%)

through water pumps (46%) for further usage. Other challenges highlighted by farmers in the scarcity zone included low water quality (20%) and lack of income (25%). Farmers in this zone reported having adopted sustainable usage of water by using drip (38%) and sprinklers (17%) irrigation, however not to the extent of assured rainfall zone. The following quotation shared by a farmer in this zone highlights the benefits of use if drip and sprinkler irrigation.

"Farm Pond is beneficial. I use water from April onwards. From April -May onwards, the well runs out of water. I planted tomatoes in three to four acres in April. I pump the water from the farm pond into the well by the motor, then the water from the well is fed to the tomatoes by drip. Thus, farming goes on all year long. I do the same for Sitaphala (custard apple) trees. I pump the water from the farm pond into the well by motor and then the water in the well is given to the Sitaphala by drip. The drip is a perfect fit."

In the transition zone, farmers highlighted the use of farm ponds (17%) and water tanks (18%). Motor pumps (46%) are used to extract water from other sources (15%) to fill (50%) these farm ponds and water tanks. Water was also reported to be purchased from water tankers (8%); however, its use is very low as compared to the use in scarcity zone. Farmers also reported using drip (13%) and sprinkler (17%) irrigation for agricultural production but at a lower rate than assured rainfall or scarcity zones.

"The mindset of the people has now changed. They understand the value of water when they sow seeds in the field. People have understood that something needs to be done for water. Farm ponds are built, rain-water is stored in them during the rainy season, and then it is used later."

Additionally, farmers also mentioned existing challenges such as water scarcity (27%) and low water quality (40%) as well as lack of income (25%), dysfunctional water system (29%), and social conflicts (25%) in water sharing and distribution. A more detailed discussion of social conflicts in water distribution is highlighted in the discussion section of the paper. are also problems they are facing currently.

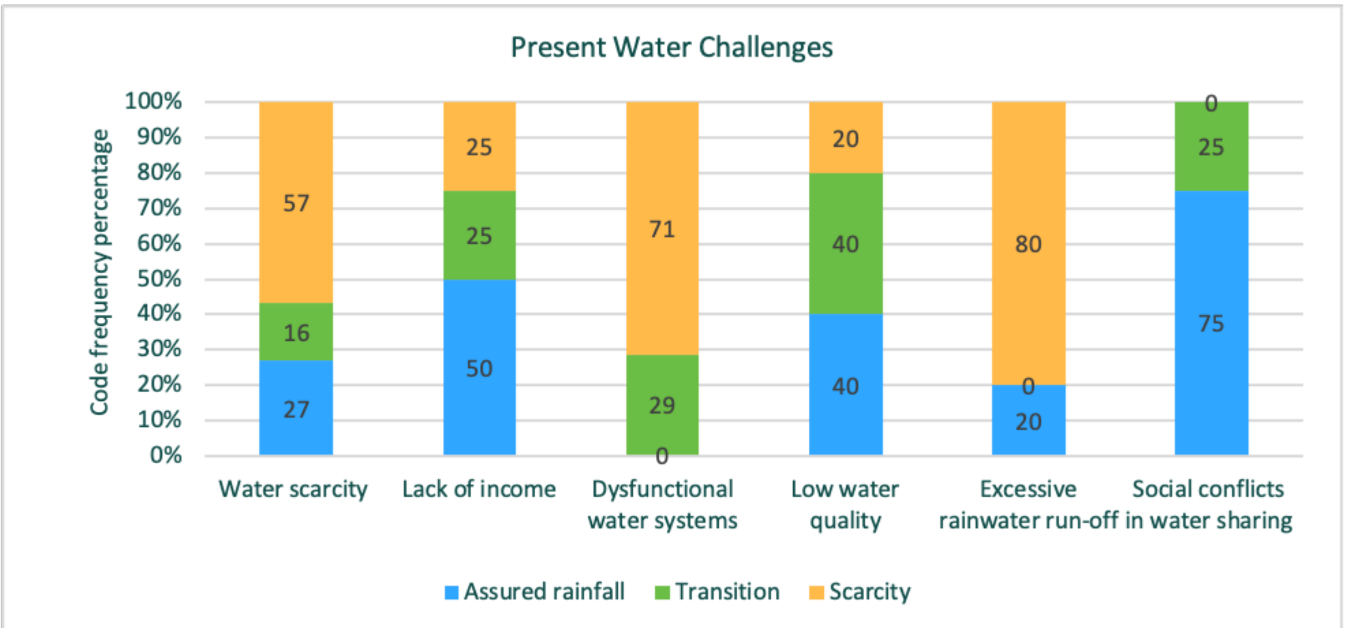

Fig 9: Code frequency percentage of mentions of present agricultural challenges

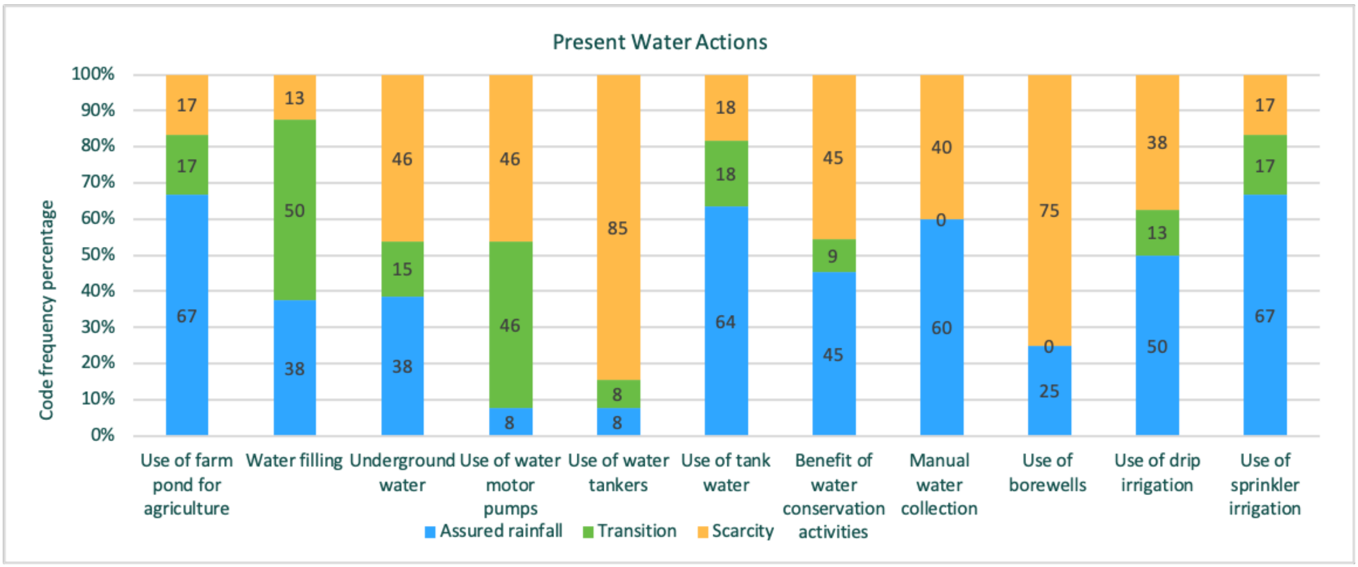

Fig 10: Code frequency percentage of mentions of present agricultural challenges

5.1.5. Beliefs, motivations, and perceptions of farmers

Apart from questions of the past and present agricultural and water-related challenges and actions were taken by farmers, our study also focused on the psychological aspects of farming and water-related issues by asking about farmers beliefs and motivations about farming and their perceptions on the future state of climate and water (Fig 11).

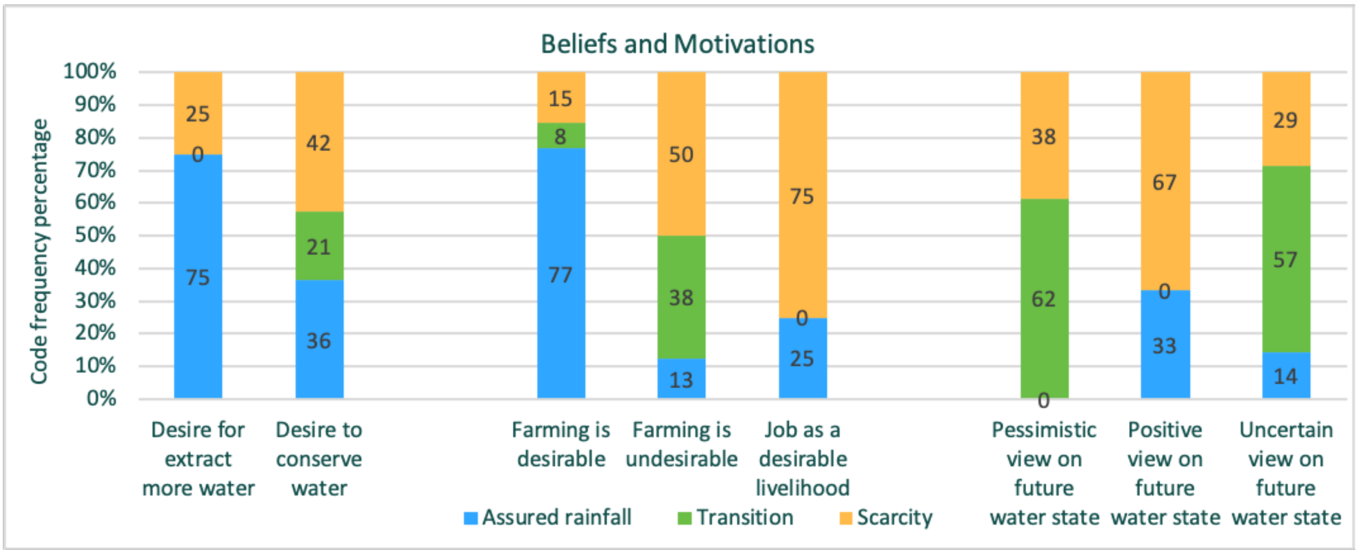

Fig 11: Percentage frequency of mentions of beliefs and motivation

Interesting insights were observed in the analysis of code frequencies: farmers in the assured rainfall zone showed the highest desire to extract more groundwater (75%) and a low desire to conserve water with (36%). An explanation of this insight can be garnered from the interviews themselves: as farmers' income increased due to the cultivation of cash crops (such as chilies and grapes); the desire to utilize more groundwater also increased along with more competition among farmers. Consider the following quotations from farmers in assured rainfall zone in support for this argument:

"Large farmers have dug wells in their fields. They survive on their own with that. Their lives are going well. We (poorer farmers) need everything from the government. The groundwater is for all but if I

pay for the bore, I will not give you water"

"[Respondent] I am thinking of digging a bre well. [Interviewer] Why do you want to dig a borewell? [Respondent] For water, should I not?"

In contrast, in the scarcity zone, the desire to conserve groundwater was expressed more (42%) than the desire to extract more water (25%). None of the respondents in the scarcity zone expressed the desire to extract more water, but they did express the desire to conserve water (21%).

The following quotation from one of the respondents encapsulates the reason why water scarcity often provides the impetus and desire among people to conserve their limited resources instead of extracting more of it:

"Due to lack of rainfall, the crop cannot be given water (irrigated) by motor, because it requires more water. The less water you use from the farm ponds or wells, the more water you can use in the future. If we use too much water, it becomes a habit and therefore the water does not suffice. If we draw more water, the water tends to run off. When it rains, the rainwater should be used in a just manner."

To work towards the vision to conserve more groundwater, respondents in the scarcity zone also highlighted their collective resolution in the village gram panchayat to ban the digging of borewells, use of drip irrigation to promote water conservation.

Further, respondents in the assured rainfall zone showed the highest desirability for farming as a livelihood source (77%). They also showed the least desirability (25%) for off-farm jobs as a livelihood source. In contrast, farmers in the scarcity zone expressed farming as undesirable (50%) and overwhelmingly, expressed that off-farm jobs were more desirable than farming (75%). Similarly, farmers in the transition zone also expressed the undesirability of farming as a livelihood option (38%). Various factors explain why farming is no longer a desirable livelihood for people in the scarcity and transition zones; market and production risks often render agriculture unviable as a source of livelihood. For example, consider the following quote from a farmer in the scarcity zone when asked if he prefers to be a farmer –

"[Interviewer] Will you prefer to be a farmer?. [Respondent]No, no I don't want to be a farmer ….When there is production of agriculture, that time there are no good market rates for products. This year only there were good rates for onion. Last year we had to sell our onion at the rate of rupees 5 to 6 per kg only… we cannot depend and survive on agriculture"

For others, especially in the assured rainfall zone, even if agricultural production is good; farming is considered undesirable due to the hard labor that agriculture requires. Further, as their children get more education, often a more viable option is for them to get a job and migrate to more urban areas. These aspects are highlighted in the following quotes from interviews in the assured rainfall and scarcity zone:

"[Interviewer] What do you want your children to do next? [Respondent] I want them to do a job [Interviewer]: but you were saying that income from agriculture is good. [Respondent]: But that is what we expect … . Agriculture is good but it takes a lot of hard work in agriculture, the risks are high."

"(In the future) The villages will be empty like this. If there are 400 people living in thirty years, then that will decrease by four in each household. The last generation will die here in the village. Everyone has to leave the village and go to Pune-Mumbai"

These contrasting desires of farmers in the assured rainfall versus the scarcity and to some extent, the transition zone, gives an insight into the behavioral aspects of farmers and their belief in the future state of the world. The farmers from the transition zone mostly expressed either pessimistic view (62%) ore uncertain views (57%) about the future state of water and agriculture. Farmers in the scarcity zone expressed a positive view on the future state of water (67%) which might explain their desire to conserve more water. Fewer farmers from the assured rainfall zone spoke about the future state of water with about 33% of codes expressing a positive view on future water state and a small percentage (14%) expressing an uncertain view of future water state. This indicates a tendency among farmers in the assured rainfall zone towards short-term thinking as opposed to long-term thinking among scarcity and transition zones.

Consider the following quotes from a farmer in the assured rainfall zone:

"I have been living my life until now. I will continue to live as I can, no matter what happens. Who knows about the future? Everyone only talks about the past."

versus a quotation from a farmer in scarcity zone:

"What does man think, there should be some work, then only he will get some money… the situation is such that one is confused on whether one should go for employment or for agriculture. Everyone is in pain. … … if this is the case right now, what will happen after twenty years?"

The pessimism amongst farmers in the scarcity and transition zones manifests in their observations of patterns in rainfall in the past which makes them anticipate that in the future, rainfall is likely to decrease drastically, leading to political, environmental and economic strife. As encapsulated by a quotation from a farmer in the transition zone when asked about his vision for the future in fifteen-twenty years:

"There will be a serious water problem. One will not get a liter of water. All the problems will be caused by water. If there is no water, there is nothing. People still do not understand the importance of water. Water is life."

5.2. Factors that influenced the trajectories of water management over time

The following models represent the collective mental models of past, present, and future trajectories of agricultural and water-related issues in the scarcity, transition, and assured-rainfall zone. These mental models highlight the institutional mechanisms through which the past agricultural and water-related actions and challenges identified in the previous sections transformed to the present agricultural and water-related actions and challenges. In each of the three mental models representing each agro-climatic zone, the green-colored shapes show agricultural challenges and actions while blue-colored shapes show water-related challenges and actions. The oval shapes represent the challenges, rectangles represent actions, circles represent institutions and organizations, parallelograms represent institutional/organizational actions. The line arrows trace the connections between the elements in the system. The depth of the green, blue and yellow shades represents the frequency of how these concepts or nodes arose in the excerpts; the deeper the color shade, the more frequent were the mentions in the excerpts. The grey rectangles represent the possible future solutions proposed by the interviewed respondents to improve the water situation in the future.

5.2.1. Mental model I: Scarcity Zone

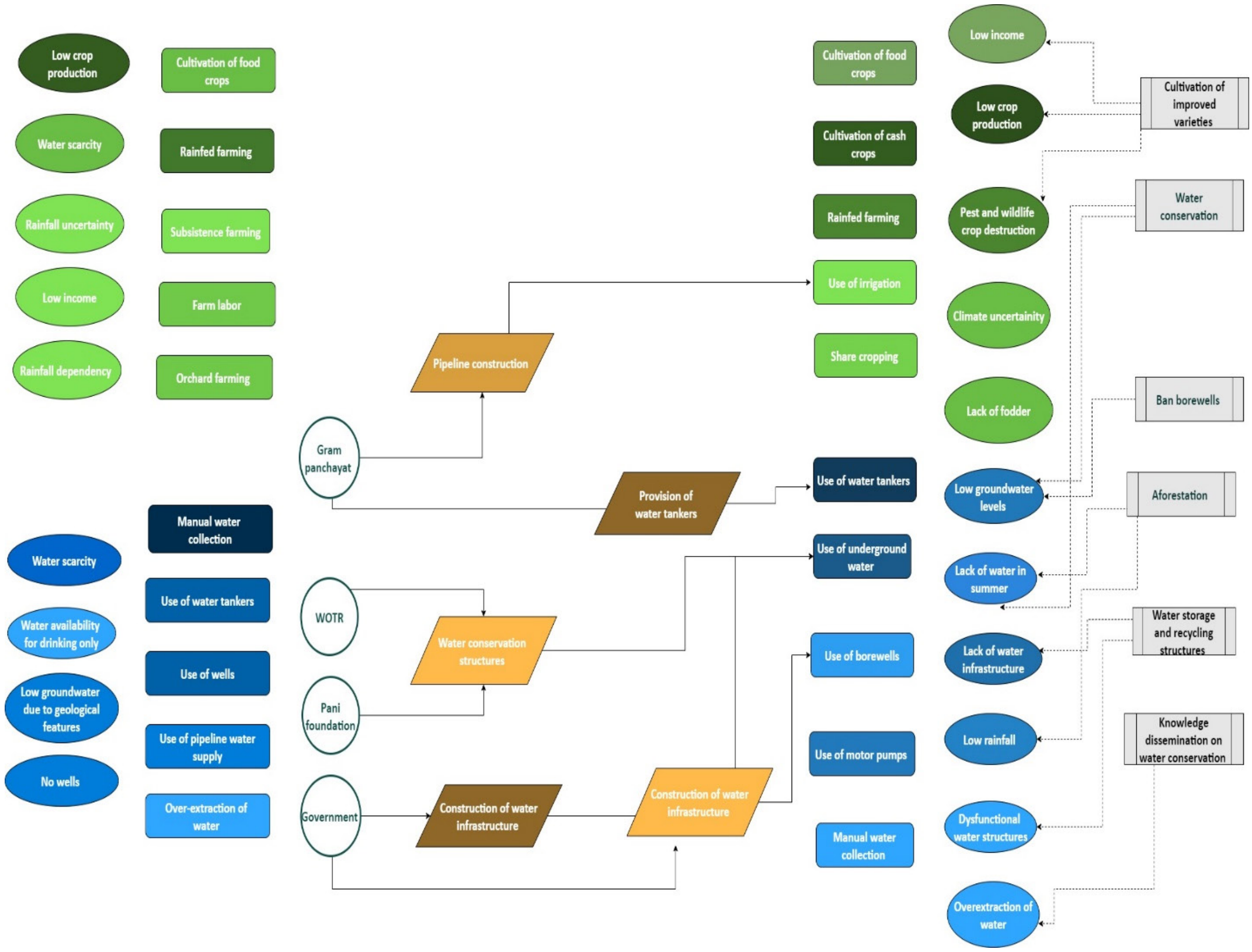

Fig 12. Mental model of Scarcity Zone

Readers will recall from the previous section that in the scarcity zone, the most prevalent past agricultural challenges perceived by farmers were low crop production, water scarcity, rainfall uncertainty, low income, and rainfall dependency. Farmers were mainly involved in the cultivation of food crops, using rainfed and subsistence farming. They also reported facing water-related challenges in the past such as lack of water for irrigation, low groundwater levels due to rocky geological formations, and lack of well structures. Farmers relied mostly on manual water collection and the use of water tankers, dug wells, and pipelines for extraction of water. Cultivation of cash crops in addition to food crops and the use of irrigation and sharecropping were reported as the present agricultural actions. Farmers report still faced low income and low crop production as the main agricultural challenges as in the past but in addition, new challenges such as pest and wildlife destruction, climate uncertainty, and lack of fodder crops for livestock manifest in the present situation. As in the past, challenges of low groundwater levels, lack of infrastructure, and low water availability continue to persist in addition to new challenges such as dysfunctional water infrastructures, low rainfall, and over-extraction of water. There is also an increase in the use of water tankers, borewells and water pumps to extract underground water.

The mental model highlights these past and present actions and challenges and highlights the role of three key institutional actors and their actions that played a role in the agricultural and water-related changes in the study area

(Fig 12). Government bodies constructed water infrastructure such as check dams. Non-governmental organizations conducted watershed development and conservation structures which increased the underground water levels. Gram panchayat constructed pipelines and increased the provision of water tankers. The activities of government bodies and gram panchayat had a higher code count (represented by the depth of color shade of the shapes in the mental model); implying that more mentions of activities by government bodies and gram panchayats such as the construction of water infrastructure (check dams) in the past and pipeline construction and provision of water tankers in the present. However, responses of farmers highlighting the works of non-governmental organizations on watershed development contained a richer description of mechanisms of agricultural and water-related trajectories. For example, farmers mentioned how collective watershed development through voluntary labor donation in the village provided them with the motivation to conserve water, especially as they started to see benefits in the form of increased water percolation and increased water availability.

"We had a lot of water scarcity problems here. In our villages there was a Social Center [NGO], they carried out the watershed activities in our village, the work was initiated by digging pits in the farms due to which water started percolating. The water started seeping in the ground. There was no progress in our village until the watershed activity started. Later, the water structure such as KT weir, bunds etc. was built. Now, there is water availability and rains in our village All types of tools and equipment are available."

Farmers also reported the benefits of collective community participation and voluntary labor in watershed development work.

"If we participate in public common works, it is very beneficial, and we get energy, inspiration, and self-satisfaction through it."

Collective action also enabled farmers to manage to village level politics by postponing village elections that may have an adverse effect on the progress of watershed development projects:

"These problems should be solved. No one should complain while the work is underway in the village. There were gram panchayat elections then, society elections were there while the work was going on in the village. We decided that we will not vote during the elections. Because it creates conflicts amongst us. There will be no conflicts if the elections do not take place."

Further, while activities by government bodies and gram panchayats such as provision of water tankers and pipelines improved water availability and allowed farmers to decrease their reliance on manual water collection in the present, respondents also highlighted various challenges of such activities. The construction of pipelines had challenges which included disputes when the pipelines were supposed to be constructed in private lands and lack of funds to complete pipeline construction work. The construction of government-built trenches and CCT's were also reported to being dysfunctional in the present as showcased in the following quotation:

"There is no rain, CCT is broken, CCTs in Maharashtra are all broken the government is lying when you build two to two-and-a-half feet high dam, it would have stopped water from one-acre area and if parallel CCTs were taken, they would have stayed. If the water rises to 100 by 100 feet dam, the dam breaks and the water runs off to the streams below, and then they all flow into the rivers. That is the situation in [village name] and all over Maharashtra"

Further, the construction of water infrastructures such as pipelines and borewells allowed farmers to irrigate their lands and start cultivating cash crops in the present. Respondents also discussed income disparities in access to water infrastructure and the use of drip and sprinkler irrigation in the region; richer farmers had higher access to capital to invest in irrigation infrastructures. Farmers also highlighted challenges in access to loans from banks and talked about mental health issues that arise from the inability to repay loans. Farmers in the scarcity zone elaborated on psychological impacts of inability to repay loans due to production failures and water scarcity:

"Why he is doing so, if he borrows money from someone and he is not able to return. Then he gives so many reasons, he lies to people. How long can he lie though? The person who has given money keeps a watch. That person does not need anyone. For him, it is the business as usual. But the farmer takes it differently. He is always scared. He is stressed out. He is weak at heart. He can lose his mind very easily. He is not able to tolerate it. Then he quickly takes a decision. He thinks it is better to die instead of taking so much tension. This is why the suicides take place. Suicides will not happen otherwise."

Despite these challenges, farmers in the scarcity zone highlighted several possible future solutions for groundwater sustainability. The solutions, as specified in the mental model, mainly included water conservation measures, banning of borewells, afforestation, water storage, and recycling structures, knowledge dissemination, and training on water conservation and cultivation of improved crop varieties. The focus of these solutions predominantly on groundwater conservation confirms the insights elaborated in the previous section that farmers have high levels of desire to conserve water.

5.2.2. Mental model II: Transition Zone 2

The collective mental models of farmers in the transition zone (Fig. 13) show that the key agricultural challenges in the past were food insecurity, low crop production, low income, and water scarcity; where farmers were mainly involved in the cultivation of food crops through rainfed, subsistence farming. Farmers also reported facing water-related challenges in the past such as water scarcity, lack of water infrastructures, and low water quality. Similar to the scarcity zone, farmers relied on manual water collection and constructed dug wells and dams in the past. In the present, farmers reported the cultivation of cash crops in addition to food crops and in addition to the use of crop inputs, farm machinery, improved crop varieties, and use of irrigation. As in the past, farmers reported facing water scarcity in the present in addition to new agricultural challenges such as excessive use of chemical fertilizers, lack of land availability, lack of market availability, and soil quality deterioration. Farmers reported an increase in the use of water pumps, and farm ponds and an increase in the use of river water, groundwater as well as the construction of dams in the present. As in past, farmers reported continued challenges of low water quality, however, development trajectories also brought new challenges such as excessive use of chemical fertilizers, lack of land availability, lack of access to the market, and deterioration of soil quality. Farmers also reported additional water-related challenges such as low groundwater levels, dysfunctional water structures, unequal distribution of water, and lack of income.

In the transition zone, apart from gram panchayat, government bodies and NGO's, farmers also described the role of collective loans and financial institutions in improving the livelihoods of farmers in the region. The code counts for institutional actions were highest for collective loans and construction of water infrastructures by the government. Such water infrastructures included the construction of dams and the use

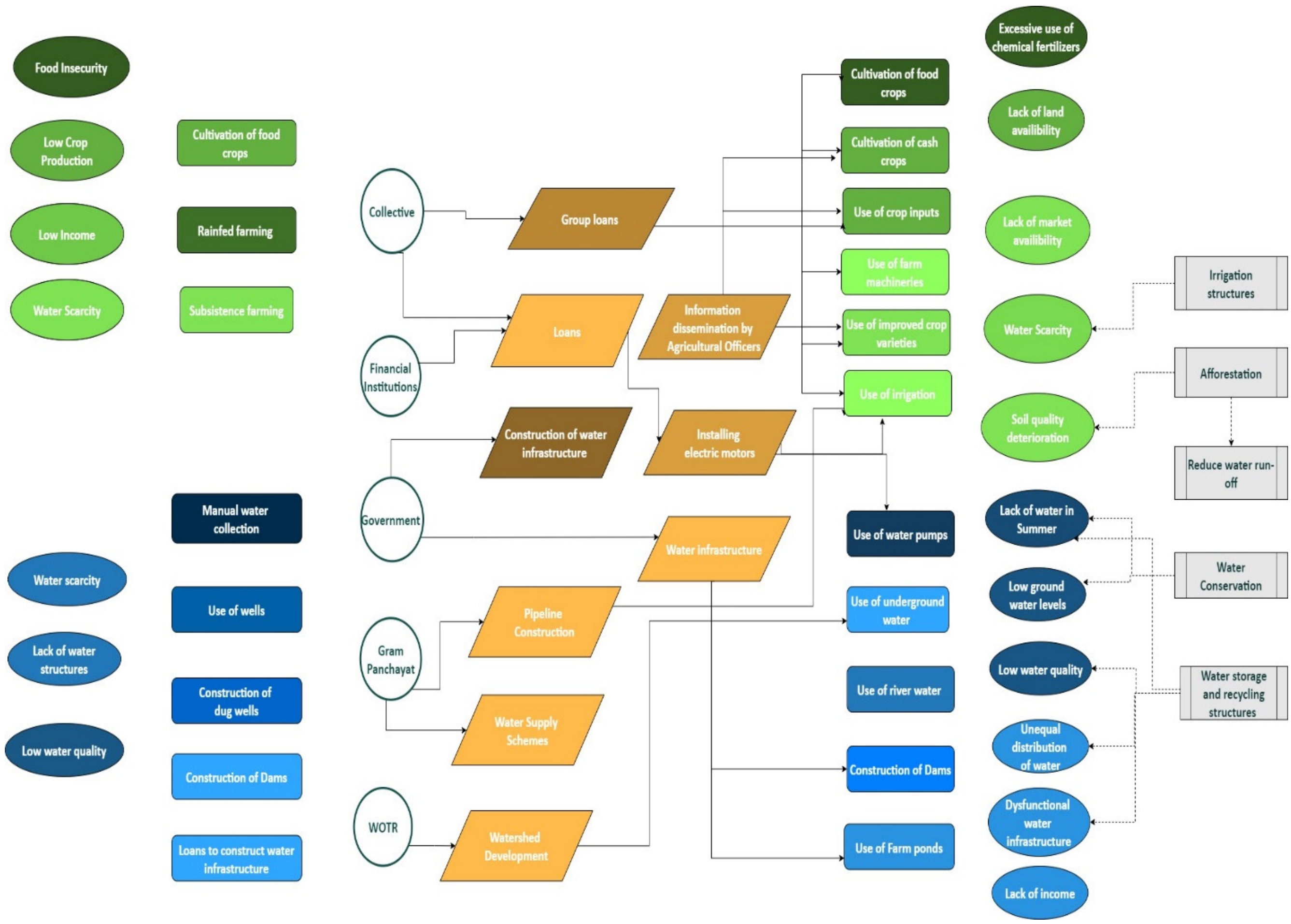

Fig 13: Mental model of Transition Zone

of farm ponds. Further, farmers also highlighted the role of agricultural officers in information dissemination of cropping techniques and the use of crop inputs which enabled farmers to shift to a mixed cash-food crop cultivation pattern.

Group loans through cooperative societies enabled farmers to purchase livestock and sell milk as an additional source of livelihood apart from farming. Various financial institutions and collective structures like the savings groups and cooperative societies enabled farmers to access loans to construct pipelines as well as access financial capital to buy crop inputs and improved seed varieties as well as invest in farm machinery

Additionally, the gram panchayat constructed pipelines and water supply schemes allowed farmers to improve their use of irrigation and decrease their dependency on manual collection of water. Farmers also reported watershed development in the past which increased the use of watershed development. Watershed development by NGOs; especially the digging of trenches, continuous contour trenches (CCTs), and farm bunds increased the percolation of water into the soil which increased water availability, improved crop production, and changed cropping pattern. Farmers volunteered both labor and land for the watershed development work collectively. Some projects by NGOs (Indo German Project) also constructed pipelines and drip irrigation to farmers.

Construction of dams was initiated by the government after the droughts in Maharashtra in 1972, but the low maintenance of dam structures led to dysfunctional water structures in the present:

"There was a drought in 1972, so the government decided to build a check dam at that time. But the dams were so built that rainwater was running off through it. That work was not done well. They

didn't pay any attention to it. The construction was very poor. The dam fills in the monsoon and gets emptied in the monsoon. There is a lot of leakage in them."

Further, despite the construction of nallahs and water structures; the poor maintenance of these structures led to encroachment of the structures where people build farm ponds and cultivated crops. Farmers often built farm ponds to store water for irrigation. As a respondent in the transition zone elaborated:

"There would be no need for farm pond if (electric) load shedding was not there. When there was no load shedding, the entire area could be irrigated. We used to give water to others then. The whole area was getting irrigated. But now the water is not enough."

However, such schemes and structures were often fraught with political hegemony.

"Last year, people borrowed money to build pipelines for water, but their crops dried due to lack of water. The water from the dam was released due to the politics played around the issue of water."

Farmers also reported challenges associate with accessing individual loans from banks due to the stringent terms and measures on loan recovery. In most of these cases, group loans by farmers were effective in enabling farmers to access the financial capital they needed. For example, the following quote by a village leader in the transition zone elaborates on the challenges of accessing loans from financial institutions:

"Those who took loans from money lenders came to us. They were worried that the money lenders would come to the doors for recovery and that would bring shame to them. When the recovery van came to the village, it would bring embarrassment to the people. People avoided taking loan out of the fear of stringent actions taken for recovery. They would borrow from others at a higher rate but did not borrow from the bank."

Farmers in the transition zone highlighted several possible future solutions for water sustainability including irrigation structures to address water scarcity; afforestation to decrease water run-off and improve soil quality deterioration; water conservation measures to increase groundwater levels and building water storage and recycling structures. These solutions focus more on increasing the short-term availability of water for agricultural consumption as well as long term conservation of water.

5.2.3. Mental model III: Assured Rainfall Zone

The collective mental models of farmers in the assured rainfall zone (Fig. 14) shows that the key agricultural challenges in the past were low income, water scarcity, dependence on rainfall, and low crop diversity. Farmers were involved in the cultivation of food crops through rainfed farming, but unlike scarcity and transition zones, farmers also cultivated cash crops such as cotton and water-intensive crops such as sugarcane. Farmers also reported facing water-related challenges in the past such as water scarcity and lack of water infrastructures. Farmers also highlighted caste-based issues as well as social conflicts in water sharing.

In particular, caste-based issues were predominant where upper caste people would often have hegemony over communal wells. Lower castes would often not be allowed to fetch water from the communal well and had to resort to their community wells. To meet the water demands, farmers relied on collecting water manually from distant places, use of water tankers, extracted excessive groundwater from wells and other sources, used water tankers, and constructed dug wells in the past. In the present,

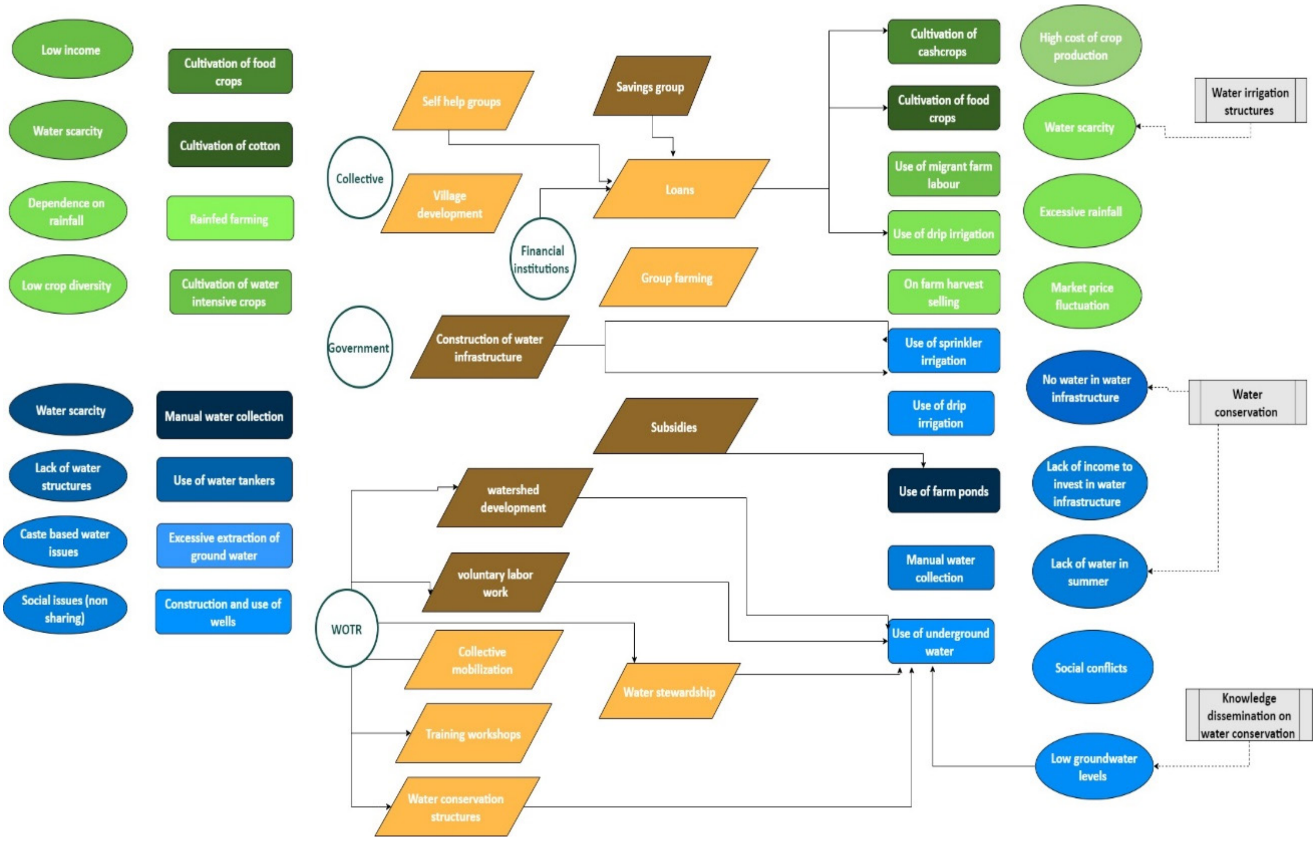

Fig 14: Mental model of Assured Rainfall Zone

farmers in the assured rainfall zone reported a higher code count for the cultivation of cash crops followed along with the employment of migrant farm labor for their cash crops, use of drip and sprinkler irrigation, and on-farm harvesting and selling of crops. As in the past, farmers reported facing water scarcity in the present in addition to new agricultural challenges such as high costs of crop production, excessive rainfall, and market price fluctuation. Farmers reported water-related actions such as the use of farm ponds, manual water collection, and extraction of underground water and additional challenges as lack of water in water infrastructures, lack of income to invest in agricultural infrastructures, lack of water in summer, social conflicts and low groundwater levels.

The key institutional factors that influenced the village development and trajectories in agriculture were attributed to NGO's and agricultural departments (KVKs). Watershed development work non-profit organizations enabled the collective mobilization of farmers through voluntary labor donation (Shram Daan), construction of water conservation structures, water stewardship, and training of farmers to improve the effectiveness of conservation and utilization of groundwater resources. Most farmers in the assured rainfall zone reported sufficient water availability in the present due to the watershed development and conservation efforts in the past. For example, a farmer recalled the early works of watershed development in the village:

Farmer recalled how the lack of information about water conservation was an issue in the past:

"It was not like that earlier, once the motor was turned on, no one cared where the water went. Earlier, people did not know the importance of water. There was no guidance."

"Everything was new, so they were working enthusiastically. When the water went down, in

the first year, 50% of the work was done. The wells got water earlier. The rainwater did runoff. In the area where work was done, there was plenty of water in the wells. After two to three years more people participated."

However, lack of income and capital often inhibits farmers to invest in water conservation techniques such a sprinkler and drip irrigation:

"65-70 % of people have understood the importance of water stewardship… The remaining 30 % of the people have some problems… Suppose, they have a bore well. In our village, one does not dig borewells more than 150 feet deep. Or, suppose he has a well. But he has no pipeline facility, no sprinkler or drip irrigation. Such people cannot do the expenditure. Those who do not have any livestock, they have to farm using a tractor. We tried so hard to convince them, but they say we have no money. Sometimes, the case is such that, more than 75 percent of the population in the village is conserving water, but in the adjoining village there is more extraction of water."

Subsidies were provided by the government to construct farm ponds which addressed the water scarcity and access in the region. Subsidies on tractors and storage units also enabled farmers to cultivate more effectively. However, these subsidies were availed mostly by large, higher-income farmers with large land size, increasing the income disparities in the region. As elaborated by a respondent:

"There is not a single person who talks well to us in the village and as is, there are not many people in the village. People coming from outside feel that this village has an orchard, so there will be no water scarcity. When there are meetings, committees are formed, the big farmers are the ones who speak. No one talks about poor farmers like us. They think the poor should just come to our fields for wage labor. They do not pay attention to us."

"No one feels like helping others. Everyone thinks we should be rich. People think that the poor should remain poor and should come to work in our fields. The people who own the farm ponds can cultivate their farms well. Due to lack of water, our situation is weak."

Collective structures and savings groups that initiated village development, group farming, and access to loans that improved the income and livelihood of farmers. Financial institutions like cooperative banks, private banks, etc., self-help groups and savings groups were the key finance providers that the farmers' bank on for agricultural and personal financing. Access to loans from these multiple sources enabled the farmers to cultivate diversified crops such as cash crops such as chilies and grapes and invest in advanced technology such as drip and sprinklers. The farmers have a network of market dealers to facilitate sales of agricultural produce directly from the farm, thereby saving their transportation costs. The future solutions proposed by respondents in the assured rainfall zone for water sustainability includes irrigation structures and knowledge dissemination on water conservation measures to increase groundwater levels.

Discussion

Overall, our analysis develops four main insights and contributions on the assessment of triggers that can promote sustainable groundwater management: future orientation of water sustainability and community participation.

First, the mental models show that there were similar trajectories of agricultural development for all agro-climatic zones with varying degrees of success, where rainfed, subsistence food cultivation in the past shifted to a mixed food-cash crop system assisted by construction of dams, pipelines, irrigation systems, borewells, and farm ponds. While agroclimatic conditions such as nearest water sources, land geological features, and availability of groundwater played a role in the development of the type of cropping patterns and the scale of agricultural development in the area, institutional conditions such as watershed development, community mobilization and construction of water structures played a role in how people managed the groundwater resources. However, our analysis shows that water scarcity is a complex problem that has many interlinked components. In other words, even if availability and access to water are improved in water-scarce regions; as was done in the assured rainfall and transition zones in the past; the demand for water increases in tandem, spurted by population growth and agricultural development, leading to more water scarcity in the present. While previous research has shown that agricultural growth in the regions west to central Maharashtra (Mohanty,2009) was more pronounced than the eastern regions including the scarcity or transition zones, people in assured rainfall zone i.e., Central Maharahstra still struggle with the challenges that were brought by increased income inequality, unequal distribution of water resources and a rise in social conflicts in sharing and distribution of water at present. In contrast, people in the scarcity zone still struggle to access minimal levels of water for domestic and agricultural use as in the past and are demotivated to pursue agricultural farming as a viable livelihood, often resorting to alternative commercial livelihoods or migrating to bigger cities for labor work. Hence, the development of water policies that promote water sustainability requires a systems approach for understanding the feedbacks and interrelations between the various elements of the groundwater use and management, especially the long-term and short-term impacts of water initiatives.

Second, viewing people only as consumers of the resource ignores the role of human values, beliefs, and perceptions that underlie decision-making and sustainability behavior. Our analysis shows that farmers in the scarcity zone expressed more desire to conserve water and had a more positive view on the future status of water in the region despite higher water-related distress and their subsequent unwillingness to continue farming as a means of livelihood. Farmers in the transition zone were more uncertain about the future state of water resources but they too expressed farming as undesirable as a livelihood source. By contrast, farmers in the assured rainfall zone reported finding farming more desirable as a livelihood option and expressed more desire to extract more groundwater for agriculture rather than conserving it. According to Corral-verdugo and Fr (2006), sustainability consciousness among people who focus on the past or the present and short-term goals, immediate priorities, and sense of urgency are lower than among people who focus on the present and potential motivations and opportunities. Farmers in the scarcity zone people showed higher sustainability consciousness than assured rainfall in their desire to conserve groundwater for future generations and suggested many future solutions that could be implemented to promote groundwater conservation and sustainability. On the other hand, people in the assured rainfall zone showed a lower sustainability consciousness through a short-term focus on income generation and utilization of groundwater resources. Indeed, as shown by the mental models, farmers in the scarcity zone had the highest number of solutions for the future than the transition and assured rainfall zone. Our study confirms insights from other scholars that resource scarcity determines its value to its users; the scarcer a resource, the more value it will be to the user (Rijsberman, 2006; Cook & Bakker, 2012).

Third, our study shows that it is an oversight to view farmers only as 'users' of water resources. Farmers and farming communities can also rise to be stewards of water, demonstrated by their participation and collective action in past watershed development works. Our analysis demonstrates that the success of watershed development works initiated by NGOs in the past was largely made possible through collective mobilization and active participation of village members towards a common goal of conserving water resources. This insight is consistent with previous studies that show that past watershed development in India was successful due to community participation and sharing of labor and costs facilitated along with financial, technical and knowledge inputs from NGO's (Kolavalli & Kerr, 2002; Joshi et al. , 2004; Sharma et al., 2011). According to Farrington & Lobo (1997), scaling up of participatory watershed development has been challenging and require certain preconditions of enhanced engagement of stakeholders at multiple scales; as well as increased collaboration of NGOs and government bodies. In our study, farmers highlighted how poverty and lack of financial resources can be an inhibitor in the collective mobilization of people to promote sustainable water management. Government interventions with regards to groundwater management, such as farm ponds or dug wells, have focused only on the supply side of the problem, i.e. access to water. This focus on physical availability and use of water leads to over extraction and use of water, which often leads to a tragedy of the commons situation where richer farmers extract groundwater to fill farm ponds even in the dry season and drought periods while poorer farmers and women in the same area depend on public tankers for basic water (Kale, 2017). Future interventions that harness the strength of collective community action will likely be more effective in the long run.

Fourth and last, the foundation of watershed development in the past focused on ecological conditions of water bodies, and agricultural land (Reddy et. al. , 2004); current water policies need to shift focus not only on improving the physical availability of water as a private good, but also to those that encourage sustainable groundwater management by influencing behaviour, norms and values around water management as a common pool resource. According to Hermanowicz (2008), the meaning and interpretation of water sustainability have changed through time: from a short-term view of water supply being at least equal to the demand to a more long term view that encompasses the environmental and social aspects of water across spatial and temporal scales. While water policies in India have been moving towards a more multidisciplinary approach of sustainable water management as evidenced by the Twelfth Five Year National Plan which calls for focus towards sustainable water management, the sustainability in water policies have mainly focused towards economic and to some extent, environmental sustainability (Katyaini & Barua, 2015). Social sustainability aspects such as intergenerational and intragenerational water inequalities, as well as enhanced participation of multi-stakeholders in formulation of water policies needs further work. For example, policies as such have ignored the sustainability aspects of ensuring that water resources "meet the needs of the present without compromising the ability of future generations to meet theirs" (WCED 1987). Our study demonstrates that people in the water scarcity regions value and acknowledge the importance of water conservation for themselves and future generations. Hence, the water policies in India need to be reassessed and revised to reflect the concerns and aspirations of people who feel it's' scarcity the most and incorporate aspects of long-term social and environmental sustainability in its policies.

Conclusion

Under the growing pressures of agricultural demands and climate variability, the dependency on groundwater is only going to increase further. To preserve and better manage this invisible water source, there is a need to move beyond a utilitarian understanding of water to encompass the psychological, cognitive, and behavioral components of water. Understanding how people perceive, evaluate, and believe in water resources and its future is imperative for water sustainability. These are issues that have, so far, been underexplored and understudied. This study is an effort towards this goal.


Research team interviewing a rich grape farmer in Kadvanchi

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