Understanding farmers' micro irrigation adoption behaviour: a case study in Maharashtra, India

MSc thesis graduation report

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by

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to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on Thursday August 31, 2023 at 10:00 AM.

Student number:	5265223	
Project duration:	November 1, 2022 – September 1, 2023	
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Cover: Personal photo taken during the fieldwork in Maharashtra, India (*April 2023*)

Preface

You are looking at the report about understanding farmers' micro irrigation adoption behavior developed through the case study in the Maharashtra state in India. I wrote this report for finalizing my journey of becoming a Master of Science in Water Management at Delft University of Technology.

Firstly, I would like to thank my main supervisor, Saket Pande, for his guidance. It was a pleasure working with him and learning from his expertise. Without Saket, it would be hard to become an expert in the field of econometrics I managed to become as a result of his support. Additionally, I would like to thank my daily supervisor, a postdoctoral researcher Soham Adla, for inspiring and useful discussions at any point I needed them. Soham made sure there were no big obstacles along my way and always made time for our discussions. Furthermore, completing the research in behavioral sciences with only engineering expertise would not be possible without my supervisor from the Faculty of Technology, Policy, and Management, Lisa Scholten. Lisa helped me gain the additional expertise I needed for doing this research and gave me motivating words when I needed them. She always gave constructive feedback and helped me progress at the critical points of my research. Furthermore, I would like to thank my supervisor Erik Mostert, for helping me overcome obstacles with the social science research, and for his enthusiasm during our progress meetings. I would like to thank my whole committee for giving me the feeling that I am not doing this research alone.

Also, I would like to thank my family, my mother Dragana, my father Branislav, and my brother Igor for their endless support during my time in Delft. Without them, my journey at the Delft University of Technology would not happen. I would also like to thank my uncle Fabio and my aunt Svetlana, for their curiosity about my study and life progress. I would like to thank my boyfriend Bart Bravenboer, for reminding me that there is always a way to solve anything, especially in the moments when I wanted to quit. I would like to thank him for reading my draft report and providing solid feedback that helped me finalize my work. Lastly, I would like to thank my friends, especially Tijana, Milka, Luna, Teodora, and Djina for staying close to me despite the distance that was between us. I am deeply grateful for everything you have done for me.

Anja Saponjic
Delft, August 2023

Abstract

India, a predominantly rural country, relies on agriculture, with smallholder farmers owning a small portion of cultivable land. Maharashtra, a major cotton-growing region, faces water scarcity and drought events, leading to low crop yields and farmer indebtedness, followed by high suicide rates. Micro irrigation, such as drip and sprinkler systems, can improve water use productivity and mitigate the impacts of climate change on farmers' incomes and thus livelihoods.

Psychosocial factors play a crucial role in farmers' decisions to adopt irrigation technologies. Incorporating both contextual and psychosocial factors provides deeper insights into the adoption processes of various irrigation systems. The RANAS model has been recognized for behavior change strategies in developing countries and was applied in this research. It integrates psychosocial factors and is used to examine the impact of psychosocial factors on behavioral outcomes.

Regression analysis was performed on survey data in order to identify the factors that are assumed to have the ability to explain irrigation and micro irrigation adoption behavior. Four models were created, each focusing on a specific irrigation system: overall uptake, furrow irrigation, sprinkler irrigation, and drip irrigation. This approach allowed for a deeper understanding of the influential factors for different irrigation systems and avoided the generalization of the results. In an attempt to broaden the understanding that can be obtained from regression results, qualitative, open-ended field interviews were conducted with farmers and key informants. The field insights revealed how the local context dynamics influence the factors that have a predictive capability on the adoption of micro irrigation systems.

Farmers' adoption of drip irrigation systems is influenced primarily by their confidence in financial capabilities and technical skills. However, the adoption of sprinkler irrigation systems is more complex. In addition to financial and technical considerations, farmers also consider factors such as easy access to water sources, concerns about future water availability, and descriptive norms, i.e. the actions other farmers take. This indicates that the barrier to adopting drip systems is mainly financial, while the adoption of sprinkler systems also involves to a certain extent normative influence and water-related concerns.

The RANAS method is effective in identifying predictive variables for micro irrigation adoption by breaking down the complex problem into manageable components. However, it has limitations. It overlooks the dynamic nature of the adoption process and fails to consider the significance of factors at different stages of behavior change. It also underestimates the role of economic and institutional constraints, which can influence farmers' investment capacities and perceptions. Additionally, the methods reliance on the design of survey questions may introduce bias and affect the reliability of the interpreted empirical data.

Field insights highlight the significance of context-specific factors and the integration of economic capacities in farmers adoption decisions. Economic stability is crucial for implementing micro irrigation systems, and financially vulnerable farmers may be risk-averse toward new technology. Community support and reduced risk perception can facilitate adoption. Examining profit margins and market prices provides a better understanding of adoption than just income. Considering practical aspects such as crop suitability and awareness of climate change and market dynamics further explain adoption choices. Trust-building is essential to enhance farmers willingness to adopt irrigation systems.

Acknowledgements

I am grateful for all the people from India who helped me make my field research happen ever since the planning of the initial fieldwork changed. Particularly Sumit Meshram and Shilpa Ganvir, his uncle Ajabrao Patil and his son Harshvardhan Patil, and their friends Bhagyashree and Sachin Deshpande. They were people who helped me get initial contacts from the farmers.

Furthermore, I would like to thank Tatyasaheb Matte, his son Shantanu Matte, and Rashmi Daduria for introducing me to the farmers from the Farmer Producer Company and helping me understand the prevailing local farming circumstances. I would like to thank Prajwal Bhautmange for helping me overcome the language barriers and for his translation from English to Marathi and vice versa. I would like to thank all the farmers who were willing to participate in my research, especially Mandar Deshpande, who introduced me to other farmers. Without them, my study would not have turned out the way it has.

During my fieldwork, I came across many farmers who are very special and who said a lot of beautiful words. They were constantly engaged in the conversation and they shared not only their farming issues but also what makes their life so challenging. The whole trip helped me broaden my perspectives. I started thinking about people-oriented projects. I realized that social factors are a cross-cutting thing, and that behavior change sometimes is a bigger issue than building infrastructure.*"To sustain you have to believe"*, and *"Any intervention is never a perfection"*, were some of the words that sparked my interest to explore how farmers think of and accept big (technological) changes in their lives.

Also, I would like to thank Hans Joachim Mosler for dedicating his time to help me understand the structure and application domain of the RANAS framework, Diana Callejas Moncaleano for our discussions at the beginning of my research, D. Daniel for his suggestions on how to build a regression model, Faiz Alam for his support on logistic regression modeling, Mario Alberto for his company and support in India, and Mithun Raj for sharing ideas about the RANAS framework and also for hosting me at his introducing me to his kids.

Finally, I would like to thank the Lamminga fund, FAST fund and India Brazil Collaborations fund for the financial support for my stay in India. Without them, this research trip would not be financially feasible. I would like to thank you all for making it possible to travel to India and for making it pleasant to stay on the other side of the world.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Problem statement

India is a developing country, consisting of a predominantly rural population, whose primary job is agriculture (Matte, 2023). Smallholder farmers (those owning less than two hectares of farmland (FAO, 2021)) constitute the bulk of all farmers (86.2%) in India, but own less than a half (47.3%) of the available cultivable land (Bisht et al., 2020). The state of Maharashtra accounts for the largest area of cotton cultivation in India (Hatch et al., 2022). However, it is a drought prone region (Camilla, 2019), characterised by a water-inefficient cotton cultivation system at a high and ever-increasing risk of rainfall variability (Den Besten et al., 2016). Additionally, climate change is increasing the uncertainty in future rainfall patterns (Rahman et al., 2020), leaving regions with less resources than demand, i.e. water scarce. Consequently, the competition for water resources among farmers rose, not guaranteeing that all will have favorable yield outcomes. i.e. enough produce since crop development is dependent on their water supply. Lack of available water resources for crops gives rise to low crop yields of insufficient quality, crop losses, and crop failure (RVO, 2022). This has a negative implication on farmers' ability to sell the crops.

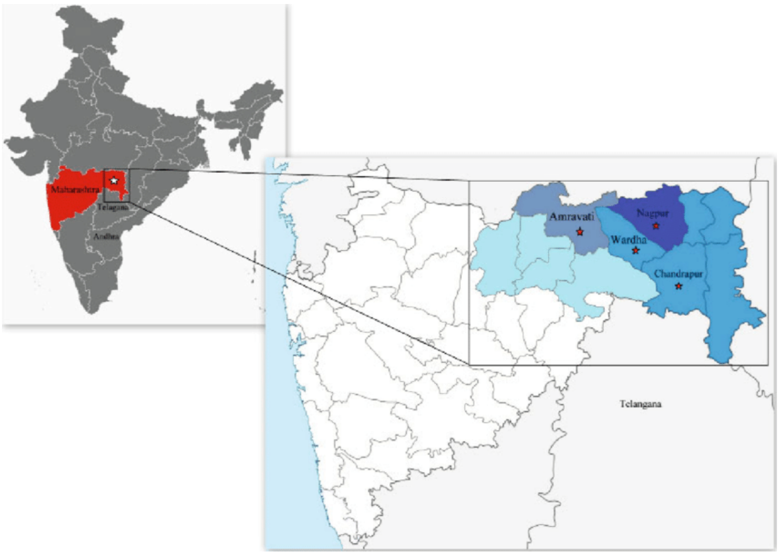

Figure 1.1: The state of Maharashtra (red) in India (Mahakalkar et al., 2017).

The worsened condition of generating profit subsequently results in household income losses and may lead to farmers going into debt (Dongre and Deshmukh, 2012). The financial hardships affect the livelihoods of many farmers, particularly in the regions of Vidarbha and Marathwada in the state of Maharashtra. (Dongre and Deshmukh, 2012) stated that 95 % of the farmers in Vidarbha are in debt. The critical districts in these two regions are Nagpur and Wardha districts in Vidarbha and Amaravati and Yavatmal districts in Marathwada (Hatch et al., 2022). The struggles of farmers in this district in Maharashtra led to high rates of farmers' suicides (Dongre and Deshmukh, 2012, Hatch et al., 2022). It has been argued that the reasons for farmers' suicides are increasing burdens on the farmers due to inflated prices of agricultural inputs (Den Besten et al., 2016; Dongre and Deshmukh, 2012). Those are not only the raw materials, but also the costs of agricultural equipment and labor costs. The surging costs farmers have to pay for farming have put them in large debt burdens (Dongre and Deshmukh, 2012). In combination with government policies, water scarcity, monsoon failure, climate change, personal challenges, and family issues (Matte, 2023), farmers started having psychological and mental health concerns.

One of the possible ways of improving livelihoods and poverty alleviation could be through improvements in agricultural outcomes and the facilitation of climate-resilient agriculture. This means that farmers need to find a way to deal with climate change-induced effects on farming, such as water scarcity and untimely rainfall that affect the amount of crops that can be grown. Micro irrigation has been recognized as a potential solution to the problem of water scarcity, as it is enhancing the water use productivity of crops (Ahmad and Hasanuzzaman, 2020). It supports the water supply process to plants, in places where rainfall does not meet the crop water requirements. Micro irrigation systems entail sprinkler and drip irrigation systems. In contrast to the surface traditional furrow irrigation method, drip irrigation is localized and is often referred to as improved irrigation practice (Venot et al., 2017) and is mentioned in the projects that contribute to Sustainable Development Goals (SDGs). Sprinkler irrigation system is able to provide more water supply in the same amount of time as the furrow irrigation system. This makes drip and sprinkler systems more favourable for improving agricultural practices (Venot et al., 2017).

Micro irrigation systems can potentially contribute to achieving the following objectives (Lee et al., 2016):

- Increased crop productivity and higher crop yields,
- Water conservation,
- Modernizing agriculture, and
- Poverty alleviation.

The schematic overview of the objectives to be reached in order to improve livelihoods of farmers can be seen in Figure 1.2.

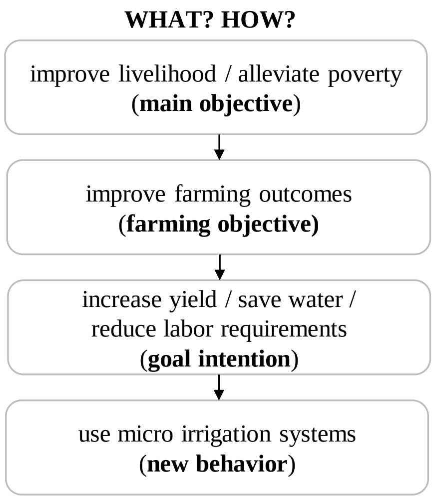

Figure 1.2: Higher and lower level objectives of farmers in Maharashtra state in India

Although micro irrigation systems have been proven to be highly efficient, and despite initiatives to promote their widespread acceptance, the adoption rate among farmers in Maharashtra state in India still remains low (Nair and Thomas, 2023). Farmers are reluctant to implement these systems and the irrigation network in the region is thus not being used to its full capacity (Express, 2019b). In Maharashtra, most areas are with no irrigation facilities (Matte, 2023). Annual rainfall varies between 1000 and 1600 mm in the districts of this state (Camilla, 2019). Only 30% of the surface area is under irrigation, and 70% of the surface area is rainfed. Out of 30% area that is under irrigation, only 5% area belongs to micro irrigation (Express, 2019a). Efforts have been made to try to investigate the limiting factors that prevent farmers from adopting efficient micro irrigation systems. It is not enough to only provide people with facilities, as they may become useless in the case of improper utilization (Mosler, 2012). In order to encourage farmers to adopt these systems, it is crucial to develop and implement effective behavior change strategies (Mosler, 2012). Tackling this issue demands an understanding of how farmers make decisions regarding the uptake of different irrigation technologies.

Socio-economic, environmental and institutional, often referred to as contextual factors, are commonly recognized as determinants that influence farmers to adopt various irrigation technologies (Balasubramanya et al., 2023, Nair and Thomas, 2023, Pathak et al., 2019). However, any human behavior, including the one related to technology adoption, is an outcome that arises from the psychological processing of internal factors within an individual (Ajzen, 1985). For this reason, psychological factors shed light on the underlying mechanisms that shape farmers' thoughts, emotions, attitudes, and decision-making processes. Recent studies have explored the importance of incorporating psychological factors into the analysis of human-water systems is growing, as can be observed from recent studies that evaluate the adoption and utilization of irrigation systems (Hatch et al., 2022, Sikka et al., 2022). By considering both contextual and psychological factors, deeper insights may be gained into the factors that influence farmers' decisions to adopt these systems. To give an example, awareness campaigns, education, and knowledge-sharing initiatives can promote the adoption of micro irrigation by creating a strong social norm. Positive individual experiences and access to information and financial support services also influence farmers' decisions to adopt these systems, improving agricultural practices and livelihoods.

The RANAS model, the framework whose name originates from an acronym that stands for: *R-risks*, *A-attitudes*, *N-norms*, *A-abilities*, and *S-self-regulation* is one of the psychological frameworks used to examine the impact of psychosocial factors on behavioral outcomes, developed by H.J.Mosler (Mosler, 2012). The RANAS integrates the psychological factors proposed by prominent theories of behavior change, such as The Theory of Planned Behavior, which states that *there is a general agreement that most human behavior is goal-directed* (Ajzen, 1985), as well as the Norm Activation Model, which states that *behavior is causally influenced by feelings of moral obligation to act on one's personally held norms* (Schwartz, 1977).

The RANAS was initially developed for the WASH (water-sanitation-hygiene) sector, but due to its potential for adaptation to a wide range of behaviors (Mosler, 2012), attempts are being made (Hatch et al., 2022, Daniel et al., 2022, Sikka et al., 2022) to test its application in describing irrigation technology adoption. Furthermore, this model has been widely recognized and accepted for designing and evaluating strategies aimed at bringing about behavior change in developing countries (Mosler, 2012). For these reasons, the RANAS framework was used as a theoretical background for this research. The psychosocial factors identified with this framework are henceforth referred to as RANAS factors throughout this report. Further elaboration on the constructs of the RANAS model can be found in Chapter 2.1.

1.2 Research objectives

In line with the aforementioned information, this research aims to analyze the underlying contextual and psychosocial factors that influence the adoption of different irrigation technologies in the case study area (the regions of Vidarbha and Marathwada in the state of Maharashtra in India). To reach the aim described above, the main research question addressed in this study is defined as follows:

"What are the main drivers of smallholder farmers' micro irrigation adoption behavior in

Maharashtra state in India?"

The sub-questions are formulated to help answer the main research question:

1. ***"What can be learned about farmers' irrigation and micro irrigation adoption behavior from applying the RANAS model to the data collected using farmer surveys?"***
2. ***"What are the strengths and limitations of the RANAS model to identify variables that have the predictive capability on micro irrigation adoption behavior?"***
3. ***"What additional information that might enrich the knowledge on the dynamics of farmers' micro irrigation adoption behavior can be collected during the fieldwork?"***

1.3 Thesis structure

In this section, the structure of this MSc thesis is presented (see flowchart in Figure 1.3).

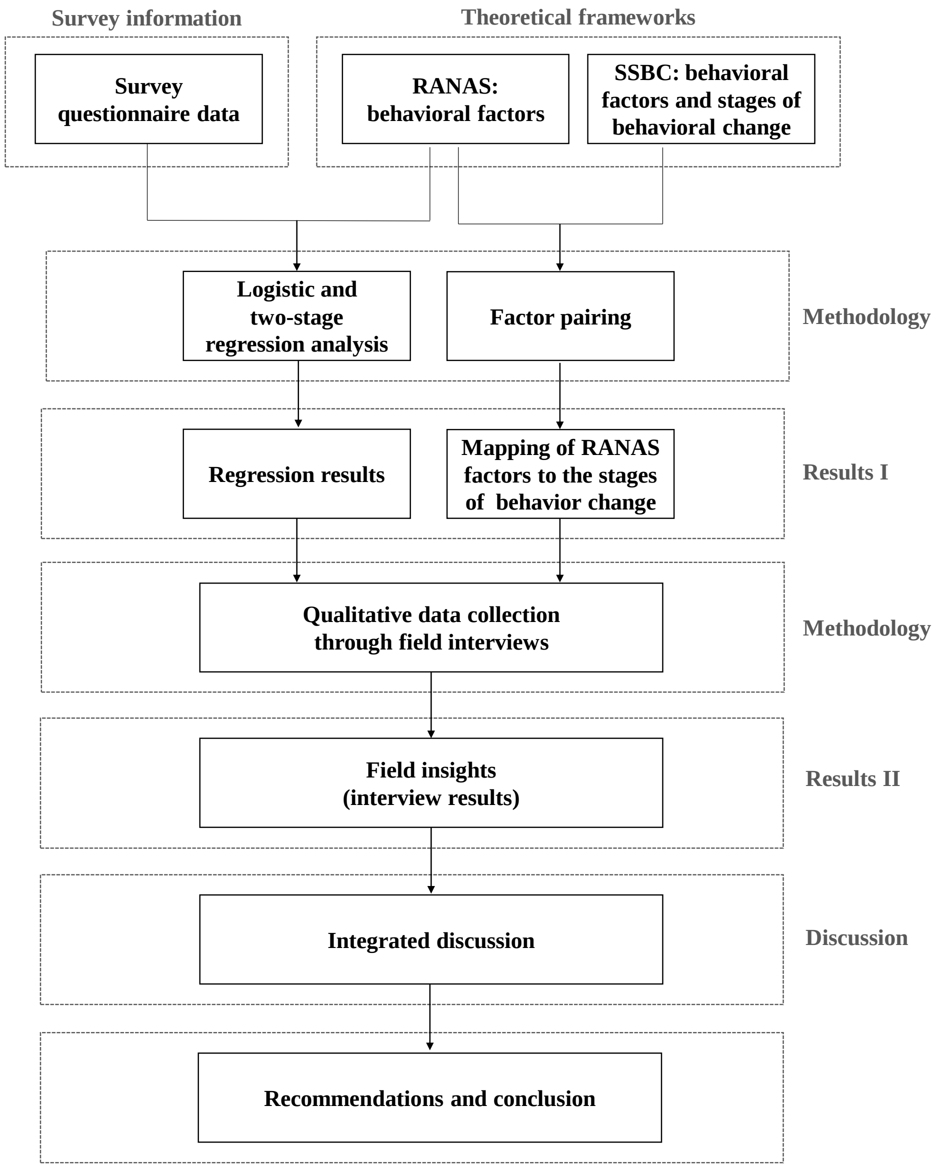

Figure 1.3: Flowchart displaying theoretical background, data and methodology used in the thesis

This MSc thesis was done in the following steps:

- The theoretical background was introduced: the RANAS and the SSBC frameworks were studied to explore the ways to analyze the factors that have an influence on behavioral outcomes.
- Quantitative survey data was received from the field.
- The influence of psychosocial factors on irrigation adoption behavior was studied by applying the RANAS model to the data collected through a survey questionnaire by building regression models.
- The stage model of self-regulated behavior change (SSBC) was explored as a theoretical alternative to the RANAS and used to perform a new mapping that could shed light on the relationship between the RANAS factors and different stages of the behavior change process.
- The results from this part were subsequently used to inform and design the field interviews.
- Interviews were conducted to gain additional insights into farmers' perceptions and irrigation practices and validate the results from regression analysis and mapping.
- Lastly, the regression results were re-interpreted and conclusions were made.
- This MSc thesis, therefore, consists of steps that are conceptualized and structured according to the flowchart in Figure 1.3.

Chapter 2

Methodology

2.1 The psychological framework: the RANAS (R-risk, A-attitude, N-norms, A-abilities, and S-self-regulation) model to describe the behavioral determinants

The RANAS framework is an established model for identifying the factors that stimulate a certain behavior in a systematically structured and logical way (Mosler, 2012, Mosler and Contzen, 2016). The RANAS models' constructs are centered around the Theory of Planned Behavior (Ajzen, 1985). Its systematic structure enables it to propose behavior change strategies that aim to alter factors in favor of the desired behavior change (Mosler, 2012).

The RANAS model consists of four main components (Mosler, 2012):

1. Psychosocial factors,
2. Contextual factors,
3. Behavioral outcomes, i.e. different behaviors, and
4. Behavior change techniques.

The model constructs can be seen in the Figure 2.1 (please note that the contextual factors are missing). Psychosocial factors, also referred to as RANAS factors, are incorporated into five blocks of factors (corresponding to the acronym of the name) that need to have a positive impact on the outcome of a desired behavior in order for it to take place. The blocks of factors are defined as follows: (R) risk factors, (A) attitudinal factors, (N) normative factors, (A) ability factors, and (S) self-regulation factors (Mosler, 2012). Every factor block consists of a different number of sub-factors. The distinction between factors and sub-factors, their definitions, and explanations according to the specific farming context is described below. All the definitions were adopted from (Mosler, 2012) and brought into the context of the adoption of efficient irrigation practices.

Risk factor block consists of sub-factors that address an individual's understanding and awareness of the risk of not having enough water for farming. The risk of insufficient water supply is closely related to the risk of low yields (Van Halsema and Vincent, 2012). Perceived vulnerability refers to a farmer's subjective perception of their risk of not having enough water. Perceived severity is a farmer's perception of the seriousness of the consequences of not having enough water. A farmer should have an understanding (through their knowledge) of how they could be affected by the lack of available water for farming, e.g. knowing the possibilities for potential yield loss. For example, being aware of climate change may influence the perceived vulnerability a farmer has.

Attitude factors express a positive or negative viewpoint on irrigation adoption behavior. These factors include so-called instrumental beliefs that are defined as expected end results, outcomes or consequences that a farmer associates with involving in the adoption of new technology, such as beliefs about needed costs in terms of money, time, and effort, and benefits in terms of water savings, yield

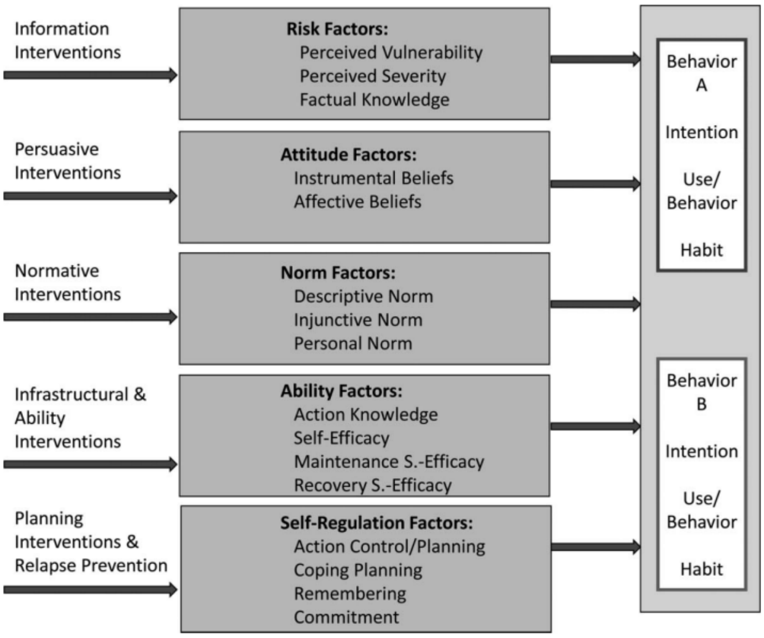

Figure 2.1: The RANAS model of behavior change (Mosler, 2012)

improvements, or other advantages of new farming practice. Furthermore, attitudes have an affective component. Affective beliefs are defined as feelings arising when irrigating or thinking of irrigation.

Norm factors account for the social influence of irrigation methods practiced by other farmers on a certain farmer. There are various sub-factors underlying the norm factor block. The descriptive norms refer to perceptions of what is commonly practiced or done in a particular group of farmers, i.e. it refers to the "imitation" of the behavior of others and can therefore influence farmer's own choices. The descriptive norm serves as a benchmark or standard for determining what is considered "normal" given a certain social setting. The injunctive norm encompasses farmers' perceptions of practices that are generally either approved or disapproved by their relatives, friends, neighbors, or other farmers. The injunctive norms contain institutional norms, which are the actions to take and actions to avoid expressed by recognized institutions. Personal norms take into account what an individual farmer personally believes they should do. This norm must be taken into account, as it can contradict the other norms.

Ability factors represent the qualities, knowledge, and skills a farmer believes they must have in order to be able to engage in an irrigation practice and reflect on a farmer's self-confidence. The ability factor block consists of four sub-factors. Action knowledge is a pre-condition and means that farmers know how to perform a behavior, i.e. engage in an irrigation practice. Self-efficacy refers to the belief a farmer has in their ability to effectively plan and carry out the necessary actions to handle future situations that are closely related to the adoption of certain irrigation practice. A positive self-efficacy is needed for steering the farming practice toward the adoption of irrigation technology. Two other kinds of self-efficacy are maintenance (coping) self-efficacy and recovery self-efficacy. Maintenance self-efficacy includes beliefs about the farmer's ability to deal with barriers that arise during the maintenance of the behavior, and recovery self-efficacy describes the experience of failure and recovery from setbacks.

Self-regulation (also called self-management) factors are responsible for the continuance and maintenance of the behavior, i.e. the continuous use of the newly adopted irrigation system. They help a farmer to manage conflicting goals and distractions that may arise when attempting to adopt and sustain, or continuously perform a behavior. Action control and planning account for thoughts about how to establish continuous behavior by specifying the when, where, and how of the behavior. Coping planning is defined as the knowledge of possible obstacles and the knowledge of ways to resolve them. To perform a continuous behavior, a farmer has to remember the behavior and commit to it, which creates a habit as a result.

"The first four blocks of factors are concerning motivation, while the fifth block (Self-regulation) deals with coming into action. However, all the factors are in one column." (H.J.Mosler, 30th of June 2023)

It can be observed that analyzing the factors that influence a particular behavior, in this case, the adoption of a certain irrigation system, is a complex problem. Analysis of behavioral factors has been found to be a successful means of predicting population behavior in the water sector of developing countries (Mosler, 2012), so in this regard, an attempt was made also in this work to describe the influences of farmers' irrigation adoption choices. For reaching this objective, the RANAS model was applied.

For the purpose of the application of the RANAS framework, adequate quantitative data was collected and an appropriate econometric method was employed. As factors defined by RANAS stimulate behavior in a systematically structured and logical way, data collection and analysis was also done in a systematic manner. For this purpose, data that includes measures of risk perception, attitudes, norms, individual abilities, and self-regulation factors was gathered. Subsequently, the econometric method that fits the type of gathered data was selected. It allowed for building a model, analyzing the relationships between the model constructs, and identifying the key determinants of behavior. Different models were developed to explore the specific factors that influence the adoption of different irrigation systems.

2.2 The alternate psychological framework: the stage model of self-regulated behavior change (SSBC)

In the previous section of this chapter, the RANAS framework was introduced. It was shown that it can identify the factors that stimulate a certain behavior in a systematic way. However, the process of adopting a new behavior is not an event happening only once, but more a dynamic process (Bamberg, 2013; Keller et al., 2019). For example, some farmers may be at different points in their behavior change journey, ranging from lacking awareness of the necessity for change to proactively making efforts to maintain the newly adopted behavior. By recognizing these stages, proper interventions can be designed according to the need of each and individual farmer (Keller et al., 2019). This highlights the fact that adoption entails more than just the act of adoption itself. Furthermore, it emphasizes the need for a more comprehensive view of the behavior change journey. In this aspect, another framework that could help understand the behavior change process farmers need to go through was identified in the existing literature: *The stage model of self-regulated behavior change* (Bamberg, 2013). This model will also be referred to as SSBC throughout this report.

According to the SSBC, behavior change is a goal-oriented process and it takes place in a series of four (qualitatively) different stages (Keller et al., 2019): predecisional, preactional, actional, and postactional (Bamberg, 2013; Keller et al., 2019). Furthermore, the SSBC marks different intentions that indicate the passing to the next stage (seen in Figure 2.2). The first three stages are concluded with different intentions: goal intention, behavioral intention, and implementation intention, to finally develop a new behavior in the postactional stage. These stages are inspired by the model of action phases (MAP) (Heckhausen and Gollwitzer, 1987). The MAP argues that each of the stages is influenced by different behavioral factors (Heckhausen and Gollwitzer, 1987). However, it does not define which behavioral factors they are and how they influence the stage transitions. For that reason, the norm-activation model (NAM) (Schwartz and Howard, 1981) and The Theory of Planned Behavior (TPB) (Ajzen, 1991) were followed to be able to identify factors relevant to each stage. The RANAS framework was also founded on the TPB, meaning that it analyzes the intentions and behaviors, but it does not take the dynamic aspect into account. The following section describes all the stages and the corresponding factors. The definitions of factors, i.e. model constructs were adopted from (Keller et al., 2019). They were subsequently brought into the context of the adoption of efficient irrigation practices.

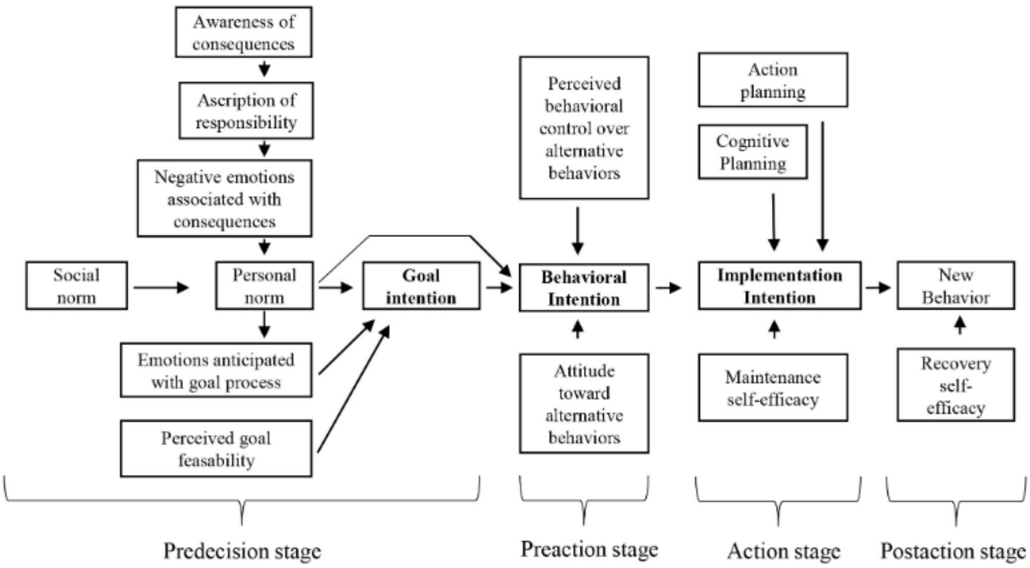

Figure 2.2: The stage model of self-regulated behavioral change, adapted from (Keller et al., 2019)

According to the theory of the stage model, the predecisional stage is influenced by the model constructs that originate from the NAM (Keller et al., 2019). In this stage, a farmer is motivated to reflect on their practices and goals. As soon as a farmer becomes aware that their current farming practice has harmful consequences for them and their family, negative feelings arise. This is called awareness of consequences. For example, a farmer knows that furrow irrigation leads to a lot of water losses that decrease the achieved yield and negatively impact the financial situation. A farmer also accepts their personal responsibility for causing this harm (ascription of responsibility). As a result of the negative feeling, the personal norm gets activated which can push a farmer to start considering how to solve the issue. Furthermore, the social norm, i.e. the behaviors and expectations of others also have an influence on an individual farmer through social norms. Altogether, these factors form a goal intention. With a goal intention, a farmer can come up with the goal of saving water or improving their yield. If a farmer is going to commit themselves to the set goal, it depends on perceived goal feasibility. If a farmer does not see their goal as feasible, they may still decide to leave the goal behind.

Second, once committed to the set goal, a farmer starts thinking of the possible ways to achieve it. The Theory of Planned Behavior (Ajzen, 1991) defines the model constructs that directly influence the formation of behavioral intention in the preaction stage. First, attitude toward alternate behaviors stands for the choice between the available behavioral alternatives, such as different types of efficient irrigation systems (e.g. sprinkler or drip) a farmer can use to reach the goal of, for example, improving their yield. Second, perceived behavioral control toward alternate behaviors stands for the advantages, disadvantages, and difficulty of each of the alternatives.

Third, the implementation intention is formulated once a farmer perceives they are able to engage in action and cognitive planning (Keller et al., 2019). Action planning initiates the thoughts of needed actions, i.e. it specifies the where and when of the behavior. Cognitive planning means that a farmer knows how to deal with different situations that could threaten the performance of behavior and what actions to take in those cases. Furthermore, maintenance self-efficacy is a factor that takes into account how self-confident a farmer is in their skills when it comes to maintaining a behavior.

Lastly, in the postactional stage, recovery self-efficacy describes a farmer's persistence in doing the behavior despite the possible encountered failures or setbacks.

Checking for different kinds of intentions that could indicate whether a farmer can proceed into the next stage was found to be difficult (Bamberg, 2013; Keller et al., 2019). For the purpose of the research, this model was identified as a theoretical alternative to the RANAS framework to point out that the RANAS may lack a dynamic component. While the SSBC was not directly applied to the data, it was used to construct a new theoretical mapping that could integrate the factors from both the RANAS and the SSBC framework. By having done this, it could show how the RANAS factors and various stages within the behavior change process are related.

2.3 RANAS and SSBC factors across different stages of the behavior change process

Both the RANAS and the SSBC framework define different behavioral factors relevant to the outcome behavior. The definitions of all the factors can be found in the separate sections on these frameworks (sections 2.1 and 2.2). Since the SSBC framework assigns behavioral factors to different stages of the behavior change process, the factor pairing was done to allow for the assignment of stages also to the RANAS factors. The process of factor pairing was therefore done in the following manner:

1. The factors that have the same meanings were identified and appropriately paired.
2. The factors that were exclusively defined by one framework and not by the other were kept as individual factors.
3. The integrated list of factors was created.

After having paired the factors, the factors were mapped to the different stages of the behavior change process by utilizing the stage progression according to the SSBC framework. In addition to factor pairing and mapping, the survey questions were designed to collect data on the different factors and different stages in the future. However, one caveat is that the mapping and questions still lack construct validity. The results of factor pairing and mapping can be found in section 3.1. The new questions can be found in separate Excel sheet (on demand).

2.4 Quantitative data collection through survey questionnaire

To find answers to the research sub-questions and that way answer the main research question, the theoretical RANAS framework had to be implemented and validated, which required proper data inputs. The primary data was collected in the field. Data collection was done at two different points in time. First quantitative, and then qualitative data were collected. Quantitative data served as input for the RANAS model (previously described in 2.1). Qualitative data served as the source of field insights and the basis for critical assessment and validation purposes of the RANAS model's capabilities to describe the psychosocial influences on irrigation technology adoption. This was achieved by gaining insights into farmers' perceptions and irrigation practices by conducting interviews directly in the field. The interview design was based on the outcomes of factor pairing and regression analysis and will be described later in section 2.8.

Quantitative data was collected through the household survey for the purpose of implementation of the RANAS model. The survey was conducted during November and December 2022, where a total of 419 farmers was interviewed in villages in the regions of Vidarbha and Marathwada in the state of Maharashtra, India (Fig 2.7).

Face-to-face interviews were structured and standardized in the form of a survey questionnaire and asked in farmers' homes or in communal spaces. The survey was designed to collect data in a quantitative manner, therefore all the respondents were asked the same questions in the same order. The questions were translated into the local language, Marathi, and interviews were carried out by enumerators. The responses were translated back into English afterward. A pilot questionnaire of 60 farmers was done and reviewed. A few adjustments were made and the survey continued with 359 more farmers. A total of 419 farmers were therefore interviewed. The sampling of farmers was random, however,

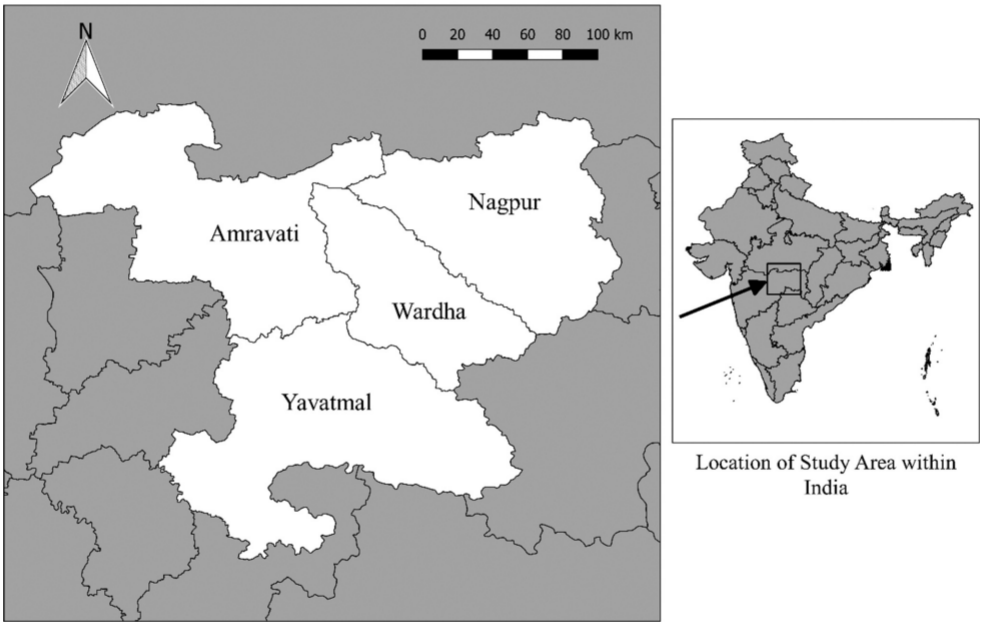

Figure 2.3: Study area districts within Maharashtra, India (left) and location of the study area within India (Hatch et al., 2022)

they were all necessarily cotton cultivators.

The survey consisted of questions that aimed to collect quantitative information on farmers' socio-economic characteristics, farming practices, financial questions (all called contextual factors), and questions related to farmers' psychological perceptions defined by the RANAS framework. The choice of the variables to be collected and included in the model was based on the definition of the RANAS model constructs. The list of chosen contextual and RANAS variables, together with their types can be found in Table 2.1 below. In addition, the list of the RANAS factors, sub-factors, and factor names is included in Table 2.2. Psychosocial RANAS questions were measured on a Likert scale from 1 to 5, while contextual factors were scored on a nominal and ordinal scale. The survey questions designed to obtain information on these variables can be found in Appendix A.

Variable	Variable category	Variable subcategory
Age	numeric	discrete
Education level	categorical	ordinal
Land area owned	numeric	continuous
Total annual income	numeric	continuous
Number of livestock owned	numeric	discrete
Number of dependents	numeric	discrete
Number of family members who help with farming	numeric	discrete
Type of irrigation system used for farming	categorical	nominal
RANAS perceptional factors	categorical	ordinal

Table 2.1: List of variables (contextual and RANAS factors) collected during the survey

2.5 Data analysis

After receiving the survey data and setting the theoretical background, the data were analyzed. Data analysis aimed to detect trends, identify patterns, uncover relationships, and draw conclusions and insights about the research questions. The understanding of the following was achieved:

Table 2.2: The RANAS factors, sub-factors and factor names

Determinant factor	Sub-factor	Factor name
Risk	Perceived severity	Met water demand
	Perceived vulnerability	Confidence of having enough water in the future
	Perceived severity	Severity of impact without water for crops
	Perceived vulnerability	Responsibility for water source
Attitude	Feelings	Extra effort taken for irrigation
	Feelings	Extra effort taken for micro irrigation
	Belief about costs and benefits	Difference in productivity achieved by irrigation
	Belief about costs and benefits	Difference in productivity achieved by micro irrigation
	Belief about costs and benefits	Willingness to pay
Norms	Other's behaviour	Proportion of people using micro irrigation systems
	Other's approval	Others' approval
	Personal importance	Importance of efficient use of irrigation water
Abilities	Confidence in performance	Confidence in buying and maintaining micro irrigation system
	Confidence in performance	Confidence in installing micro irrigation system
	Confidence in performance	Confidence in operating micro irrigation system
	Confidence in performance	Extra time taken for irrigation
	Confidence in performance	Extra time taken for micro irrigation
	Confidence in recovering	Difficulty to get water in the last 10 years
Self-regulation	Barrier planning	Limit of water shortage withstanding

- Influential (contextual and RANAS) factors on the irrigation adoption behavior: by logistic regression analysis (see 2.6),
- Institutional influence on RANAS factors: by the instrument variable (IV) approach and two-stage regression analysis (see 2.7).

The details of the points mentioned above are presented in the following sections.

2.6 Logistic regression analysis

The data obtained from the quantitative survey (described in 2.4) was utilized to construct a model to determine the effect of different contextual and RANAS factors on the use of irrigation systems, i.e. a model which identifies the variables that have predictive capability on irrigation adoption behavior and answer the research sub-question 1 in that manner. In this regard, the contextual and the RANAS factors were considered independent (predictor or explanatory) variables in the model build-up as they may influence the outcome, or dependent variable, while the use of an irrigation system (also referred to as behavior in this case) was considered a dependent variable. The hypothesis was formed: **the adoption of different irrigation systems can be explained by different contextual and RANAS factors**. In line with this hypothesis, the selection of the independent variables consisted of contextual and RANAS factors (described in section 2.4).

The goal was to determine the relevant variables that can explain the adoption of an irrigation system (i.e. formation of a behavioral pattern), as well as to determine the conditions that discourage it. In this aspect, the possible outcomes were "yes" (a farmer is using an irrigation system) or "no" (a farmer is not using an irrigation system). *This introduced the classification problem where the dependent variable is binary, i.e. it has only two possible outcomes: either a farmer adopts an irrigation system or not.* The statistical method chosen as the suitable one for solving this was logistic regression since it models the probability of an outcome occurring based on individual characteristics (Sperandei, 2014), and is commonly applied to binary classification problems (Mirko Stojiljkovic, 2023). The conceptualization of the model can be seen in Figure 2.4.

2.6.1 Scenario development for the application of the RANAS framework

With regard to the objectives of this research, the behavior of interest was defined as *the use of irrigation systems*. However, while farmers may already be using a certain irrigation system, it remains

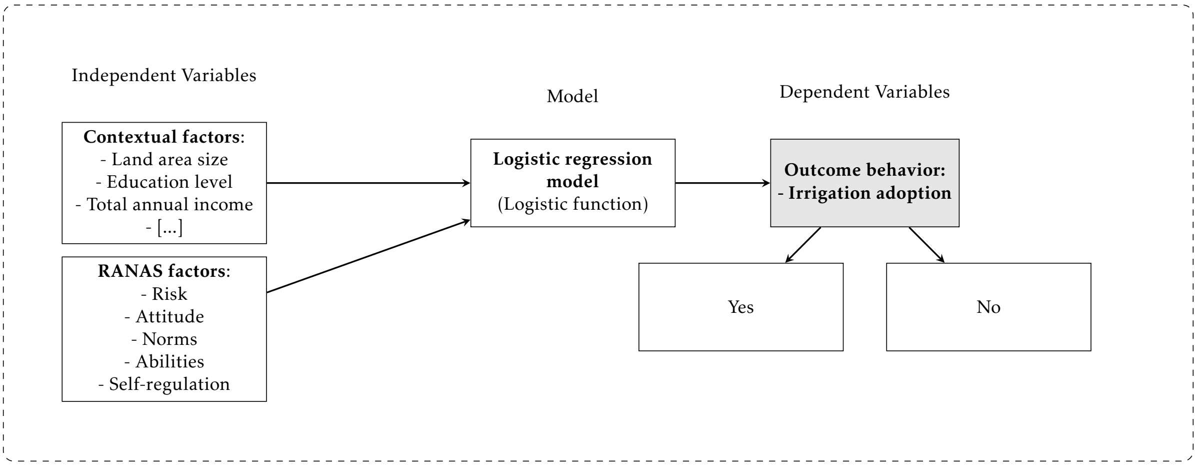

Figure 2.4: The conceptualization of the logistic regression model: The independent variables (contextual and RANAS factors) are inputs, and the dependent variable (irrigation adoption) is the output

a concern if they solely rely on traditional furrow irrigation systems or irrigate in a more efficient manner, such as with sprinkler or drip irrigation systems. Using furrow irrigation systems can still create problems when it comes to water efficiency and enhanced crop yields. Therefore, by identifying the factors that influence farmers' choices in relation to the use of different irrigation systems, the factors that matter for each of them can be identified and targeted through proper interventions. Four distinct scenarios were defined to capture factors relevant to the adoption of the four different irrigation systems. The adoption of micro irrigation systems was explored by developing the scenarios for sprinkler and drip systems adoption. Next, one scenario explored the adoption of furrow irrigation systems. Lastly, in order to see the overall affects of farmers' decisions to irrigate, the adoption of all irrigation systems was analyzed through last scenario. In this way, there were four scenarios defined in Table 2.3. As the main focus of this work it to find the factors that can explain the adoption of micro irrigation systems, the scenarios for the adoption of furrow, and irrigation systems overall were developed to check internal consistency of the relevant influential factors with the factors relevant to the adoption of micro irrigation systems.

Table 2.3: The definition of four scenarios related to the use of four different groups of irrigation systems

Scenario	Favorable behavior	Alternate behaviors
1	Use of irrigation systems overall	Rainfed irrigation
2	Use of furrow irrigation systems	Rainfed, sprinkler or drip irrigation
3	Use of sprinkler irrigation systems	Rainfed, furrow or drip irrigation
4	Use of drip irrigation systems	Rainfed, furrow or sprinkler irrigation

After having introduced the RANAS theoretical framework and developed the scenarios to be analyzed, the RANAS framework was applied in the following way:

1. The psychological (RANAS) sub-factors of farmers were identified and the survey questions were designed to collect data on these sub-factors. The (sub-) factors were measured using a Likert scale (from 1 to 5). Questions were taken from (Hatch et al., 2022).
2. Data on the adoption of different irrigation systems (as defined in the four scenarios in Table 2.3) were collected through a survey by asking questions related to irrigation practices.
3. Data on contextual factors were collected through a survey by asking questions related to the socioeconomic characteristics of farmers.
4. Logistic regression model was developed and trained on the data collected during the survey to determine the contextual and the RANAS factors that could explain the irrigation adoption behavior of farmers.

All the steps are described in detail in the following sections.

2.6.2 Binary logistic regression model definition

Binary logistic regression is a statistical method, a special case of logistic regression that estimates the probability of a dependent variable belonging to a particular class ("yes" or "no" or in this case) by considering the collection of independent (contextual and RANAS) variables (DeMaris, 1995). By introducing a threshold value, the probability can be turned into a binary variable (0 or 1), or simply provide answers "yes" or "no". By having trained the binary logistic regression model on a specific data set, it potentially becomes capable of making predictions that can be valuable when one wants to make informed decisions (Bruce et al., 2020). While the outcome of the model should strictly be binary, the logistic regression model allows independent variables to fall into different scales of data, discrete categorical (nominal or ordinal), and continuous numerical (interval or ratio) (Niu, 2020). To provide a more comprehensible illustration of the logistic regression method, the relevant terms (followed by the equations adopted from Mustafa Murat, 2023) are first introduced. To start with, the analogy with the linear regression equation was made. In the linear regression model, the relationship between outcome (y) and (n) independent features is modeled with a linear equation (2.1):

$$y^{(i)} = \beta_0 + \beta_1 x_1^{(i)} + \beta_2 x_2^{(i)} ... + \beta_n x_n^{(i)} \tag{2.1}$$

where β_0 is a constant term, while β_1, ... β_n are the regression coefficients.

In the case of logistic regression, the weighted sum (the right side of equation (2.1)) is transformed into the probability between 0 and 1 using a logistic function (Kumar and Rath, 2016):

$$p(y_i = 1|x_i, \beta) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1 + ... + \beta_j x_j + ... + \beta_n x_n)}} \tag{2.2}$$

where p stands for the probability of the occurrence of an event given the set of predictors.

The probability (p) that an event will occur is the fraction of times that event is expected to be seen in many trials, always ranging between 0 and 1. Odds are defined as the probability that the event will occur divided by the probability that the event will not occur and explained in equation (2.3).

$$odds = \frac{p}{1-p} \tag{2.3}$$

The logistic regression model is a linear model for the log odds (Mustafa Murat, 2023). This will be demonstrated by developing the odds term in equation (2.3) into the log function (Kumar and Rath, 2016):

$$\begin{gathered} log(\frac{p(y_i = 1)}{p(y_i = 0)}) = log(\frac{p(y_i = 1)}{1 - p(y_i = 1)}) = log(\frac{\frac{1}{1+e^{-(\beta_0+\beta_1 x_1+...+\beta_j x_j+...+\beta_n x_n)}}}{1 - (\frac{1}{1+e^{-(\beta_0+\beta_1 x_1+...+\beta_j x_j+...+\beta_n x_n)}})}) = \\ log(e^{\beta_0+\beta_1 x_1^{(i)}+\beta_2 x_2^{(i)}...+\beta_n x_n^{(i)}}) = \beta_0 + \beta_1 x_1^{(i)} + \beta_2 x_2^{(i)} ... + \beta_n x_n^{(i)} \end{gathered} \tag{2.4}$$

The odds term inside the brackets of the log function is called log odds. It can be observed that the logistic regression model is a linear model for the log odds, i.e. a linear relationship between the logit transformed odds and the predictor variables can be established.

For observing the effect of increasing one of the feature values by 1 unit, the ratio of the two predictions should be considered:

$$\frac{odds_{x_j+1}}{odds_{x_j}} = \frac{e^{\beta_0+\beta_1 x_1+...+\beta_j(x_j+1)+...+\beta_n x_n}}{e^{\beta_0+\beta_1 x_1+...+\beta_j x_j+...+\beta_n x_n}} = e^{\beta_j} \tag{2.5}$$

where odds ratio is the ratio between the odds once the feature changed for one unit over the odds ratio when that is not the case (left side of the equation 2.5).

Lastly, a simple term of exponential function of a feature weight β_j remains. It implies that one unit feature change changes the odds ratio (multiplicative) by a factor of e^{β_j}. In other words, a one-unit change (increase) in a certain independent variable (x_j to x_j+1) results in the increase of the log odds ratio by the value of the corresponding weight:

$$log(\frac{odds_{x_j+1}}{odds}) = \beta_j \tag{2.6}$$

Note: the probability ranges from 0 to 1. Odds range from 0 to +∞. Log odds range from -∞ to +∞.

The logistic regression model outputs are the logits, i.e. the log-odds. These outputs are obtained by building a logistic regression model in Python.

2.6.3 Assumptions of the logistic regression model

The assumptions underlying the logistic regression model were assessed to validate the appropriateness of the model chosen for the data set and to ensure the meaningfulness and reliability of the model's outputs. The underlying assumptions of the logistic regression model and its applicability to this case are listed below (Bruce et al., 2020):

I Binary logistic regression is used for **binary categorical dependent variables**.

II The relationship between the independent variables and the log odds (**logit**) of the dependent variable is assumed to be **linear**, as shown in equation 2.4.

III The independent variables should not be highly correlated with each other, meaning that there should not be a high correlation between the independent predictor variables. If that is not the case, it can be difficult to interpret the individual effects of the variables through estimates of coefficients.

IV The sample size should be large enough to have meaningful results. Adequate sample size ensures stable estimates and accurate inference. The rule of thumb is to include at least 10 (preferably 15) (Sperandei, 2014) observations per every independent variable in the model. If the sample size is too small, or there is not enough input data, the model fails to find the patterns in it, i.e. it is unable to capture the relationships between independent and dependent variables. This is known as the under fitting of the model, which may result in wrong predictions.

V The presence of extreme outliers can influence the estimation of logistic regression coefficients, therefore it is important to identify and handle outliers appropriately.

The model assumptions were checked by verifying that the dependent variable is discrete and takes on only two categories. To check whether the sample size was sufficiently large to capture the relationships between independent and dependent variables, i.e. to avoid underfitting of the model, the number of observations was compared to the number of included independent variables. Ultimately, to check whether the assumption of no outliers was satisfied, all the observations where an observation significantly deviates from the remaining values in the dataset were excluded during the step 1 of the model fitting process described in 2.6.4 that follows. The outliers were data points that occur in the low probability regions of the data distribution (Belhaouari et al., 2021), i.e. the points that deviate for more than 3 standard deviations from the mean (Belhaouari et al., 2021).

2.6.4 Model fitting

The logistic regression model fitting process consists of the steps engaged in estimating the parameters (log odds) of a logistic regression model based on a given data set. The logistic regression model was fitted to the data obtained from the field survey by using the Python Scikit-learn library identified in the literature (Subasi, 2020). The purpose of this process is to find the best-fitting model that can accurately estimate the log odds of the binary outcome based on the given set of explanatory variables. The steps are inspired by (Subasi, 2020) and described below:

1. **Data preparation and preprocessing**.
   Prior to model fitting, data were prepared and preprocessed. This included removing all the observations that contained missing values, encoding ordinal categorical variables, and scaling

numerical features. Scaling was done to compare the variables' coefficients. Regression coefficients are related to the unit and the scale of the variables, so they can only be compared if they are all converted to the unitless scale, i.e. z-score.

2. **Model formulation**.
   The binary logistic regression model was formulated by specifying the independent (explanatory) variables and the dependent variable (binary outcome).
3. **Model training**.
   The model was trained by using the provided data set to estimate the parameters (β) of the logistic regression model. This was done through an optimization algorithm, known as maximum likelihood estimation (MLE), which seeks to maximize the likelihood of the observed data given the model constructs (Kumar and Rath, 2016).
4. **Model evaluation**.
   The 'goodness of fit' was measured by log-likelihood-based pseudo-R^2, which represents the improvement in model likelihood over a null model (Hemmert et al., 2018). The improvement over the null model entails the additional explanatory power of independent variables added to the model. While this (McFaddens) pseudo-R^2 quantifies improvement over the null model, it does not quantify the correlation between predicted and observed values (Tjur, 2009). The equation of the pseudo-R^2 is described with equation (2.7) below:

$$R^2 = 1 - \frac{logL(m_1^*)}{logL(m_0^*)} \tag{2.7}$$

   where m_1 is the fitted model and m_0 is the null model.
5. **Model refinement**.
   Based on the model outcomes, the variables that are statistically significant in the regression model can be identified and used to refine the model. The variables that yield significant regression coefficients are those which have a p-value of lower than 0.05.

Four logistic regression models were created to analyze four scenarios that were developed in subsection 2.6.1. The model results will be presented in section 3.3 of Chapter 3.

2.7 Endogeneity in irrigation adoption behavior

In cases when regression models are not accurately specified, not all relevant predictors are included in the model and thus the relationship between the independent and the dependent variables is not accurately captured. As a consequence, key causal variables or relationships may be omitted, and the model estimates may be biased (Hill et al., 2021). It is possible to occur that the assumed cause-and-effect relationship is reversed, resulting in the effect becoming a new cause (Daniel et al., 2022; Hill et al., 2021). This effect is known as the endogeneity effect in regression analysis (Hill et al., 2021). Endogeneity, also referred to as reverse causality, is a result of the feedback effect from a dependent target variable to the independent variables (Daniel et al., 2022). The correlation between the independent variables and the error terms can arise due to endogeneity, despite the assumption that this is usually not the case (Daniel et al., 2022). Consequently, the independent variable is also influenced by the outcome, thereby introducing the potential for biased estimations in regression analysis (Daniel et al., 2022; Hill et al., 2021). Biased estimations of regression coefficients consequently lead to the incorrect interpretation of the results.

Logistic regression analysis was used to estimate the effect of the RANAS factors on the behavior of irrigation adoption, as it was previously described in section 2.6. In this analysis, the RANAS factors were treated as independent variables or predictors, while the dependent variable was the output variable representing irrigation adoption. The independent variables were assumed to be exogenous and unrelated to the error term (Daniel et al., 2022). To check whether this assumption is violated and overcome the endogeneity issue, and to avoid potential bias it can cause in regression analysis, the instrumental variable (IV) approach was used. A representation of the presence of a feedback effect or reverse causality on irrigation adoption behavior is shown in Figure 2.5.

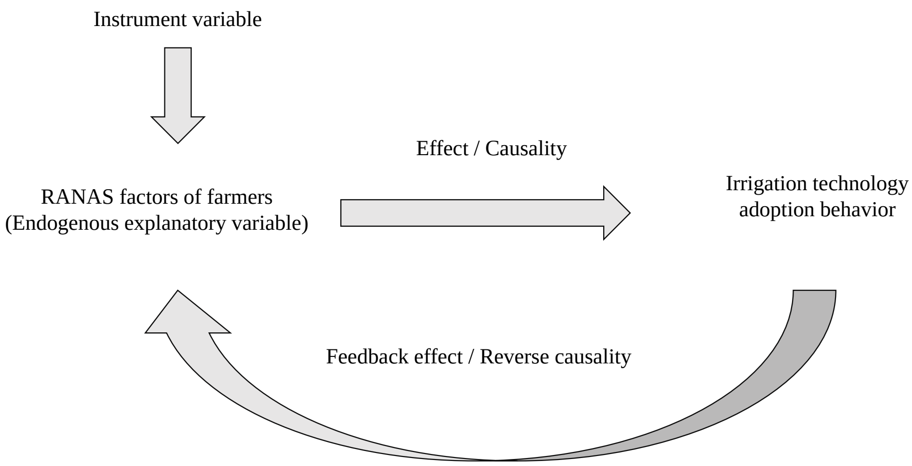

Figure 2.5: A representation of the presence of a feedback effect or reverse causality on the irrigation technology adoption behavior, modified from (Daniel et al., 2022).

2.7.1 The instrumental variable (IV) approach

The instrumental variable approach is a technique that introduces one or more instrument variables (IVs) that help avoid bias in estimating regression coefficients (and causal relationships between the independent variables and the dependent variable) and help remedy endogeneity (Hill et al., 2021). This is achieved by using IVs to predict the independent endogenous RANAS variables (noted as *Risk*, *Attitude*, etc). The prediction of the new RANAS factors (noted using "hat" symbol) is done by applying the ordinary least squares (OLS) linear regression and this step is thus called the first-stage regression. The equations showing the first-stage linear regression are included below. In these equations, γ_i is the i.i.d. (independent and identically distributed) variable, and $a_{i,0}$ and $a_{i,1}$ are first stage regression parameters.

$$\hat{Risk}_i = a_{r,0} + a_{r,i} IV_i + \gamma_{r,i} \tag{2.8}$$

$$\hat{Attitude}_i = a_{at,0} + a_{at,i} IV_i + \gamma_{at,i} \tag{2.9}$$

$$\hat{Norms}_i = a_{n,0} + a_{n,i} IV_i + \gamma_{n,i} \tag{2.10}$$

$$\hat{Abilities}_i = a_{ab,0} + a_{ab,i} IV_i + \gamma_{ab,i} \tag{2.11}$$

$$\hat{Self-regulation}_i = a_{sr,0} + a_{sr,i} IV_i + \gamma_{sr,i} \tag{2.12}$$

where the "hat" symbol stands for the predicted RANAS factors, a_0, a_1, ..., a_n stand for the regression coefficients estimated by using OLS, and IV stands for the instrument variable used as an independent variable to predict the RANAS factor.

In the second stage, the predicted values of the RANAS variables (x') are used instead of the original variables in the logistic regression analysis to estimate the effects on the dependent variable, i.e. irrigation adoption. For this reason, the second stage of logistic regression is called "instrumentalized" logistic regression. The equations describing "non-instrumentalized" (2.13) and "instrumentalized" (2.14) logistic regression are included below.

$$p(y_i = 1) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 SEC_i + \beta_2 Risk_i + \beta_3 Attitude_i + \beta_4 Norms_i + \beta_5 Abilities_i + \beta_6 Self-regultion_i)}} \tag{2.13}$$

$$p(y_i = 1) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 SEC_i + \beta_2 \hat{Risk}_i + \beta_3 \hat{Attitude}_i + \beta_4 \hat{Norms}_i + \beta_5 \hat{Abilities}_i + \beta_6 \hat{Self-regultion}_i)}} \quad (2.14)$$

Therefore, the IV approach requires the application of two-stage regression.

To be able to perform this analysis, a valid instrument variable (IV) must be chosen in the first place. Previous studies have proposed that economic, and subsequently technological development is influenced by culture and institutions (Tabellini, 2010). Institutions play a crucial role in shaping the motivations of individuals to innovate and invest (Tabellini, 2010). They are influenced by geography, historical events, or the political system, underscoring that the specifics of a certain place could have an effect on the psychology of people (Alesina and Giuliano, 2015) as they generate the regularity of behavior (Greif, 2006). On top of that, institutions remain in place for long periods of time (Tabellini, 2010), and can thus be considered "slow-moving variables" (Pande et al., 2020) which can have a lasting influence on the perceptions of individuals. Although commonly understood or interpreted as social norms (Legros and Cislaghi, 2020), institutions may shape and impact an individual's perceptions of risk and attitude (Daniel et al., 2022). On these grounds, an institutional quality was suggested as a potential IV (Daniel et al., 2022). For the above-mentioned reasons, variables related to institutions were used as IVs to predict the RANAS factors. The questions were developed to collect data on institutional influences and are included in Table A.3 in Appendix A.

However, these conceptual arguments for the reliability of the chosen instrumental variables are not enough. Finding satisfactory instrument variables can thus be challenging as they must meet two conditions (Daniel et al., 2022; Hill et al., 2021): (1) relevance, and (2) exogeneity. Relevance means that an instrumental variable affects the endogenous predictor, i.e. RANAS variable, and it can be tested directly by estimating the correlation coefficient between instrumental variables (IVs) and the RANAS factors (Daniel et al., 2022). The second is exogeneity, which means that IVs are factors that are not directly influencing irrigation adoption, but only influencing the RANAS factors. This means that IV is uncorrelated with the residual of the outcome (irrigation adoption) (Hill et al., 2021). The exogeneity condition can be checked by examining the significance of instrumental variables (IVs) in the second stage of regression. The condition is fulfilled if the IVs are not significant (i.e. they do not have a p-value of 0.05 or less) factors in the results of the "instrumentalized" logistic regression.

2.8 Qualitative data collection through open-ended interviews

2.8.1 Interview objective

Unlike the analysis of quantitative data, a qualitative data analysis adds more perspective and context. An interview is a more personal form of research compared to a survey through general questionnaires, and as such includes firstly defined and then follow-up questions that allow the participant to open up (Hammer and Wildavsky, 2018). It is a research approach used in qualitative studies where more personal interaction is required and detailed data is gathered from the participant, in this case, a farmer. Qualitative interviews with farmers accompanied factor pairing and regression analysis. The purpose of these interviews was, first, to validate the regression results by checking whether the statistical significance corresponds to practical relevance. Second, an attempt was made to find out whether the RANAS factors have a dynamic component and could be attributed to different stages. Lastly, a specific context of the irrigation adoption process in Maharashtra state was explored in order to confirm whether the RANAS model constructs have sufficient capacity in describing the irrigation adoption in this region.

2.8.2 Interview design

The interview type that was deployed for the qualitative phase of this MSc thesis research was an open-ended interview format with some specific questions at the beginning to gather the farmers' socio-economic profiles. As the goal of interviews was to allow for gathering additional information in the field, the open-ended question format was advantageous in this case. Factor pairing and regression analysis results were used to inform the interview design, therefore the fieldwork was a second part of this research project. The interview questionnaire can be found in Appendix B. The follow-up questions differed per respondent.

2.8.3 Interview conduction

The participants were reached and recruited using a technique known as snowball sampling. Snowball sampling is a method of recruiting study participants not easily accessible or known to the researcher (Leighton et al., 2021). In a nutshell, it is a qualitative research sampling technique where the researcher indirectly recruits participants by reaching out to contacts who subsequently connect them with potential research participants (Parker et al., 2019).

Initially, a small and limited number of individuals who meet the research criteria are invited to participate in the study and are called "seeds" (Parker et al., 2019). These participants are then asked to suggest other contacts who also meet the research criteria and might be willing to take part in the research etc. This is how the snowball grows (see Figure 2.6 below for the graphical representation of the method).

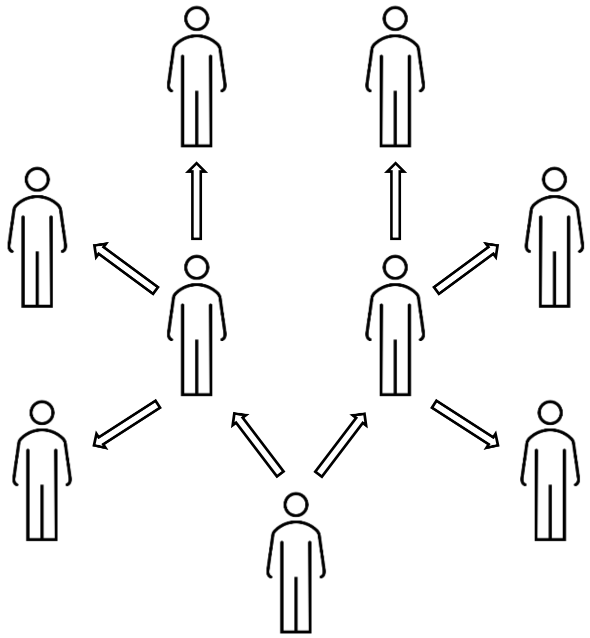

Figure 2.6: Graphical illustration of the snowball sampling method, inspired by the knowledge from (Parker et al., 2019) and adapted from (Simply Psychology, 2023).

In this regard, a few farmers were contacted and asked to participate in the interviews. They gave additional contacts of farmers who were also recruited in the interview process. Participants were all farmers who are growing their crops in the study area. Interviews were conducted through face-to-face conversations with farmers in order to gather information on irrigation practices, psychosocial perceptions, and context specifics. To avoid potential data loss, interviews were recorded and accurately transcribed afterward. Transcription was done manually by playing back the interview recordings and noting down the farmers' responses. The interview transcripts were subsequently turned into interview summaries for qualitative data analysis.

2.8.4 Interview analysis

Interviews were analyzed by the process of qualitative coding (Castleberry and Nolen, 2018). A combination of inductive (unstructured) and deductive (structured) approaches was used. The deductive approach meant that the interview transcripts were approached with predetermined (the RANAS

Figure 2.7: Interview conduction. (Photo by: S.Adla)

and the SSBC) frameworks and therefore the factors to be identified were known in advance. This was done for the purpose of validation of the RANAS framework. In order to explore additional information, the factors that farmers reported as relevant but could not match with concepts reported in the existing literature were also identified during the interview coding process. This was a part of the inductive approach.

While deductive analysis allowed for the validation of the regression results, inductive analysis was able to produce more nuanced findings, unexpected findings from the regression analysis, and additional factors farmers believe might influence the dependent variable, i.e. micro irrigation adoption. Using the field insights, the potential limitations of the regression model were subsequently addressed in the discussion chapter.

2.9 Comparative analysis between the regression results and the insights gathered from interviews

The regression model was created to show which factors can and which factors cannot explain the adoption of irrigation systems and provide valuable quantitative insights. The interview data was analyzed alongside the regression results to gather qualitative information that may shed light on the interpretation and understanding of the regression findings in relation to the adoption of sprinkler and drip (micro) irrigation systems. The qualitative interview results are used here to validate (contrast or complement) the findings obtained from the regression results. The combination of regression analysis and interview data enabled the validity and reliability of the regression results. Additionally, it revealed the factors that are important in explaining the irrigation adoption behavior that were not identified in the theory. The analysis was done in the following way:

1. The validity of the regression results, i.e. the factors that were identified as statistically significant in the regression analysis were assessed by checking whether these factors were also mentioned and recognized as relevant during the interviews. The following factors were identified: first, the factors significant according to regression results and mentioned as relevant to the adoption in the interviews. Second, the factors significant according to regression results but not mentioned as relevant to the adoption in the interviews.
2. Factors that were relevant according to the interview participants but did not appear as significant results in the regression model.

Chapter 3

Results

3.1 New mapping of RANAS and SSBC factors

In this section, the results of the factor pairing are shown in Table 3.1.

Table 3.1: The theoretical pairing of the RANAS factors (Mosler, 2012) and the SSBC (Bamberg, 2013) factors. Each pair represents factors that have the same meaning or contribute to the understanding of a particular model construct.

RANAS factor/sub-factor	SSBC factor
Risk / Perceived severity Risk / Perceived vulnerability Risk / Factual knowledge	Awareness of consequences
Attitude / Affective beliefs	Emotions anticipated with the goal process
Norms / Descriptive norm	Social norm
Norms / Injunctive norm	-
Norms / Personal norm	Personal norm
-	Ascription of responsibility
-	Negative emotions associated with consequences
-	Perceived goal feasibility
Goal intention	
Attitude / Instrumental beliefs	Attitude towards the alternative behaviours
Ability / Self-efficacy	Perceived behavioral control over alternative behaviors
Behavioral intention	
Ability / Action knowledge	Cognitive planning
Ability / Maintenance self-efficacy	Maintenance self-efficacy
Self-regulation / Action planning	Action planning
Self-regulation / Coping planning	-
Implementation intention	
Ability / Recovery self-efficacy	Recovery self-efficacy
Self-regulation / Remembering	-
Self-regulation / Commitment	-
New behavior	

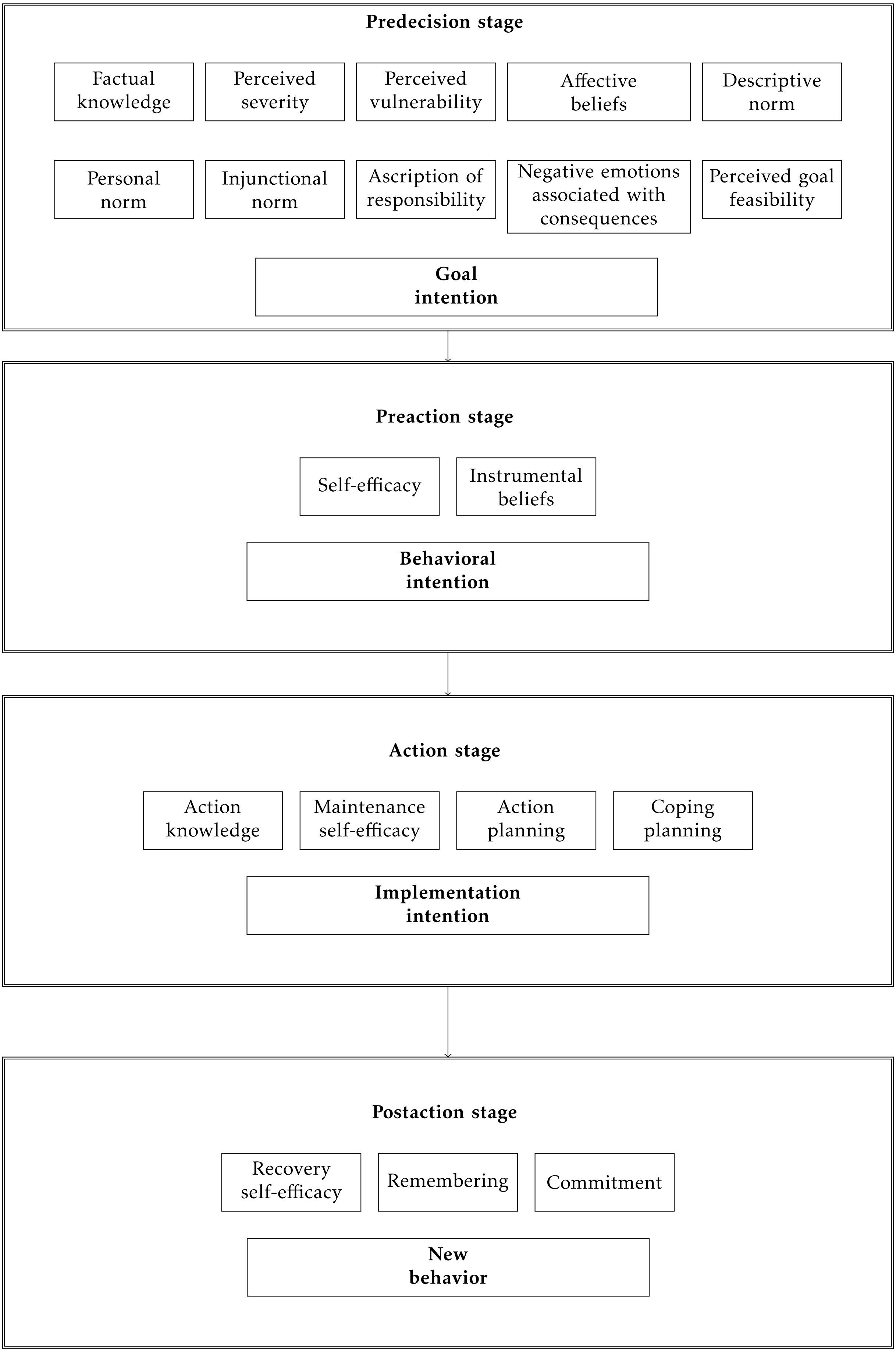

Figure 3.1: New mapping of the RANAS and the SSBC factors across four qualitatively different stages of behavior change process: a schematization of the mixed factors in each of the stages

By looking at Table 3.1, it can be observed that the SSBC is sometimes more comprehensive (factors "Ascription of responsibility", "Negative emotions associated with consequences", and "Perceived goal feasibility"). The RANAS is more comprehensive in one case (factor "Coping planning") and sometimes more detailed (through sub-factors of "Risk").

In order to answer the question of whether the SSBC and the RANAS frameworks appear to cover all the factors relevant to the specific context of micro irrigation adoption, this collection of factors was compared to the factors identified from the interviews.

3.2 Descriptive statistics

The survey collected data from 419 respondents. After removing the data with missing values and outliers, the final data set consisted of 354 points, indicating a data loss of approximately 15 %.

3.2.1 Contextual factors

Out of the analyzed respondents, 348 were male and 6 were female. The mean age of farmers was 49 years old (standard deviation (SD) = 13 years), with a minimum age of 21 and a maximum age of 80 years. Most farmers completed the tenth and twelfth levels of education. The average size of the land area owned is 6.55 acres (SD = 7.51 acres), while the average total annual income is 284042 rupees (SD = 273285 rupees). Farmers owned 3 livestock (cows, goats or bulls).

The descriptive statistics results also showed that almost a third, i.e. 99 farmers have no irrigation technology, i.e. they rely only on rainfall as the water input for their crops. Out of the farmers that reported that they use some kind of an irrigation system, 74% of farmers use sprinkler irrigation systems, 15% of farmers use drip irrigation systems, 9% of farmers use furrow irrigation systems, while less than 2% use other kinds of irrigation systems. The distribution of irrigation systems across farmers is shown in Figure 3.2 below. By visualizing this data, it can be observed that sprinkler irrigation systems are the most popular among farmers.

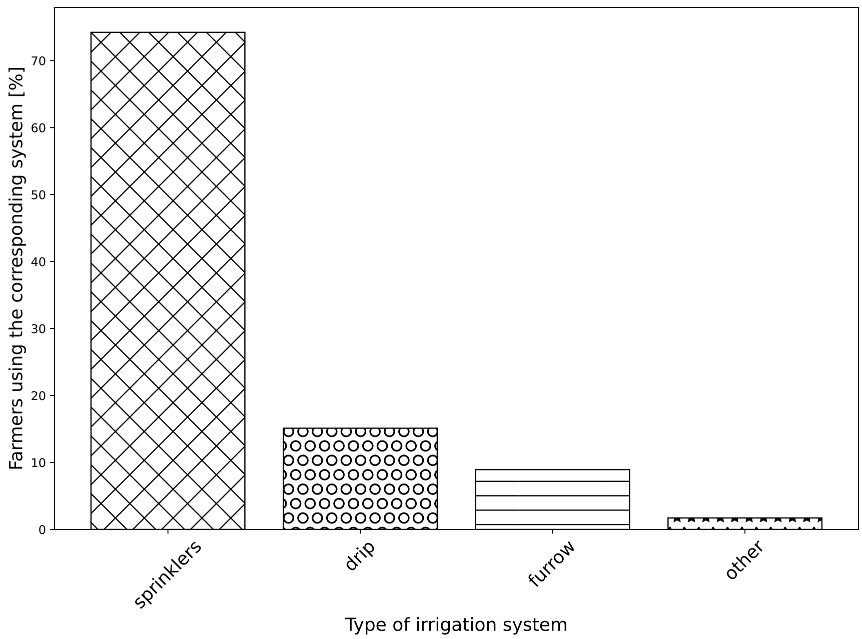

Figure 3.2: The percentage of farmers that use a specific irrigation system. The x-axis displays the different irrigation systems being considered, while the y-axis represents the percentage of farmers who use the respective system. The height of each bar corresponds to the proportion of farmers using the indicated irrigation method.

3.2.2 RANAS factors

The descriptive statistics (mean and standard deviation) of the RANAS sub-factors can be found in Table 3.2. The RANAS factors were assessed using a categorical Likert scale ranging from 1 to 5, where 1 represents the most negative sentiment and 5 indicates the most positive sentiment regarding specific RANAS sub-factors.

Table 3.2: The descriptive statistics (mean and standard deviation) of the RANAS sub-factors

Determinant factor	Factor name	Mean	SD
Risk	Met water demand	3.25	1.06
	Confidence of having enough water in the future	2.50	0.99
	Severity of impact without water for crops	1.38	0.79
	Responsibility for water source	1.49	0.52
Attitude	Extra effort taken for irrigation	2.08	0.62
	Extra effort taken for micro irrigation	2.59	0.99
	Difference in productivity achieved by irrigation	3.12	1.06
	Difference in productivity achieved by micro irrigation	3.56	0.96
	Willingness to pay	2.08	0.54
Norms	Proportion of people using micro irrigation systems	2.91	0.98
	Others' approval	4.30	1.00
	Importance of efficient use of irrigation water	4.67	0.56
Abilities	Confidence in buying and maintaining micro irrigation system	4.51	0.64
	Confidence in installing micro irrigation system	4.50	0.67
	Confidence in operating micro irrigation system	4.49	0.68
	Extra time taken for irrigation	2.06	0.59
	Extra time taken for micro irrigation	2.65	0.99
	Difficulty to get water in the last 10 years	2.67	0.92
Self-regulation	Limit of water shortage withstanding	3.98	0.65

The results were obtained using the mean values and the Likert scale from the questionnaire for the interpretation. Based on the obtained average scores, farmers perceive that their water supply adequately meets their water demands. However, they lack confidence in securing sufficient water in the future, and they view the consequences of water scarcity for their crops as highly severe. Additionally, farmers believe that they are responsible for their water sources. Regarding farmers' attitudes, they believe that putting more effort into irrigation is necessary, but they do not anticipate a significant increase in yield. They are willing to pay a small amount, primarily with the help of subsidies, to implement an irrigation system on their farms. A considerable portion of farmers already utilize irrigation systems, and the majority of them support its adoption. Water conservation in irrigation practices has great importance to them. Farmers are self-confident in their abilities, feeling very confident in their ability to buy and maintain, to install, and to operate a micro irrigation system. This indicates that their skills are not a concern. They perceive that using irrigation (compared to relying solely on rainfall) takes more time, and the use of micro irrigation (compared to furrow irrigation) requires nearly the same amount of time. Over the past 10 years, obtaining water for farming has not become more challenging. In the event of a water shortage, they estimate they could withstand a crop loss of 25%.

3.3 Identification of influential factors for adoption of different irrigation systems using binary logistic regression model

The results from the binary logistic regression models are presented in this section. Contextual and the RANAS factors were included as the independent variables because they were assumed to have a predictive capability on irrigation adoption behavior. The RANAS factors, as listed in Table 2.2 were included on the sub-factor level. Four models were created, each customized to the use of a specific irrigation system as the behavioral outcome and as defined in the subsection 2.6.1. With identical independent variables, four different models were created by altering the dependent variable or the outcome, i.e. the irrigation system used.

The first model explored the factors influencing the overall uptake of irrigation systems (farmers who depend solely on rainfall were distinguished from those who do not). The second model focused on the factors influencing the adoption of furrow irrigation systems (farmers who either use the traditional furrow systems or depend on rainfall were distinguished from those who use micro irrigation systems). The third model explored the factors influencing the adoption of sprinkler irrigation systems, and lastly, the fourth model explored the factors influencing the adoption of drip irrigation systems.

The idea behind creating four models was to gain a deeper understanding of the influential factors of the uptake of different irrigation systems while overcoming the issue of analyzing multiple behavioral alternatives. Even though all the alternatives are related to the process of irrigation, they can still be considered distinct behaviors. This is because the diverse characteristics of different systems impact the decision-making process of farmers in different ways (Hatch et al., 2022). The scenario approach allowed for the comparative analysis of factors across different systems and helped avoid generalizing the results.

The forthcoming section presents tables with results for statistically significant regression factors which are likely to have a real effect (Bruce et al., 2020) (at a confidence level alpha = 5%). Therefore, the discussion will also be based on these factors. The complete regression tables can be found in Appendix C. Tables indicate the contextual and the RANAS factors as "Term" and contain their impact on the odds ratio of the observed event of interest (adoption of a certain type of irrigation system) in case a predictor variable is increased for one unit. The impact is presented in various formats, which are: β estimate, odds ratio (OR), p-value, and percentage (%) change of likelihood of the adoption, which presents a sensitivity analysis. The percentage (%) change is calculated as (OR - 1) * 100 [%] and is positive for the positive β estimates.

The changes in the outcome (dependent variable) in the logistic regression model are normally reported as the change in outcome per one unit change of the independent variable. However, the independent variables were scaled in the preprocessing of the data. Scaling entailed transforming a variable to a z-score, i.e. to a variable with a mean of 0 and a standard deviation of 1. This was done to better understand the magnitudes and impacts of variables that have different units and scales. Consequently, the interpretation of the coefficients changed and the changes were reported as changes in outcome associated with one standard deviation change in the independent variable. This means that one unit change of the scaled variable corresponded to one standard deviation change in the original variable.

The results for four outcomes are included in the following tables: Table 3.3 (uptake of irrigation systems overall), Table 3.4 (uptake of furrow irrigation systems), Table 3.5 (uptake of sprinkler irrigation systems), and Table 3.6 (uptake of drip irrigation systems). The corresponding stage of change is indicated for every factor. The goodness-of-fit measure of every model is estimated by its pseudo R^2 value. The regression results are based on 354 observations, after removing the missing data.

Table 3.3: Logistic regression results of influential factors for the adoption of irrigation systems: weight coefficients, odd ratios, p-values and percentages of likelihood change (Pseudo R^2 = 0.248)

Term	β estimate	OR	p-value	% change	Stage
Education level category [1] (β_1)	1.55	4.73	0.047	372.7	-
Education level category [6] (β_2)	2.34	10.40	0.037	940.3	-
Land area size (β_3)	1.18	3.25	0.007	225.5	-
Met water demand (β_4)	0.55	1.73	0.000	72.9	Predecision (1)
Confidence of having enough water in the future (β_5)	0.47	1.60	0.016	59.8	Predecision (1)
Difference in productivity achieved by micro irrigation (β_6)	0.38	1.46	0.016	46.1	Preaction (2)
Difficulty to get water in the last 10 years (β_7)	0.53	1.70	0.005	70.4	Postaction (4)
Pseudo R^2	0.248				

The results indicate that among contextual factors, education level and land area size significantly influence the adoption of irrigation systems. Higher education levels and larger farming areas correspond to a 940.3% and 225.5% increase in the likelihood of adoption, respectively. Moreover, a positive shift in farmers' perception of severity and vulnerability means that they perceive they are less susceptible to the risks of water scarcity and other climate change effects and leads to a 72.9% and 59.8% higher likelihood of adopting irrigation systems. Additionally, perceiving a substantial increase in productivity achieved by micro irrigation increases the likelihood of adoption by 46.1%. Furthermore, as the perceived difficulty in accessing water decreases, reflecting stronger recovery self-efficacy among farmers, the likelihood of adoption increases by 70.4%.

Table 3.4: Logistic regression results of influential factors for the adoption of **furrow irrigation systems**: weight coefficients, odd ratios, p-values and percentages of likelihood change (Pseudo R^2 = 0.474)

Term	β estimate	OR	p-value	% change	Stage
Number of family members (β_1)	-1.15	0.32	0.039	-68.3	-
Met water demand (β_2)	1.52	4.56	0.002	356.3	Predecision (1)
Proportion of people using micro irrigation systems (β_3)	-1.34	0.26	0.001	-73.9	Predecision (1)
Confidence in buying and maintaining micro irrigation system (β_4)	-1.52	0.22	0.027	-78.1	Action (3)
Confidence in installing micro irrigation system (β_5)	-1.88	0.15	0.026	-84.7	Action (3)
Confidence in operating micro irrigation system (β_6)	2.95	19.10	0.018	1809.6	Action (3)
Limit of withstanding water shortage (β_7)	0.62	1.86	0.029	86.0	Action (3)
Pseudo R^2	0.474				

As far as the adoption of furrow irrigation systems is concerned, the likelihood of adoption decreases by 68.3% with an increase in the number of family members. Furthermore, a less severe perception of how the water supply meets the water demand leads to a significant increase of 356.3% in the likelihood of adopting furrow irrigation systems. A higher proportion of people perceived to be using micro irrigation systems decreases furrow system adoption by 73.9%. Regarding abilities, an increased confidence in buying and maintaining micro irrigation systems reduces adoption likelihood by 78.1%. Similarly, increased confidence in installing a micro irrigation system decreases adoption likelihood by 84.7%. However, higher confidence in operating a micro irrigation system drastically increases furrow system adoption by 1809%. Finally, stronger coping planning described by an increased limit of withstanding water shortage leads to an 86% increase in the likelihood of adoption.

Table 3.5: Logistic regression results of influential factors for the adoption of **sprinkler** irrigation systems: weight coefficients, odd ratios, p-values and percentages of likelihood change (Pseudo R^2 = 0.251)

Term	β estimate	OR	p-value	% change	Stage
Land area size (β_1)	0.68	1.98	0.016	98.4	-
Confidence of having enough water in the future (β_2)	0.38	1.46	0.027	46	Predecision (1)
Proportion of people using irrigation systems (β_3)	0.41	1.51	0.011	50.8	Predecision (1)
Personal importance of saving water in irrigation (β_4)	0.35	1.42	0.044	42.4	Predecision (1)
Confidence in buying and maintaining micro irrigation system (β_5)	0.84	2.32	0.009	132.3	Action (3)
Difficulty to get water (β_6)	0.64	1.89	0.000	88.7	Postaction (4)
Pseudo R^2	0.251				

As far as the adoption of sprinkler irrigation systems is concerned, an increase in land area size results in a 98.4% increase in adoption likelihood. A perceived decrease in vulnerability about future water availability leads to a 46% increase in likelihood. A higher proportion of people using micro irrigation systems, indicating a strong descriptive norm, corresponds to a 50.8% increase in likelihood. The personal norm emphasizing the importance of saving irrigation water has a positive impact on adoption, with a 42.2% increase. Confidence in buying and maintaining micro irrigation systems has the largest impact, with a 132.3% increase in likelihood. Lastly, as the perception of access to water becomes easier (strong recovery self-efficacy), the adoption rate increases by 88.7%.

Table 3.6: Logistic regression results of influential factors for the adoption of **drip** irrigation systems: weight coefficients, odd ratios, p-values and percentages of likelihood change (Pseudo R^2 = 0.265)

Term	β estimate	OR	p-value	% change	Stage
Difference in productivity achieved by micro irrigation (β_1)	0.48	1.61	0.046	61.4	Preaction (2)
Confidence in buying and maintaining micro irrigation system (β_2)	-1.23	0.29	0.003	-70.9	Action (3)
Pseudo R^2	0.265				

The adoption of drip irrigation systems is influenced by a minimal number of factors, where none of them is contextual. Firstly, a strong perception of the productivity increase achieved by micro irrigation positively impacts the adoption of drip irrigation systems, leading to a 61.4% increase in the likelihood of adoption. Conversely, an increase in confidence regarding buying and maintaining a micro irrigation system decreases the likelihood of adopting drip systems by 70.9%.

3.4 Checking for endogeneity and reverse causality effects using IV approach: two-stage regression model results

Prior to doing two-stage regression, the validity of the instrument variables (IVs) was checked by checking the assumptions of a "good instrument": The assumption (1) of relevance, i.e. strong correlation of IVs with RANAS (sub-)factors was checked in the following way: multiple linear regression analyses were performed by regressing all the IVs for each of the RANAS sub-factors. All the IVs were simultaneously used as predictors to predict the RANAS sub-factors, i.e. a total of twelve IVs for every RANAS sub-factor. The reason for including all the twelve instrumental variables (IVs) in the single prediction simultaneously was because in that case the highest possible R^2 value could be achieved. The guideline for determining a "good" correlation, with an R^2 threshold of 0.3, was adopted based on previous work (Daniel et al., 2022). If the R^2 value in the scenario when all the IVs were included in the prediction was below 0.3 (indicating a weak correlation with the instrumental variables (IVs)), the factor was considered to have no correlation with the IVs and was therefore excluded from the further analysis. The list of R^2 values obtained from the multiple linear regression of all IVs on each of the independent RANAS variables is shown in Table 3.7.

The results indicate that using multiple IVs as independent variables is necessary for predicting the RANAS sub-factors and enhancing the R^2 value between the observed and the predicted RANAS variables. It can be observed that only two RANAS sub-factors had an R^2 above 0.3 and could be considered in the second-stage regression: "Risk" sub-factor "Confidence of having enough water in the future" (R^2 = 0.380) and "Attitude" sub-factor "Difference in productivity achieved by irrigation" (R^2 = 0.351). However, despite its strong correlation with instrumental variables (IVs), the "Attitude" sub-factor "Difference in productivity achieved by irrigation" was also excluded from further analysis. This decision was based on the previous observation that this sub-factor did not appear to be significant in the "non-instrumentalized" regression (see that this factor does not appear in the tables that are showing significant logistic regression factors, i.e. tables: Table 3.3, Table 3.4, Table 3.5, and Table 3.6, making it irrelevant to the further analysis. The same holds for two sub-factors that had an R^2 that could be considered acceptable: "Extra effort taken for micro irrigation" (R^2 = 0.241) and "Extra time taken for micro irrigation" (R^2 = 0.230). However, they also did not appear to be significant in the "non-instrumentalized" regression and were therefore not considered in the further analysis.

The second assumption of (2) exogeneity of a valid instrument was fulfilled in the case of the "Risk" sub-factor "Confidence of having enough water in the future". When directly included in the logistic regression equation with other predictors, i.e. the contextual factors, the RANAS non-predicted sub-factors, and the predicted RANAS sub-factor "Confidence of having enough water in the future", IVs were not significant.

To do the first stage regression, all the IV factors were used. However, only the IV predictors that were found to be significant in the first stage of the prediction of "Risk" sub-factor "Confidence of

Table 3.7: Weighted multiple linear regression of all IVs on each of the independent RANAS variables

Variable	R^2
Confidence of having enough water in the next 5 years	**0.380**
Difference in productivity achieved by irrigation	**0.351**
Extra effort taken for micro irrigation	0.241
Extra time taken for micro irrigation	0.230
Importance of efficient use of irrigation water	0.198
Confidence in buying and maintaining irrigation system	0.198
Confidence in installing irrigation system	0.195
Confidence in operating irrigation system	0.190
Others approval	0.183
Difficulty to get water in the last 10 years	0.144
Proportion of people using irrigation systems	0.112
Severity of impact without water for crops	0.116
Met water demand	0.113
Responsibility for water source	0.079
Willingness to pay	0.034
Difference in productivity achieved by micro irrigation	0.052
Limit of water shortage withstanding	0.052
Extra time taken for irrigation	0.035
Extra effort taken for irrigation	0.031

having enough water in the future" were kept as the final set of predictors. They had positive correlations with "Confidence of having enough water in the future", which means that an increase in one variable is associated with an increase in the other variable. This indicates that as the positive affect of IVs increases, "Confidence of having enough water in the future" also increases. There were 4 significant instrument variables (see Table A.3 for the list of all considered factors): "Knowledge on water scarcity" and "Effectiveness of government drought relief measures" ("Risk"-related), "Knowledge on government irrigation policies" ("Norms"-related), and "Ease of reaching the local irrigation officer and getting work done" ("Ability"-related). One should note that the mapping of IVs to certain RANAS factors could be improved, as significant predictors of the sub-factor related to "Risk" are noted as "Risk"-related, "Norms"-related, and "Ability"-related.

The second stage of the two-stage regression analysis was similar to the logistic regression analysis but also included one predicted factor from the first stage. After the two-stage regression, the results from the previously performed standard ("non-instrumentalized") logistic regression were compared with the two-stage regression results for the adoption of different kinds of irrigation systems. Furrow and drip irrigation systems adoption was omitted from the two-stage regression because the predicted factor did not appear to be significant for the adoption of these two systems. Therefore, this quantitative regression analysis suggests that institutions do not impact the adoption of furrow and drip irrigation systems, as they influence factors that are irrelevant for their adoption. However, more support from the literature is needed in order to make a strong conclusion on this, as it may also be the RANAS limitation. All the variables except the "Confidence of having enough water in the future" were treated as exogenous in the two-stage regression analyses for the adoption of irrigation and sprinkler irrigation systems. "Confidence of having enough water in the future" was treated as an endogenous variable. Comparative results for the "non-instrumentalized" and "instrumentalized" (second-stage) logistic regression for the adoption of irrigation and sprinkler irrigation systems are shown in Table 3.8 and Table 3.9 below.

Table 3.8: Comparative results for the non-instrumentalized and instrumentalized (second-stage) logistic regression for the adoption of irrigation systems

	Coefficients in irrigation adoption			
	Non-instrumentalized		Instrumentalized	
Term	β	**p-value**	β_{inst}	**p-value**
Education category [1]	1.55	0.047	-	-
Education category [6]	2.34	0.037	-	-
Land area size	1.18	0.007	1.20	0.006
Met water demand	0.55	0.000	0.51	0.001
Confidence of having enough water in the future*	**0.47**	0.016	**0.69**	0.044
Difference in productivity achieved by micro irrigation	0.38	0.016	0.38	0.018
Difficulty to get water	0.53	0.005	0.47	0.013
Pseudo R^2	0.248		0.244	

Table 3.9: Comparative results for the non-instrumentalized and instrumentalized (second-stage) logistic regression for the adoption of **sprinkler** irrigation systems

	Coefficients in irrigation adoption			
	Non-instrumentalized		Instrumentalized	
Term	β	**p-value**	β_{inst}	**p-value**
Land area size	0.68	0.016	0.69	0.014
Confidence of having enough water in the future*	**0.38**	0.027	**0.83**	0.009
Proportion of people using irrigation systems	0.41	0.011	0.42	0.008
Others' approval	-	-	-0.36	0.044
Personal importance of saving water in irrigation	0.35	0.044	0.36	0.037
Confidence in buying and maintaining micro irrigation system	0.84	0.009	0.86	0.008
Difficulty to get water	0.64	0.000	0.62	0.000
Pseudo R^2	0.251		0.256	

It can be observed that Pseudo R^2 was reduced in the case of the adoption of irrigation systems overall, while it increased in the case of sprinkler irrigation systems adoption. This implies that more accurate results can be obtained by zooming in into a specific system, i.e. by narrowing down the scope of analysis. Additionally, the predicted factor "Confidence of having enough water in the future" was also significant in the second-stage regression for the adoption of both irrigation and sprinkler irrigation systems (see tables 3.8 and 3.9).

Based on tables 3.8 and 3.9, it becomes apparent that the impact of "Confidence in having enough water in the future" on the adoption of different irrigation systems was underestimated by the standard logistic regression. Specifically, the β values were 0.47 and 0.38 for irrigation and sprinkler irrigation systems, respectively. In contrast, the second-stage regression, where this variable was treated as an endogenous and controlled for by predicting new values using assigned IVs, yielded higher values of β: 0.69 (47 % higher) and 0.83 (118 % higher) for irrigation and sprinkler irrigation systems, respectively.

In case of the "instrumentalized" logistic regression, the most important factor (with the highest weight, i.e. largest β coefficient) changed in the case of irrigation systems adoption, while it stayed the same for the adoption of sprinkler irrigation systems. For the adoption of irrigation systems, the most important factor was the high education level. After controlling for the endogeneity effect, the size of land area became the most important factor, shifting relevance from knowledge towards the physical constraints. For the adoption of sprinkler irrigation systems, the most important factor is the RANAS sub-factor "Confidence in buying and maintaining micro irrigation system". The magnitude of the effect of the other significant factors did not drastically change by including the predicted endogenous variable.

The instrument variable approach found that "Confidence of having enough water in the future" is endogenous in irrigation and sprinkler irrigation adoption behavior and the endogeneity effect led to a biased estimation of the corresponding effect by 47 and 118 % for the adoption of irrigation and sprinkler irrigation systems, respectively.

All predictors positively influenced the adoption, both in the first and in the second stage regression, as shown by the positive coefficients. Therefore the only observed difference was in the magnitude of the effect. However, the exception was the "Norms" sub-factor "Others' approval" that was significant only in the second stage regression for the adoption of sprinkler irrigation systems. It was the only factor that had a negative influence on the outcome. Therefore, when controlling for bias of the sprinkler irrigation system adoption itself, how other people approve of using sprinkler irrigation systems impacts the likelihood of the adoption. If more people approve, the less the chance of adoption. Lastly, the influence of institutions is evident in the risk and normative perceptions, by the change of the effect magnitude and the significance.

3.5 Interview results. Field insights factors influencing the adoption of micro (drip and sprinkler) irrigation systems

As an attempt to broaden the understanding of the results from the regression analysis, qualitative data was collected in the form of interview recordings and turned into interview summaries afterward. A total of 20 farmers and 2 key informants were interviewed using a snowball sampling technique (described in 2.8.3) and analyzed using a qualitative coding process (described in 2.8.4).

The analysis was carried out taking into account the four stages of the behavior change and habituation process, and therefore the findings, i.e. the identified relevant factors will also be presented in alignment with those stages (see Figure 3.1 for the mapping of the stages). The results of the qualitative analysis are given below. The number of interviews where the factor was identified is included in the brackets. A visual matrix was created to list all the identified factors (along with their corresponding stage) against the interview number whenever a farmer mentioned the factor. The matrix can be found in Figure 3.3 below. Summaries of the interviews can be found in Appendix D.

3.5.1 Predecision stage (1)

In the predecision stage, a goal intention has to be formed so that a farmer can proceed to the stage of behavioral intention (Keller et al., 2019). Farmers expressed various goal intentions regarding their farming objectives, with each goal intention favoring a specific solution, indicated between "//":

1. **Water productivity /drip system/**
   Water productivity is defined as the amount of yield (biomass product) over the amount of consumed water (Van Halsema and Vincent, 2012):
   WP = [product]/[water consumed] = [yield or biomass]/[(evapo)transpiration] [kg/m^3].
   According to farmers, higher WP practically implies increasing yield with the available amount of water. Farmers perceive that it could be achieved by the precision of a drip irrigation system. The reason for increasing yield is to increase the income from farming (D.4, D.6, D.8, D.11, D.19, D.20).
2. **Water use efficiency /drip system/ sprinkler system/**
   Water use efficiency is defined as (Van Halsema and Vincent, 2012):
   WUE = [product]/[water applied/available] = [yield or biomass]/[water applied] [kg/m^3].
   According to farmers, higher WUE practically implies saving water while keeping the yield production stable (constant). It can also relate to one of the ways to deal with water scarcity: as the available amount of water becomes less, this could be a way to keep the amount of produced crops at a stable level (D.4, D.6, D.7, D.9, D.10, D.13, D.20).

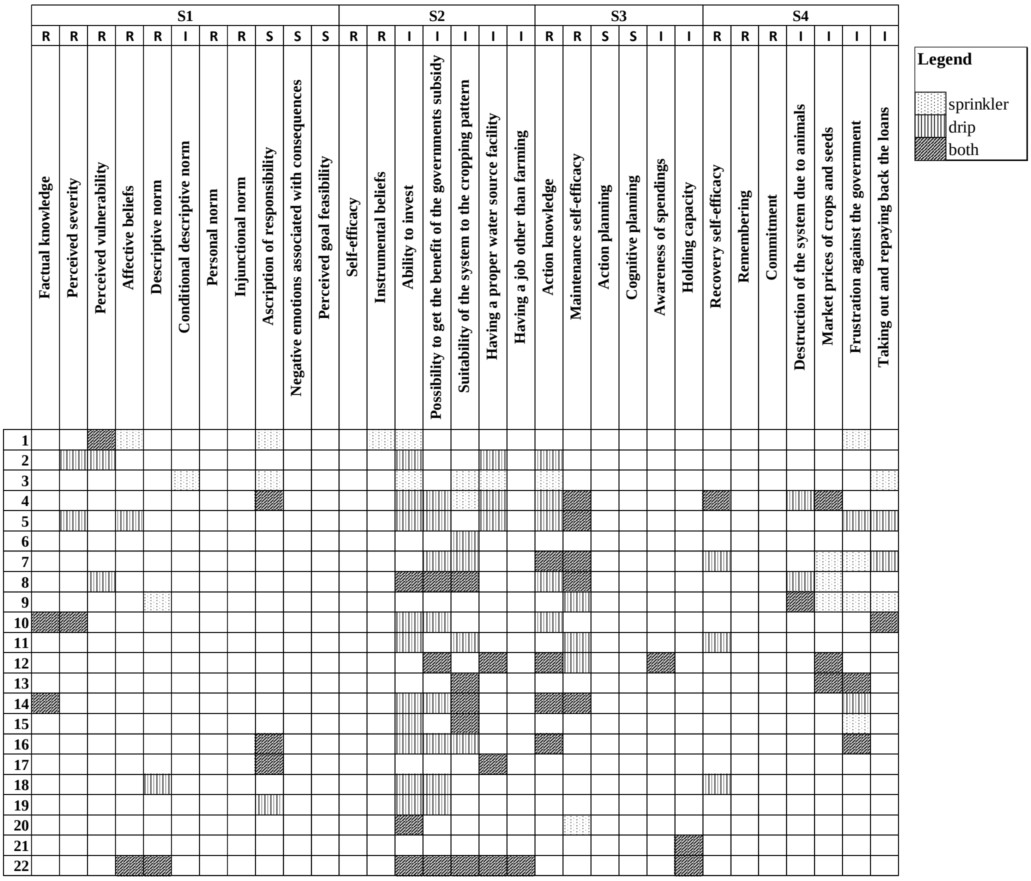

Figure 3.3: The matrix that represents the factors from qualitative coding against interviewee number. A cell contains a pattern if a farmer mentioned the corresponding factor as relevant during the interview. Three different patterns in cells indicate that the response was related to the use of drip, sprinkler, or both irrigation systems (as indicated in the Legend in the upper right corner). S1, S2, S3 and S4 indicate four stages of behavior change: predecisional, preactional, actional, and postactional, respectively. R indicates a factor that comes from the RANAS framework, I indicates the factor that was identified in the process of interview coding, and S indicates the factor that comes from the SSBC framework.

3. **Crop diversification /sprinkler system/**
   Farmers' reason for diversifying the crops grown on the farm is to reduce financial risks, i.e. to establish the certainty of profit (D.3, D.5, D.10). Crop diversification can be achieved by the coverage of a sprinkler system, they said. This is because sprinkler systems are able to distribute water over a large area, in comparison to a drip system that is delivering water directly to the root zone. In case when farmers want to plant more crop types, a drip system would need to be placed for every individual crop type, while a sprinkler system could cover more crops.
4. **Labour reduction /drip system/**
   This could be done by automatizing the process of irrigation. Additionally, fertilizers application could be done through the process of fertigation. The fertigation process is done by using a drip system that gives the fertilizers together with the irrigation water (D.5, D.8, D.10, D.11, D.13, D.14, D.19, D.20).
5. **Prevention of the crop damage /fencing/**
   This is another way to keep the yield stable (next to water efficiency). However, substantial financial resources are necessary to implement fencing around the farming area in order to provide physical protection against wild animals (D.6, D.7, D.8, D.9, D.10, D.13, D.14, D.15).
6. **Overcoming untimely rainfall /drip system/ sprinkler system/**
   As rainfall patterns become more unpredictable, farmers must discover ways to ensure the water supplies at all demand times, but also to avoid crop damage caused by untimely rainfall events (D.1, D.12).

Farmers with different goal intentions opt for different ways to achieve them.

The perceptional factors identified during the interviews that were relevant to the formation of goal intention are listed below. The indication of the magnitude of influence on the adoption of sprinkler or drip systems when the perception increases in the positive affect is provided within the brackets with positive and negative signs.

1. **Factual knowledge** (s+, d+): farmers are aware that micro irrigation systems are more efficient and are able to deal with water scarcity. In addition, they are aware of the negative impacts that changing climate has on farming (D.10, D.14).
2. **Perceived severity** (s+, d+): farmers who are aware of the impacts of less water availability report that they want to start using drip or sprinkler irrigation systems. This is to achieve crop productivity, i.e. increase the yield with the same (or less) amount of water available (D.2, D.5, D.10).
3. **Perceived vulnerability** (s+, d+): farmers who perceive themselves as vulnerable to changing climate report that they want to start using drip or sprinkler irrigation systems. They are aware of the negative impacts on their crop yields resulting from using the furrow irrigation method or depending solely on rainfall and develop a goal of achieving higher water productivity. The traditional methods fail to ensure stable yield production. This represents creating resilience through technology adoption (D.1, D.2, D.8).
4. **Affective beliefs** (s+, d+): farmers who feel pleasant about using an irrigation system are eager to adopt it (D.1, D.5, D.22).
5. **Descriptive norm** (s+, d+): farmers who see what the progressive farmers in the village are implementing and get to acquire some skills from working on the other farms decide to adopt the same kinds of irrigation technologies (D.9, D.18, D.22).
6. **Conditional descriptive norm** (s+): farmers will adopt the systems their neighbours or other farmers are using if there are observable achieved benefits by using that kind of a system (D.3).
7. **Ascription of responsibility** (s-, d-): farmers think that the government is responsible to provide them with proper facilities (primarily water sources, but also irrigation technologies). The perception that this is their own responsibility is low, sometimes resulting in farmers not taking any actions towards the adoption (D.1, D.3, D.4, D.16, D.17, D.19).

3.5.2 Preaction stage (2)

After the goal intention was formed, a farmer forms a behavioral intention as a way to reach his goal. However, the decision to consider the behavior depends on several factors listed below:

1. **Instrumental beliefs** (s+): farmers who are convinced that investing in the irrigation system is beneficial for their long-term farming and thus financial situation would be more likely to take efforts to adopt these systems (D.1).
2. **Ability to invest** (s+, d+): farmers who believe they are able to invest in buying an irrigation system would more likely implement it (D.1, D.2, D.3, D.4, D.5, D.8, D.10, D.11, D.14, D.15, D.16, D.18, D.19, D.20, D.22).
3. **Possibility to get the benefit of the governments subsidy scheme** (s+, d+): farmers who perceive that they could get the help from the government in the form of a subsidy for buying an irrigation system will more probably implement it (D.4, D.5, D.7, D.8, D.10, D.12, D.14, D.16, D.18, D.19, D.22).
4. **Suitability of the system to the cropping pattern** (s+, d+): farmers who think that a certain irrigation system is suitable for the crops they grow on their farms are more likely to get it (D.3, D.4, D.6, D.7, D.8, D.11, D.13, D.14, D.15, D.16, D.22).
5. **Having a proper water source facility** (s+, d+): farmers who have a water source to operate their irrigation technology or fulfill a pre-condition for the government subsidy application would be more likely to adopt a micro (drip or sprinkler) irrigation system (D.2, D.3, D.4, D.5, D.12, D.17, D.22).

6. **Having a job other than farming** (s+, d+): Farmers whose only job is farming show more risk-aversion towards taking the initial financial risk of adopting new technologies, as they have no financial buffer in case a situation fails. This is because in the process of adopting a new technology, there is not only a risk related to the stability of yields but also a challenge of finding a proper market to sell these new crops (D.22).

3.5.3 Action stage (3)

The identified factors important for implementation intention forming according to farmers are listed below:

1. **Action knowledge** (s+, d+): farmers who have knowledge of installing and maintaining a drip or sprinkler irrigation system are more likely to adopt it. This factor is not a problem for most farmers. This is because they obtained the required skills by having the systems on their own, or working on other farms (D.2, D.3, D.4, D.5, D.7, D.8, D.10, D.12, D.14, D.16).
2. **Maintenance self-efficacy** (s+, d+): first, farmers need to have the proper knowlegde and skills of maintaing the irrigation systems on the farm. Second, maintenance self-efficacy also entails financial aspects. High maintenance costs of a drip system are a problem for many farmers. Sprinkler systems are sometimes more favourable due to less maintenance costs, and fewer maintenance activities. Loans that farmers have in the bank negatively impact maintenance self-efficacy, as they cannot cope with the financial burden of maintaining irrigation systems on their own. Additionally, irregular supply of electricity also negatively influences this factor, because of which farmers are dependent on the local electricity suppliers for running their systems (D.4, D.5, D.7, D.8, D.9, D.11, D.12, D.14, D.20).
3. **Awareness of spendings** (s-, d-): some farmers are not maintaining records of how much they spend. The lack of financial planning can lead to financial loss and reduce their abilities to sustain their families and farms (D.12).
4. **Storage capacity** (s+, d+): farmers who have possibilities to store their crops are more flexible in terms of timing of the crop sale. This flexibility would allow them to sell the crops once the market rates are the most favorable. Working in a group of farmers, such as farmer producer companies could enhance this capacity and bring benefits to all the individuals in the group (D.21, D.22).

3.5.4 Postaction stage (4)

The identified factors for making new behavior a habit are listed below:

1. **Recovery self-efficacy** (s+, d+): farmers realize that irrigation systems can break down. In that case, those who find a way to fix it are strong in dealing with failures and coping with relapse. In additon, it may happen that a farmer does not see the long-term benefit of using the system, so he will only continue using it if he gets convinced that he benefits from it (D.4, D.7, D.11, D.18).
2. **Commitment** (s+, d+): farmers who believe that hard work is the reason of success commit themselves to dedicating attention to their crops. This is followed by dedicated and consistent use of irrigation systems to ensure the water to the crops. A farmer said about his dedication: I am working 24 hours in the field. No festivals for me (D.14).
3. **Destruction of the system due to animals** (s-, d-): farmers decide to stop using an irrigation system if the animals continuously destroy the system pipes. This was particularly reported as the case in using a drip irrigation system (D.4, D.8, D.9).
4. **Market prices of crops and seeds** (s-, d-): market prices and rates for which farmers sell their crops are decided by the government. It was reported that rates of products are the same for the last 10 to 12 years (D.7). However, insecticides, pesticides, seeds, labor, technology, and electricity prices rose. This means that the profit margin is reduced and farmers would not sustain their practices if they are facing financial loss and take loans for a longer period of time (D.4, D.7, D.8, D.9, D.12, D.13).

5. **Frustration against the government** (s-, d-): the strong frustration of farmers against the government has a negative consequence on the motivation of farmers to make any efforts for the adoption of irrigation systems. Furthermore, it results in the low level of trust, which further lowers farmers confidence in having hopes for the improvement of the farming situation (D.1, D.5, D.7D.9, D.14, D.15, D.16).
6. **Taking out and repaying back the loans** (s-, d-): farmers who need money for farming inputs and their living situation usually take out loans. This is followed by the loan repayment, on which they get an interest rate. This creates a debt trap which can sometimes result in a farmer not being able to pay the loan back anymore. This consequently has a very negative psychological impact on a farmer and can have catastrophic consequences (D.3, D.5, D.7D.9, D.10).

The summary above is a result of the interview coding process and therefore contains all the factors reported as relevant by farmers. The following section will present a comparative analysis of the factors that are statistically significant and practically relevant. This analysis aims to ensure the validity of the results' interpretation.

3.6 Results of the comparative analysis

The comparative analysis was done with an intention to validate the regression results by examining the consistency between factors identified as statistically significant in the regression analysis and those recognized as practically relevant during the interviews. Furthermore, factors that were relevant according to the interview participants but did not appear as significant results in the regression model were also identified.

3.6.1 The validity of regression results

In this section, the validity of the regression results was checked for the adoption of sprinkler and drip irrigation systems. Table 3.10 below shows a list of significant regression factors for the adoption of sprinkler irrigation systems (as already shown in Table 3.5) and indicates whether those factors were also mentioned as relevant during interviews.

Table 3.10: Comparison of the influential regression factors for sprinkler irrigation system adoption with interview relevance. The column "Interviews" indicates whether these factors were recognized as important according to interview participants. The number included in the brackets indicates how many (out of 22 in total) respondents mentioned the factor as relevant

Term	RANAS sub-factor	Interviews
Land area size	Contextual	no (0)
Confidence of having enough water in the future	Perceived vulnerability (R)	yes (1)
Proportion of people using irrigation systems	Descriptive norm (N)	yes (2)
Personal importance of saving water in irrigation	Personal norm (N)	no (0)
Confidence in buying and maintaining irrigation system	Maintenance self-efficacy (Ab)	yes (6)
Difficulty to get water	Recovery self-efficacy (Ab)	yes (1)

It can be observed that factors "Confidence of having enough water in the future" (Perceived vulnerability), "Proportion of people using irrigation systems" (Descriptive norm), "Confidence in buying and maintaining irrigation system" (Maintenance self-efficacy), and "Difficulty to get water" (Recovery self-efficacy) were both significant in the regression results and relevant in the interview results. The alignment between the regression analysis and interview findings strengthens the reliability of the identified influential factors, as they are supported by both quantitative and qualitative evidence.

The factors that were significant according to the regression results, but were not mentioned by farmers were "Land area size" and "Personal importance of saving water in irrigation" (Personal norm). The absence of these factors in the interviews raises questions about the practical importance. This identified discrepancy highlights the need for checking the predictive capability of these factors in the future. Interview findings reveal that the land area size in practice does not have an effect on the adoption of sprinkler irrigation systems because farmers with various farm sizes have adopted and want to adopt these systems. The bigger concern when it comes to the contextual factors is the financial situation of a farmer, as will be further shown in the text. Personal norms turned out to be irrelevant according to farmers' responses, indicating the absence of moral questions in relation to technology adoption.

The validity of the regression results was checked for the adoption of drip irrigation systems the same way as it was done for the sprinkler irrigation systems. Table 3.11 below shows a list of significant regression factors for the adoption of drip irrigation systems (as already shown in Table 3.6) and indicates whether those factors were also mentioned as relevant during interviews.

Table 3.11: Comparison of the influential regression factors for drip irrigation system adoption with interview relevance. The column "Interviews" indicates whether these factors were recognized as important according to interview participants. The number included in the brackets indicates how many (out of 22 in total) respondents mentioned the factor as relevant

Term	RANAS sub-factor	Interviews
Difference in productivity achieved by micro irrigation	Instrumental beliefs (At)	no (0)
Confidence in buying and maintaining irrigation system	Maintenance self-efficacy (Ab)	yes (8)

It can be observed that the regression results show only two factors that can explain the adoption of drip irrigation systems: "Difference in productivity achieved by micro irrigation" (Instrumental beliefs) and "Confidence in buying and maintaining irrigation system" (Maintenance self-efficacy). Out of these two factors, only "Maintenance self-efficacy" was both significant in the regression results and relevant in the interview results.

However, the factor "Difference in productivity achieved by micro irrigation" was not mentioned among interview participants as the one relevant for the adoption of drip irrigation systems. The reason for this was identified as ability to invest that outweighs the importance of perceived costs and benefits when it comes to the barriers to adopt drip irrigation systems.

3.7 The additional factors that have the predictive capability on irrigation adoption behavior

Besides the factors that were common to the regression modeling, additional relevant factors reported by interviewees are presented in this section. Table 3.12 below shows the factors identified as relevant for the adoption of sprinkler irrigation systems, while Table 3.13 shows the factors identified as relevant for the adoption of drip irrigation systems.

Table 3.12: Identified additional influential factors for sprinkler irrigation system adoption. The number in brackets next to the factor name indicates the number of interviewees who mentioned the factor as a relevant one. As a rule of thumb, the factors that were mentioned at least among 5 respondents were considered relevant

Factor	Origin
Suitability of the system to the cropping pattern (7)	Interviews
Market prices of crops and seeds (6)	Interviews
Frustration against the government (6)	Interviews
Ascription of responsibility (5)	SSBC
Ability to invest (5)	Interviews
Action knowledge (5)	RANAS

It can be noticed that field insights identified 6 additional factors that can explain sprinkler irrigation technology adoption. "Suitability of the system to the cropping pattern", "Market prices of crops and seeds", "Frustration against the government", and "Ability to invest" were not identified in the theory, but were newly identified factors from the interviews. All of these factors are reflecting the local context and circumstances in which the study was conducted. "Suitability of the system to the cropping pattern" is pointing toward the existence of the opportunity to use a certain irrigation system. The opportunity factor has not been discussed in the RANAS or the SSBC frameworks, but it has been discussed in (Michie et al., 2011) as the factor that lies outside the individual and makes the behavior possible. Furthermore, "Frustration against the government" may be relevant because it is related to the low trust in institutions or responsible water authorities, and has been discussed in (Contzen et al., 2023). In addition to the 4 factors mentioned above, one factor defined by the SSBC framework was also identified as one with a predictive capability: "Ascription of responsibility". Lastly, one RANAS factor was also identified: "Action knowledge".

Table 3.13: Identified additional influential factors for drip irrigation system adoption. The number in brackets next to the factor name indicates the number of interviewees who mentioned the factor as a relevant one. As a rule of thumb, the factors that were mentioned at least among 5 respondents were considered relevant

Factor	Origin
Ability to invest (13)	Interviews
Possibility to get the benefit of the governments subsidy scheme (11)	Interviews
Suitability of the system to the cropping pattern (9)	Interviews
Action knowledge (9)	RANAS
Having a proper water source facility (6)	Interviews

As far as the adoption of drip irrigation systems is concerned, field insights identified 5 additional factors that can explain the drip irrigation technology adoption, out of which 4 were not identified in the theory: "Ability to invest", "Possibility to get the benefit of the government's subsidy scheme", "Suitability of the system to the cropping pattern", and "Having a proper water source facility". Despite not being explicitly recognized in the literature, these factors might all be related to opportunity and capability factors (Michie et al., 2011). In addition to these 4 factors, one factor defined by the RANAS framework was also identified as one with a predictive capability: "Action knowledge".

Identified additional factors reflect the limitations of the constructed model to capture all the relevant predictors of micro irrigation technology adoption. The factor "Action knowledge" represents the limitation of the logistic regression model, as it already exists in the RANAS framework, while the factors that were identified by the SSBC and found in the interviews represent the limitations of the RANAS framework itself. The explanation of the context in which these factors were identified will follow in Chapter 4 (Discussion).

3.8 Descriptive statistics: average land area, total annual income, livestock count, and willingness to pay

"Ability to invest" was the factor identified as critical for the adoption of micro, especially drip irrigation systems (mentioned by 13 respondents). As a quantitative support for the validity of this factor and its influence, the descriptive statistics of survey data for average wealth indicators were calculated, assuming that farmers who are well-off are able to invest, and therefore adopt drip and sprinkler irrigation systems at a higher rate. The wealth indicators of farmers are the land area, total annual income, and livestock count (Hatch et al., 2022), so the descriptive statistics were analyzed for farmers who adopted, and farmers who did not adopt certain irrigation systems. Furthermore, perceptional factors, "Willingness to pay" and "Confidence in buying and maintaining a micro irrigation system" were also taken into account as the psychosocial reflection of the "Ability to invest". Table 3.14 shows the descriptive statistics for the wealth indicators for the adopters and non-adopters, while Table 3.15 shows the descriptive statistics for the perceptions that reflect the "Ability to invest" (the RANAS sub-factors "Willingness to pay" and "Confidence in buying and maintaining a micro irrigation system").

Table 3.14: The average land area in acres, total annual income in Indian rupees (INR) and livestock count, for adopters (indicated as "1") and non-adopters (indicated as "0") of various irrigation systems

System	Adopters	Area	Total annual income	Livestock
Irrigation	**0**	4.34	219616	2.2
	1	7.41	309054	3.3
Furrow	**0**	6.72	285577	3.0
	1	4.42	263840	2.6
Sprinkler	**0**	4.86	250138	2.3
	1	7.64	305703	3.4
Drip	**0**	5.87	271290	2.7
	1	11.39	373886	5.0

It can be observed that farmers who are adopters of all irrigation systems except furrow irrigation have, on average, larger farming areas, higher total annual income, and more livestock on their farms. This highlights the fact that adopters are often wealthier. The adopters of furrow irrigation systems are farmers who use exclusively these systems, while the non-adopters of furrow irrigation systems could either rely on rainfall, but also use micro irrigation systems. For this reason, it can be observed that people who have more economic capabilities are marked as "0" in the adoption of furrow irrigation systems.

Table 3.15: The average "Willingness to pay" and "Confidence in buying and maintaining a micro irrigation system", for adopters and non-adopters of various irrigation systems

System	Doers	Willingness to pay	Confidence in buying and maintaining a micro irrigation system
Irrigation	**0**	2.03	4.42
	1	2.10	4.55
Furrow	**0**	2.07	4.56
	1	2.20	3.88
Sprinkler	**0**	2.09	4.29
	1	2.07	4.66
Drip	**0**	2.06	4.50
	1	2.20	4.61

Farmers who are adopters are more willing to pay for an irrigation system in all the cases except for the sprinkler irrigation system. Adopters of drip and sprinkler irrigation systems also have higher confidence in buying and maintaining a micro irrigation system. This is not the case for the adoption for furrow irrigation systems, where adopters have lower confidence in buying and maintaining a micro irrigation system.

To summarize, the general pattern between the successful micro irrigation systems adoption and financial factors was found. Farmers who adopt drip or sprinkler irrigation systems are often well-off, more willing to pay and more self-confident in their abilities to buy and maintain a systems, compared to farmers who rely on furrow irrigation systems.

Chapter 4

Discussion

4.1 Key results interpretation

Based on the findings from the comparative analysis (described in 3.6), and due to the agreement between qualitative and quantitative findings, the following statements can be inferred about adoption:

I. **Farmers who are concerned with the availability of their water source and think that getting water is becoming more difficult lately may not adopt sprinkler irrigation systems.**

   To be able to start with irrigation, farmers need to have access to an adequate water source from which they can extract water for their irrigation needs. Therefore, the sufficient availability of water sources is an essential prerequisite for using irrigation systems on a farm and positively impacts the adoption of sprinkler irrigation systems both according to regression and interview results. The ways through which farmers can get water are surface water sources, or groundwater extraction (by drilling wells or borewells). Farmers who are aware of potential risks to their water supply may alter their decisions regarding the adoption of sprinkler irrigation systems. The awareness of potential risks and farmers' vulnerabilities in the form of difficulties for future water supplies for the farm therefore explains the decision of farmers to adopt sprinkler irrigation systems. Farmers who have confidence in their water supply have relatively lesser concerns about water scarcity. Therefore they are more likely to adopt sprinkler irrigation systems. This situation enables farmers to take advantage of improved water use efficiency. On the other hand, some farmers are worried, for example because while water is available, they cannot use it properly (D.1, and decide not to adopt sprinkler irrigation systems as a result. Furthermore, there is a feedback effect on how the adoption itself influences the perception of farmers confidence in having enough water in the future. Once the bias of the adoption itself is removed, it appears that the adoption rate was underestimated by more than double.

II. **Descriptive norms shape sprinkler irrigation adoption and influence farmers actions and choices.**

   As the number of farmers using sprinkler irrigation systems increases, the likelihood of adoption by others also increases, thus indicating a strong descriptive norm according to the regression model. This was confirmed in the interviews where farmers stated that they opt for using a certain irrigation system if they see and learn from the other, often progressive farmers. Furthermore, the increasing adoption of these systems by farmers leads to the reduction of the use of traditional furrow systems. However, only observing the practices of other farmers is insufficient for the adoption of drip irrigation systems. It is equally crucial for a farmer to have the financial capacity to invest in such systems. Additionally, the farmer's maintenance skills become a relevant factor in the drip irrigation adoption process. This can be observed through the significance of confidence in buying and maintaining an irrigation system that was confirmed in the interviews.

III. **Strong financial abilities and technical skills promote the adoption of sprinkler irrigation systems and relinquish traditional furrow irrigation methods.**

Farmers who believe they can invest in and maintain a sprinkler irrigation system become less doubtful about their financial abilities and technical skills. The adoption of sprinkler irrigation systems is more likely once a farmer is self-confident in these abilities. In cases when they become more confident about practicing the novel systems, they may choose to stop using furrow systems and transition to more productive irrigation methods. This is followed by relinquishing furrow irrigation systems once they become confident in installing and operating more efficient sprinkler irrigation systems.

IV. **A farmer's perception of ease of access to water over the past decade influences their perception of how well they are equipped to deal with setbacks or relapses.**

If this perception is positive, they also perceive they can get more benefits out of farming, according to regression results. This is particularly important for the long-term continuation of the sprinkler irrigation practice, as the factor "Difficulty to get water" is mapped to the postaction (4) stage. It was observed in the interviews that a farmer with a weak perception of recovery self-efficacy stopped with farming (D.4).

V. **Farmers' confidence in their abilities to buy and maintain an irrigation system, i.e. their maintenance self-efficacy affects the adoption of drip irrigation technology.**

Economic conditions are a pre-requirement for a farmer to adopt a drip irrigation system. Subsequently, once he has adopted it, he must know how to maintain it, but also he must keep up with high maintenance costs. Therefore the abilty that refers to maintenance self-effiacy was shown both in regression outcomes and interview insights as a very relevant factor to the adoption of drip irrigation systems.

VI. **Farmers who adopt drip or sprinkler irrigation systems are often more well-off than the ones who adopt furrow irrigation systems**

As shown by the indicators of wealth for the analysis of adopters vs. non-adopters, the adopters of micro irrigation systems are often more wealthy than the adopters of furrow irrigation systems. This was confirmed by the interview respondents. Establishing evidence of causality, however, will require more work.

4.2 Interpretation of the additional factors identified in the field

4.2.1 Market prices of crops and seeds

Farmers need to sell their crops on the market in order to generate profit. Despite the amount of crops they produce, the profit is still dependent on the market price which they can get for selling their crops. This highlights that the benefits are only achieved if farmers have both sufficient crop production and sufficiently high selling price, which requires the ability to store their post-harvest produce.

4.2.2 Ascription of responsibility

Farmers who believe that getting proper facilities, such as water sources or irrigation systems for their farms is not their own, but the government's responsibility, often take no effort towards the adoption.

4.2.3 Action knowledge

Farmers who have enough knowledge on the use of micro irrigation systems, such as how to install and operate the system, are more likely to implement it.

4.2.4 The influence of the ability to invest, the process of subsidizing, the availability of water source facilities and farmers' frustration against the government on micro irrigation technology adoption

In this section, the mutual influence of factors "Ability to invest", "Possibility to get the benefit of the government's subsidy scheme", "Having a proper water source facility", and "Frustration against the government" will be described by describing the subsidizing process. All the insights were gathered through the interviews.

Farmers who are able to invest in (afford) micro irrigation systems are among the few farmers in Maharashtra state who have adopted it. The government has created a subsidy scheme to give some benefits to the farmers in adopting micro irrigation systems (Ministry of Agriculture and Farmers' Welfare, Government of India, 2018). The process of applying for a subsidy, however, requires a farmer to make a significant effort in dealing with administration and initially falls under their own financial responsibility. This practically means that a farmer is required to pay the entire amount in the beginning and is reimbursed only after a few months. Additionally, it is time-consuming and has no assurance that a farmer will get any benefits. This is because the subsidies are given through the lottery system. Farmers who do not have the ability (capital) to invest cannot get the benefit of the scheme. "The whole process of micro irrigation technology adoption is meant for the farmers who can invest a lot. Schemes, unfortunately, do not work for the poor farmers (D.22)". The ones who can invest still need to make efforts. Furthermore, to be able to apply for the government's subsidy, a farmer needs to have a water source (e.g. an open well or a farm pond), otherwise, they are not eligible for the application process. Thus farmers who cannot invest in digging a well cannot even apply for the subsidy. If farmers want the government's help in digging a well, they need to have at least 3 acres of farming area, so in that case they are conditioned upon the size of their land area.

If a farmer potentially gets the subsidy, they need to alter the field to be barren, i.e. they need to empty the field at any given time it is required of them. This is so that the irrigation officer could come and install the irrigation system. However, farmers are mentally prepared for the financial year, and it is very hard to deviate spontaneously from their plans and practices since it brings risks of yield loss. This uncertain, effortful, and complicated process, combined with low trust in governmental institutions, results in the reluctant mindset of a farmer toward the adoption of micro irrigation systems. The flowchart describing the subsidizing process and identified perceptions of farmers related to each of the steps is described in Figure 4.1.

The ability to invest indirectly influences the perception of the possibility to benefit from the government's subsidy scheme and the perception of the possibility to apply for getting the water well (which is a pre-requirement for a farmer to apply for the subsidy for a drip or sprinkler irrigation system). In this way, the ability to invest both directly and indirectly determines if a farmer proceeds from the preaction (2) to the action (3) stage. Even though they may have a behavioral intention to use micro irrigation systems, they would not be able to move on to the implementation intention without at least some financial capacity. This process shows that mainly ability to invest, but also perceived ease, perceived certainty, and perceived motivation and self-confidence play a role in how ready farmers are to make efforts in order to get benefits, which ultimately is the use of sprinkler or drip irrigation systems. They reflect the instrumental beliefs of farmers about the process to obtain a subsidy, which is a key step in micro irrigation adoption.

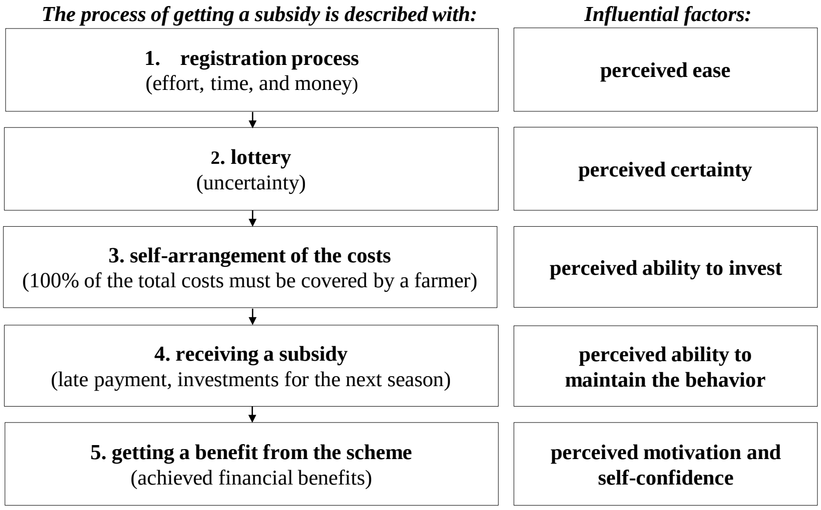

Figure 4.1: The chart that describes the process of getting a subsidy. The influential factors for each phase were identified using knowledge obtained from interview summaries. The outcome of this process suggests that trust in governmental institutions is lost and a mentality with low self-confidence is created

Farmers were saying: *"Government is giving a 90% subsidy for the drip system, but not for the well.* (D.2) *"If you do not have a well on the farm, then you also cannot get money for the drip system. The main issue is that the own funds are needed which I do not have, so I can not even reach out to the government. There is no flexibility in asking for subsidies!"* (D.4)

In a nutshell, while the government may have good intentions to provide help to the farmers (and strengthen their abilities), in practice it often results in only a few, often also rich farmers being able to benefit from the subsidy programs. This negatively influences farmers' beliefs, as they stop believing that all the efforts in terms of money and time would be outweighed by the latter benefits. It also lowers farmers' trust in governmental institutions, as they go through a long and hard process, without knowing if they would achieve something by being involved in it. Tremendous efforts, high uncertainty of the process of getting a subsidy, combined with low trust in the government, and feelings of unfairness negatively influence the psychological state and perceptions of farmers. This implies that what happens in the preactional stage is an ultimate conditioning factor for the progression onto the next stage, despite the strong goal intention.

4.2.5 The suitability of irrigation system to the cropping pattern influences the adoption

Cropping pattern dictates what kind of irrigation system a farmer needs. For example, drip irrigation has no practical use with traditional crops, while the furrow system is suitable for them. Furthermore, a drip system is not suitable for farmers who grow diverse crops or have a dense canopy. It is suitable for those who grow a limited number of crops and want to achieve precision. Farmers who have drip irrigation are usually farmers who are growing horticulture crops. This makes farmers going for a change in cropping patterns the ones who usually adopt drip irrigation systems. *"To make farmers adopt drip irrigation systems, we have to motivate them to change the cropping patterns."* (D.22)" However, one must take into account that if a farmer is surviving only on farming, they would most probably not take the risk of changing their cropping patterns. In addition to the risk related to the stability of yields, when growing new types of crops, the challenge would be to find a proper market to sell them. Before the new product becomes recognized, its purchase is not assured. With horticulture, a farmer can wait for many years before they collect the produce from the farm. This is a process known as perennialization, i.e. the conversion of a plant from an annual to a perennial (Kreitzman et al., 2020). Perennial plants are plants that may be productive for multiple years without the need for replanting (Kreitzman et al., 2020). Furthermore, the types of crops farmers grow are influenced by farmers' ability to buy certain types of seeds. This highlights the fact that the observable benefits do not come instantly. Another challenge in persuading a change in cropping patterns is the lack of road facilities, which makes farmers unable to have a supply of seed inputs to the field at the required time, i.e. at the beginning of the cropping season.

4.3 Counter intuitive regression results

In some of the regression results, contradictory trends were observed that created nuances in the dynamics of adoption and posed a challenge in making firm conclusions:

I. **Furrow irrigation systems adoption: logistic regression results**

While it was observed that higher confidence in buying, maintaining and installing a micro irrigation system decreases the adoption rate of furrow irrigation systems, higher confidence in operating a micro irrigation system increases furrow system adoption by 1809%. This suggests that a big barrier for people to move away from furrow irrigation is the technical knowledge of "how to operate" a micro irrigation system. The validity of this result should be further investigated in the future.

II. **Drip irrigation systems adoption: logistic regression results**

An increase in confidence regarding buying and maintaining a micro irrigation system decreases the likelihood of adopting drip systems by 70.9%. This result may have come out as a consequence of the question being asked as the question with two meanings, i.e. confidence in buying, and confidence in maintaining an irrigation system, which resulted in the counter intuitive result.

III. **Sprinkler irrigation systems adoption: two stage regression results**

As more people approve of using sprinkler irrigation technology, less likelihood of adoption was observed in the second stage of logistic regression with an endogenous RANAS factor. The possible reason to have this counter intuitive result is that farmers take into account economic factors such as the cost of implementing these systems and the regulatory government policies on top of just the social norm that prevails. The second reason why this result was observed is because of the incorrect mapping of the questions used to perform an instrument variable approach that may yield this result. This contradiction should be further explored in future studies.

4.4 Limitations

Limitations related to different parts of this work, as well as the limitations of this work as a whole are addressed in this section.

4.4.1 Limitations of the survey questionnaire design (Hatch et al., 2022)

Questions used to collect data on the RANAS factors were not designed as a part of this research but by (Hatch et al., 2022) and contained in Table A.2. Two design limitations were found.

First, the terminology of factors in this research design is inconsistent with the original framework terminology (Mosler, 2012). While some factors were named exactly the same as in the original framework ("Perceived severity" and "Perceived vulnerability"), other factors had differences in naming. Despite this, they held the same meaning. Factor "Feelings" corresponds to "Affective beliefs", factor "Beliefs about costs and benefits" corresponds to "Instrumental beliefs", factor "Others' behaviour" corresponds to "Descriptive norm", factor "Others' approval" corresponds to "Injunctive norm", factor

"Personal importance" corresponds to "Personal norm", factor "Confidence in recovering" corresponds to "Recovery self-efficacy", and factor "Barrier planning" corresponds to "Coping planning". For these factors, it was straightforward to determine the correspondence between them and their respective original factors. However, five factors were named "Confidence in performance" but responded to either "Maintenance self-efficacy" or "Action knowledge". To avoid misinterpretation of what "Confidence in performance" means, it should stay consistent with original factor names. On the grounds of factor definitions, the factors were assigned the original names as specified in (Mosler, 2012).

Second, the question "How self-confident are you about buying and maintaining a micro irrigation system?" had two parts and therefore two possible meanings, therefore it left room for interpretation and could have significantly impacted the farmers' responses based on their own understanding. While buying an irrigation system relates to the ability to invest, maintaining an irrigation system relates to knowledge and skills. Farmers may have been confused due to the mixing up of these terms and may have given their responses purely in relation to buying or maintaining an irrigation system. The reduced construct validity may have led to inconsistent responses, bringing additional difficulties in interpreting the data. This can particularly be observed in the case of the adoption of drip irrigation systems, where the lack of ability to invest is considered a major obstacle to the adoption according to field insights. However, this factor has a negative sign on the β coefficient in regression results thus indicating inconsistency between the qualitative and quantitative results. This may have happened due to the ambiguity of the question and its' subjective interpretation.

4.4.2 Self-reported data limitations

Both survey quantitative data and interview qualitative data are self-reported data. In contrast to the observable data, self-reported data may have a lack of reliability due to response bias (Rosenman et al., 2011).

First, during the survey, farmers were asked to respond to specific questions related to their psychosocial perceptions and their irrigation practices. The bias may have occurred because farmers wanted to give socially desirable responses. It could have also been that the phrasing of the questions was suggestive, therefore it lead farmers to respond in a particular way.

The idea of conducting interviews was to overcome the problem of suggestibility and allow for the inflow of additional information relevant to the context of using micro irrigation technology. However, it could have also been subject to bias. This is because farmers saw a researcher who was a young white woman. On top of that, they may have been afraid of the purpose of interviewing and did not want to tell the truth. Lastly, the interviews were conducted with a translator, because the native language of the region is Marathi. The translator may have introduced his own subjectivity in translating the responses. This consequently may have had an impact on the interpretation of the results. In addition, the last farmer to be interviewed on any particular day may have been influenced by the responses of the other farmers. This is because it was difficult to conduct private conversations with the farmers in the field, as they arrived for the interviews in groups.

4.4.3 The RANAS framework limitations

While the RANAS model provides valuable insights into the factors that may explain the irrigation adoption behavior, it has a few limitations that were identified during this research.

First, the RANAS gives a simplified representation of reality. It summarizes complex psychological perceptions into factors while assuming they are independent, i.e. all on the same level of priority and chronology. Furthermore, contextual factors that are also assumed to be independent of the RANAS factors may have an influence on farmers perceptions. This way the complexity of farmers' irrigation adoption behavior is simplified in a way that relationships between the factors may have been omitted, as some of the factors may actually be dependent on each other.

Second, the RANAS takes into account insufficient contextual details. Field insights revealed that the RANAS framework does not account for the factors that are specific to a certain cultural, environmental, and institutional context. Each and every context requires supplementary factors capable of capturing the influences on behavior.

Third, the alignment of the original model constructs with the behavior in consideration is lacking precision. As this case study examines the behavioral determinants for the adoption of irrigation technology, it may be relevant to include factors that account for economic constraints and governmental support, in addition to the original factors so to allow for its valid applicability.

Lastly, the RANAS lacks a dynamic component. While the RANAS factors are considered static variables, in reality, things happen and progress over time and certain factors may have smaller or larger importance at a particular moment of the behavior change process. An attempt was made to point this out by introducing the SSBC framework and mapping out the RANAS factors to the stages of the behavior change (irrigation adoption) process. It was observed that significant factors belong to different stages of change. This way it was indicated that each of the factors may be influential at different points in time.

The questions were designed to collect data on the behavioral factors and stage assignment. This limitation of dynamic component may be verified by testing the construct validity in the future.

In summary, the main limitations of the RANAS framework are the lack of context-specific factors, such as economic constraints related to the specific behavior in consideration (irrigation technology adoption), and the lack of temporal relevance of the factors used to describe the behavioral determinants.

4.4.4 The logistic regression model limitations

The logistic regression model is able to identify the variables that are significant for a specific outcome, and that is why it was used in this research to explore the variables that have a predictive capability on irrigation adoption behavior. However, it assumes that the observations are independent of each other, while farmers may have been biased in giving responses by, for example, listening to what the other farmers were saying. In addition, it assumes that there is no high correlation between the variables. However, the financial situation may be correlated with farmers abilities through opportunities that are open to rich farmers to strengthen their skills and invest in new technology. This observation was made through an understanding of the subsidization process. Lastly, the logistic regression model required no missing data, therefore many observations had to be excluded from the analysis and the sample size was reduced. The missing data occurred either due to loss of physical data that was noted on paper, or due to the farmers refusal to respond to a specific question. This may have had an impact on the results, as a larger sample size often leads to more reliable inferences about the relationship between variables in logistic regression.

4.4.5 Snowball sampling limitations

It was shown that snowball sampling is a convenient method of recruiting participants for the interview process. However, by applying this method, selection bias and lack of randomness may be encountered and thus the sample may not always be representative. This is because the contacts obtained from farmers may lead to farmers of similar characteristics and socio-economic profiles. This means that the sample obtained in this way may not be appropriate for upscaling.

4.4.6 Interview analysis limitations

The interview analysis was prone to a researcher's subjectivity and therefore the insights may have been impacted by this. The expert's opinion about the subject might influence thinking in a particular manner.

4.4.7 The overall limitations of the study

In a nutshell, this work is subject to various limitations. They include questionnaire design constraints, self-reported data interpretations, limitations of the RANAS framework, logistic regression model limitations, potential impact of a researcher's subjectivity, and their combinations. In addition, the results or findings from one phase of the study serve as an input for the subsequent phase, thus their scope is constrained by the preceding part and can lead to certain conclusions. Besides that, the data sample may not fully represent the broader population of farmers. For this reason, the findings may not be easy to generalize and scale up. Awareness of these limitations is important when interpreting the results and drawing conclusions from the study.

Chapter 5

Conclusion and recommendations

5.1 The answer to the research question

This section answers the main research question: **"What are the main drivers of smallholder farmers micro irrigation adoption behavior in Maharashtra state in India?"** by answering three research sub-questions.

5.1.1 "What can be learned about farmers irrigation and micro irrigation adoption behavior from applying the RANAS model to the data collected using farmer surveys?"

By applying the RANAS model to the survey data, it can be learned that the unique characteristics of each irrigation system trigger different perceptions regarding its adoption. It was observed that farmers are more likely to reduce their reliance on traditional furrow irrigation systems as they gain more confidence in their abilities regarding the uptake and maintenance of micro irrigation systems. Income itself is not able to explain the adoption process of any kind of irrigation system, as it accounts only for how much a farmer earns, and not for the information about their expenditures and other factors that describe their ability to invest.

Farmers are more likely to adopt drip irrigation systems if they are confident in their financial capabilities and technical skills. For the adoption of sprinkler irrigation systems, the situation is a bit more complex. To adopt sprinkler irrigation systems, in addition to the confidence in buying and maintaining these types of systems, farmers must perceive that access to the water source is easy, and they should not be concerned about water scarcity, i.e. future water availability. If they see other farmers using sprinkler irrigation systems, they will also be more likely to adopt them. This highlights that the barrier to adopting drip systems is mostly related to financial constraints, while for the adoption of sprinkler systems farmers take into account also normative influence and water-related concerns.

5.1.2 "What are the strengths and limitations of the RANAS model to identify variables that have the predictive capability on micro irrigation adoption behavior?"

The strength of the RANAS model to identify variables that have the predictive capability on micro irrigation adoption behavior is its ability to break down the complex problem into simplified systematic components that give a fairly good representation of reality. In addition, it is able to take into account system specifics when explaining the adoption. However, the RANAS model also has limitations.

First, it neglects the dynamic component of the irrigation adoption process and is not able to determine the significance of each factor at a specific point in time, i.e. it does not account for the stages of behavioral change. This is because it assumes that all the factors are independent. However, different stages of the behavior change process involve varying influential factors, therefore it is crucial to know how to target them so to make sure that a farmer will implement a micro irrigation system in the long-term.

Second, it underestimates the importance of economic and institutional constraints. When the adoption of technology is considered, these constraints can have a significant influence by affecting the investment capacities of farmers, affordability, infrastructure and support, market dynamics, and perceptions of cost-effectiveness. These factors indirectly influence the perceptions of farmers. To explain the adoption process, it is important to also recognize these factors.

Lastly, another limitation of the RANAS method is its dependence on the design of survey questions used for data collection, as the results can be influenced by the specific phrasing of the questions. The formulation and order of the questions can influence how farmers interpret and respond, likely affecting the conclusions that are gathered from the empirical data.

5.1.3 "What additional information that might enrich the knowledge on the dynamics of farmers micro irrigation adoption behavior can be collected during the fieldwork?"

Field insights revealed that context-specific factors play an important role in explaining farmers' adoption choices. Moreover, psychosocial and economic capacity should not be looked at separately. Economic capacity opens the door towards making the adoption of technology possible, while psychosocial capacity sustains the persistence in maintaining the newly adopted practice.

Economic conditions are a pre-requirement for a farmer to implement an irrigation system smoothly. Only if a farmer is economically sound, he will be able to invest in an irrigation system or take the benefits of the facilities that the government is providing. Due to the possible risk of failure related to the adoption of new technology, farmers who only rely on farming and are economically weak tend to be more risk-averse. For this reason, reduced feeling of individual risk, i.e. increased feeling of community support may help overcome obstacles related to the adoption. What is better able to explain the adoption than farmers' income is an integrated view of earnings and expenditures, i.e. a profit margin, together with the market prices.

Finally, considering practical aspects such as the suitability of an irrigation system to the cropping pattern will help in explaining the adoption choices. The adoption of a micro irrigation system often entails a change in cropping patterns. Changing cropping patterns may happen because environmental conditions are changing, so farmers need to be aware not only of the ongoing climate change impacts but also of changes in market dynamics.

5.2 Recommendations for future studies

Based on the results of this study and identified limitations, several recommendations for future research are made:

1. **Survey questionnaire design**: to accurately interpret the results, future research should ensure consistency in terminology and aim for singularity in question design.

2. **Factor interdependency**: try to examine the interdependence of certain factors on one another. Check whether there is a model that could describe this interdependence and account for stage-related factor importance and conditions they set. Possible models to consider could be the hurdle model, structural equation modeling, or logistic regression for each of the phases.

3. **The RANAS framework**: Expand the RANAS framework with the factors found from the interview insights. Include the ability to invest, the possibility to get the benefit out of the governments' subsidy scheme, the suitability of the system to a cropping pattern, and the frustration against the local governmental bodies (not the frustration related to the irrigation itself). These variables may have the ability to shed light on the barriers that influence the adoption if not fully explain it.

4. **Check whether the adoption could be better explained by accounting for stages of behavior change and additional factors identified in the field**: a new survey design was developed to test the hypothesis that the RANAS factors are dynamic. The questions and their corresponding factors and stage assignments could be found in separate Microsoft Excel worksheet (on demand). This could be tested by developing a logistic regression model for each of the stages. Further, it could be checked whether the mapped factors indeed appear as significant in the corresponding stages. Second, the newly identified factors via qualitative interviews may also be incorporated into the questionnaire to account for the context-specific factors.

   The newly identified factors and example questions to include these factors could be: ability to invest ("Are you able to invest in the new micro (drip or sprinkler) irrigation system?"), possibility to get the benefit of the governments' subsidy ("Do you think you have a change of getting a benefit out of the governments' subsidy scheme if you apply?"), suitability of the system to the cropping pattern ("Are the crops that you are growing on your farm suitable for the sprinkler or drip irrigation system?"), having a proper water source facility ("Do you own or have access to a water well which you need as a pre-condition to apply for the subsidy?"), having a job other than farming ("Is the farming your only job?"), awareness of spendings ("Are you aware of how much out of your total income is being used for the costs of farming inputs? How much out of your total income is being used for other purposes?"), holding capacity ("Do you have a storage place where you can store your crops before you sell them on the market?"), destruction of systems due to animals ("Are your irrigation pipes destroyed by animals, such as rats?"), market prices of crops and seeds ("Do you know what is the best market to buy your seeds and sell your crops?"), frustration against the government ("How do you feel about governments' initiative to help farmers with getting a micro irrigation system?"), taking out and repaying back the loans ("Are you taking out loans, and if yes, are you able to repay them back on time?")

5. **Try to minimize the dependence between observations**: minimize the presence of group settings, where certain farmers may be dominant and have an influence on other farmers.

6. **Include conditional variables**: consider taking into account the conditional variables that may indicate whether a farmer has an opportunity to succeed in doing something. For example, if an irrigation system type suits the cropping pattern, then a farmer may get the behavioral intention, or else not. The opportunity in developing a behavioral intention lies in the physical opportunity (environment). Furthermore, if a farmer has the ability to invest, then he would be eligible for the subsidy application, or else not. The social opportunity lies in cultural context.

7. **Ensure sufficient sample size**: prior to data collection, do a sample size calculation and add a safety factor on top of it, so to account for the potential missing data that may occur.

8. **Avoid subjectivity in interview coding process**: even though being completely objective may be difficult, a few steps can be taken to avoid subjectivity in qualitative data analysis as much as possible. First, try to involve multiple people in the interview coding process. Let other researchers review the work and give their own feedback. This can be a confirmation of the achieved degree of analytical approach.

9. **Overcome the limitations of the study as a whole**: To overcome the overall limitations this work is subject to (see 4.4.7), a triangulation method could be applied. Triangulation entails either the use of multiple methods or data sources in qualitative research to develop a comprehensive

understanding of phenomena (Nancy Carter et al., 2014). This understanding is achieved by testing the validity through the convergence of information from different sources (Nancy Carter et al., 2014).

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Appendix A

Survey questions

This Appendix contains the questions that were included in the survey and asked to obtain information on contextual characteristics (Table A.1),the RANAS factors (Table A.2), and instrument variables (IVs) (Table A.3).

Table A.1: Survey questions to obtain the contextual factors

Variable	Survey question
Age	What is your age?
Education level	What is your highest education level completed?
Land area owned	How much land do you own (acre)?
Annual income from crops	How much income from all crops do you receive roughly per year?
Annual income from family	What is the total annual income from your family members living with you?
Off farm income	How much income do you receive from other work besides farming per year?
Number of cows owned	How many cows do you own?
Number of bulls owned	How many bulls do you own?
Number of goats owned	How many goat do you own
Number of dependents	How many of your family members are financially dependent?
Number of family members who help with farming	How many of your family members are helping you with farming?

Table A.2: Survey questions to obtain the RANAS factors

Determinant factor	Sub-factor	Corresponding question
Risk	Perceived severity	How does the current water supply compare to the water you need for your crops?
	Perceived vulnerability	How confident are you that you have enough water in the next 5 years ?
	Perceived severity	How severe is the impact on you when you do not have any water for your crops?
	Perceived vulnerability	How responsible are you for your water source?
Attitude	Feelings	How much more effort does irrigation take compared to not irrigating?
	Feelings	How much more effort do micro irrigation systems take compared to flood irrigation?
	Belief about costs and benefits	Compared to not irrigating, how much difference in productivity is caused by irrigation?
	Belief about costs and benefits	Compared to flood irrigation, how much difference in productivity is caused by micro irrigation?
	Belief about costs and benefits	How willing are you to pay for a new irrigation system?
Norms	Other's behaviour	What proportion of people in your village use irrigation systems?
	Other's approval	People who are important to you, how much do they approve of using irrigation systems?
	Perosnal importance	How important is saving water for you (in irrigation)?
Abilities	Confidence in performance	How self-confident are you about operating an irrigation system?
	Confidence in performance	How much more time does irrigation take compared to not irrigating?
	Confidence in performance	How much more time do micro irrigation systems take compared to flood irrigation?
	Confidence in recovering	Has it become more or less difficult to get water in the last 10 years?
Self-regulation	Barrier planning	To what limit could you withstand water shortage?

Table A.3: Survey questions to obtain the IV factors

Instrument variable (IV)	Corresponding question
Risk-related	
IV_risk_i	How often do you hear or read about water scarcity in the newspaper, radio, or TV?
IV_risk_ii	How effective are government drought relief measures?
Attitude-related	
IV_attitude_i	How attentive is the government to farmers' concerns?
IV_attitude_ii	How much trust do you have in the government's advice?
Norms-related	
IV_norms_i	How often do you hear or read government irrigation policies or programs in the newspaper, radio, or TV?
IV_norms_ii	How concerned are the government officers or extension (KVK) agents about farmers' water problems?
Ability-related	
IV_ability_i	How often do you get invited or take part to (KVK) demonstrations of irrigation technologies by agriculture extension services?
IV_ability_ii	How active are agriculture extension services (KVK) in your area?
IV_ability_iii	How would you rate the quality of the agriculture extension service (KVK) agents in your area?
IV_ability_iv	How easily reachable is the local irrigation officer? How easy is it to get work done (e.g., applying for schemes, subsidies)?
Self-regulation-related	
IV_selfreg_i	Compared to 3 years earlier, how much more dependent are you on chemical fertilisers or pesticides?
IV_selfreg_vii	Compared to 3 years ago, how much more have you applied for crop insurance?
IV_selfreg_viii	How many times have you applied for crop insurance in the past 3 years?

Appendix B

Interview questions

This Appendix contains the questions that were included in the interviews to obtain the information on the socio-economic profile, farming practices and irrigation behavior of farmers. Please note that while these questions were primarily used to gather initial insights, the conversations were open-ended, allowing farmers to share diverse and unique information (Hammer and Wildavsky, 2018).

To obtain the information on the socio-economic profile of a farmer:

What is your age?
What is the highest education level you completed?
How many family members do you have?
How many of them are financially dependent?
How big is your farming area?
What kind of crops do you grow on your farm?
How much money do you invest in farming?
How much money do you earn from farming?
Do you take out loans? If yes, for what purpose?

Farming practices:

What is your water source?
Do you irrigate? If yes, what system(s) do you use and why? If not, why?
Would you like to start irrigating?
Would you like to switch to a more efficient irrgation system, such as drip or sprinkler irrigation system?
Do you have an intention to enhance your crop production?
Do you have an intention to save the water?
Have you noticed any changes in farming in the last 5 to 10 years?
Who do you think is responsible for the provision of facilities?
What is the main reason for your crop failure?
What kind of improvements would you like to have on your farm?
Do you have an intention to stop with farming?
Could you indicate what are the main obstacles in farming for you?
Did it happen that your irrigation system broke down? If yes, what did you do then?

Appendix C

Regression tables

These are the full regression tables from the logistic regression analysis for the adoption of irrigation systems, furrow irrigation systems, sprinkler irrigation systems, and drip irrigation systems.

Dep. Variable:	irrigation_yes_no	**No. Observations:**	354
Model:	Logit	**Df Residuals:**	322
Method:	MLE	**Df Model:**	31
Date:	Sun, 02 Jul 2023	**Pseudo R-squ.:**	0.2484
Time:	18:28:19	**Log-Likelihood:**	-157.69
converged:	True	**LL-Null:**	-209.79
Covariance Type:	nonrobust	**LLR p-value:**	7.554e-10

	coef	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	0.2525	0.678	0.372	0.710	-1.077	1.582
Ed_Category_Nr[T.1]	1.5533	0.784	1.982	0.047	0.017	3.089
Ed_Category_Nr[T.2]	0.8988	0.727	1.236	0.216	-0.526	2.324
Ed_Category_Nr[T.3]	1.2087	0.728	1.660	0.097	-0.218	2.636
Ed_Category_Nr[T.4]	1.0720	0.750	1.429	0.153	-0.398	2.542
Ed_Category_Nr[T.5]	1.4344	0.867	1.655	0.098	-0.264	3.133
Ed_Category_Nr[T.6]	2.3421	1.125	2.081	0.037	0.137	4.548
M2_land_own_land_area_scaled	1.1801	0.438	2.696	0.007	0.322	2.038
M16_total_annual_income_scaled	-0.0728	0.224	-0.325	0.745	-0.511	0.366
M3_livestock_C1_scaled	0.2216	0.195	1.139	0.255	-0.160	0.603
age_scaled	-0.0387	0.165	-0.235	0.815	-0.362	0.285
M1_dependents_family_n_members_scaled	0.0763	0.196	0.390	0.697	-0.308	0.460
M1_family_help_family_n_members_scaled	0.1304	0.191	0.683	0.495	-0.244	0.505
water_demand_met_scaled	0.5473	0.156	3.520	0.000	0.243	0.852
water_future_confidence_scaled	0.4686	0.195	2.405	0.016	0.087	0.850
impact_severity_scaled	-0.2292	0.174	-1.319	0.187	-0.570	0.111
water_responsibility_scaled	-0.1565	0.152	-1.029	0.304	-0.455	0.142
extra_effort_irr_gen_scaled	-0.1167	0.155	-0.752	0.452	-0.421	0.188
extra_effort_irr_micro_scaled	0.1767	0.239	0.740	0.459	-0.291	0.645
irrigation_productivity_scaled	0.0857	0.219	0.392	0.695	-0.343	0.515
irrigation_micro_productivity_scaled	0.3794	0.158	2.399	0.016	0.069	0.689
willing_to_pay_scaled	0.1976	0.163	1.214	0.225	-0.121	0.517
proportion_irrigation_select_scaled	0.0919	0.171	0.536	0.592	-0.244	0.428
approval_scaled	-0.2002	0.201	-0.998	0.318	-0.593	0.193
importance_irrigation_efficiency_scaled	0.0188	0.191	0.099	0.921	-0.355	0.393
confidence_buying_maintaining_irrigation_micro_confidence_scaled	0.4844	0.332	1.459	0.145	-0.166	1.135
confidence_installing_irrigation_micro_confidence_scaled	-0.4646	0.449	-1.036	0.300	-1.344	0.415
confidence_operating_irrigation_micro_confidence_scaled	0.5127	0.464	1.105	0.269	-0.396	1.422
extra_time_irr_gen_scaled	0.0013	0.180	0.007	0.994	-0.351	0.353
extra_time_irr_micro_scaled	-0.0535	0.248	-0.216	0.829	-0.539	0.432
difficulty_water_scaled	0.5329	0.191	2.788	0.005	0.158	0.907
limit_shortage_scaled	-0.0985	0.170	-0.579	0.562	-0.432	0.235

Dep. Variable:	furrow_irrigation_yes_no	**No. Observations:**	354
Model:	Logit	**Df Residuals:**	322
Method:	MLE	**Df Model:**	31
Date:	Sun, 02 Jul 2023	**Pseudo R-squ.:**	0.4740
Time:	18:50:26	**Log-Likelihood:**	-47.524
converged:	False	**LL-Null:**	-90.356
Covariance Type:	nonrobust	**LLR p-value:**	5.085e-07

	coef	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	-5.9503	1.612	-3.692	0.000	-9.109	-2.792
Ed_Category_Nr[T.1]	1.4123	1.498	0.943	0.346	-1.524	4.348
Ed_Category_Nr[T.2]	1.1724	1.445	0.811	0.417	-1.660	4.005
Ed_Category_Nr[T.3]	0.1190	1.543	0.077	0.939	-2.904	3.142
Ed_Category_Nr[T.4]	1.0988	1.578	0.696	0.486	-1.995	4.192
Ed_Category_Nr[T.5]	0.9417	1.742	0.540	0.589	-2.473	4.357
Ed_Category_Nr[T.6]	-23.4538	7325.737	-0.003	0.997	-1.44e+04	1.43e+04
M2_land_own_land_area_scaled	-1.2406	1.090	-1.138	0.255	-3.377	0.896
M16_total_annual_income_scaled	-0.4379	0.490	-0.893	0.372	-1.399	0.523
M3_livestock_C1_scaled	-0.9591	0.516	-1.858	0.063	-1.971	0.052
age_scaled	0.1111	0.383	0.290	0.772	-0.640	0.862
M1_dependents_family_n_members_scaled	-1.1482	0.555	-2.067	0.039	-2.237	-0.060
M1_family_help_family_n_members_scaled	0.2242	0.335	0.668	0.504	-0.433	0.881
water_demand_met_scaled	1.5179	0.482	3.149	0.002	0.573	2.463
water_future_confidence_scaled	-0.3407	0.303	-1.123	0.262	-0.936	0.254
impact_severity_scaled	-0.9291	0.530	-1.751	0.080	-1.969	0.111
water_responsibility_scaled	0.2334	0.306	0.762	0.446	-0.367	0.834
extra_effort_irr_gen_scaled	-0.3359	0.405	-0.830	0.406	-1.129	0.457
extra_effort_irr_micro_scaled	0.6100	0.403	1.513	0.130	-0.180	1.400
irrigation_productivity_scaled	0.6088	0.494	1.233	0.217	-0.359	1.576
irrigation_micro_productivity_scaled	-0.0940	0.310	-0.303	0.762	-0.702	0.514
willing_to_pay_scaled	0.1562	0.227	0.687	0.492	-0.289	0.602
proportion_irrigation_select_scaled	-1.3433	0.402	-3.342	0.001	-2.131	-0.556
approval_scaled	0.6392	0.410	1.558	0.119	-0.165	1.443
importance_irrigation_efficiency_scaled	-0.6543	0.339	-1.933	0.053	-1.318	0.009
confidence_buying_maintaining_irrigation_micro_confidence_scaled	-1.5204	0.688	-2.211	0.027	-2.868	-0.173
confidence_installing_irrigation_micro_confidence_scaled	-1.8804	0.846	-2.223	0.026	-3.538	-0.222
confidence_operating_irrigation_micro_confidence_scaled	2.9495	1.245	2.369	0.018	0.509	5.389
extra_time_irr_gen_scaled	-0.5700	0.447	-1.274	0.203	-1.447	0.307
extra_time_irr_micro_scaled	-0.3478	0.413	-0.842	0.400	-1.157	0.461
difficulty_water_scaled	-0.5269	0.349	-1.509	0.131	-1.212	0.158
limit_shortage_scaled	0.6206	0.285	2.178	0.029	0.062	1.179

Dep. Variable:	sprinkler_irrigation_yes_no	**No. Observations:**	354
Model:	Logit	**Df Residuals:**	322
Method:	MLE	**Df Model:**	31
Date:	Sun, 02 Jul 2023	**Pseudo R-squ.:**	0.2510
Time:	18:58:20	**Log-Likelihood:**	-177.30
converged:	True	**LL-Null:**	-236.71
Covariance Type:	nonrobust	**LLR p-value:**	3.252e-12

	coef	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	-0.0750	0.660	-0.114	0.910	-1.369	1.219
Ed_Category_Nr[T.1]	0.7470	0.744	1.004	0.316	-0.712	2.206
Ed_Category_Nr[T.2]	0.3831	0.707	0.542	0.588	-1.004	1.770
Ed_Category_Nr[T.3]	0.8722	0.705	1.237	0.216	-0.510	2.254
Ed_Category_Nr[T.4]	0.6662	0.733	0.909	0.363	-0.770	2.102
Ed_Category_Nr[T.5]	1.1206	0.824	1.359	0.174	-0.495	2.736
Ed_Category_Nr[T.6]	1.8880	0.997	1.893	0.058	-0.067	3.843
M2_land_own_land_area_scaled	0.6849	0.285	2.402	0.016	0.126	1.244
M16_total_annual_income_scaled	0.2090	0.199	1.050	0.294	-0.181	0.599
M3_livestock_C1_scaled	0.3543	0.182	1.950	0.051	-0.002	0.710
age_scaled	0.1269	0.155	0.821	0.412	-0.176	0.430
M1_dependents_family_n_members_scaled	0.2478	0.190	1.308	0.191	-0.124	0.619
M1_family_help_family_n_members_scaled	-0.2333	0.169	-1.378	0.168	-0.565	0.099
water_demand_met_scaled	0.1931	0.143	1.350	0.177	-0.087	0.473
water_future_confidence_scaled	0.3786	0.172	2.206	0.027	0.042	0.715
impact_severity_scaled	-0.1809	0.171	-1.060	0.289	-0.515	0.154
water_responsibility_scaled	-0.1771	0.142	-1.251	0.211	-0.455	0.100
extra_effort_irr_gen_scaled	-0.1458	0.156	-0.936	0.349	-0.451	0.160
extra_effort_irr_micro_scaled	-0.0016	0.214	-0.008	0.994	-0.421	0.418
irrigation_productivity_scaled	0.1722	0.219	0.785	0.432	-0.258	0.602
irrigation_micro_productivity_scaled	0.2508	0.146	1.712	0.087	-0.036	0.538
willing_to_pay_scaled	0.0264	0.135	0.196	0.845	-0.239	0.292
proportion_irrigation_select_scaled	0.4111	0.161	2.551	0.011	0.095	0.727
approval_scaled	-0.3468	0.179	-1.936	0.053	-0.698	0.004
importance_irrigation_efficiency_scaled	0.3532	0.175	2.016	0.044	0.010	0.697
M14_confidence_buying_maintaining_irrigation_micro_confidence_scaled	0.8429	0.321	2.627	0.009	0.214	1.472
M14_confidence_installing_irrigation_micro_confidence_scaled	0.2437	0.404	0.604	0.546	-0.548	1.035
M14_confidence_operating_irrigation_micro_confidence_scaled	-0.1542	0.429	-0.360	0.719	-0.994	0.686
extra_time_irr_gen_scaled	0.0928	0.167	0.555	0.579	-0.235	0.420
extra_time_irr_micro_scaled	0.0136	0.224	0.061	0.952	-0.425	0.453
difficulty_water_scaled	0.6350	0.177	3.592	0.000	0.289	0.982
limit_shortage_scaled	-0.2288	0.150	-1.529	0.126	-0.522	0.065

Dep. Variable:	drip_irrigation_yes_no	**No. Observations:**	354
Model:	Logit	**Df Residuals:**	322
Method:	MLE	**Df Model:**	31
Date:	Sun, 02 Jul 2023	**Pseudo R-squ.:**	0.2653
Time:	18:59:58	**Log-Likelihood:**	-97.640
converged:	False	**LL-Null:**	-132.89
Covariance Type:	nonrobust	**LLR p-value:**	6.574e-05

	coef	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
Intercept	-21.0933	7049.980	-0.003	0.998	-1.38e+04	1.38e+04
Ed_Category_Nr[T.1]	18.2064	7049.980	0.003	0.998	-1.38e+04	1.38e+04
Ed_Category_Nr[T.2]	18.3576	7049.980	0.003	0.998	-1.38e+04	1.38e+04
Ed_Category_Nr[T.3]	18.1143	7049.980	0.003	0.998	-1.38e+04	1.38e+04
Ed_Category_Nr[T.4]	18.4428	7049.980	0.003	0.998	-1.38e+04	1.38e+04
Ed_Category_Nr[T.5]	18.3805	7049.980	0.003	0.998	-1.38e+04	1.38e+04
Ed_Category_Nr[T.6]	19.8107	7049.980	0.003	0.998	-1.38e+04	1.38e+04
M2_land_own_land_area_scaled	0.4015	0.248	1.620	0.105	-0.084	0.887
M16_total_annual_income_scaled	0.2942	0.240	1.225	0.221	-0.177	0.765
M3_livestock_C1_scaled	0.1812	0.179	1.013	0.311	-0.169	0.532
age_scaled	0.0943	0.221	0.428	0.669	-0.338	0.527
M1_dependents_family_n_members_scaled	-0.1717	0.251	-0.685	0.493	-0.663	0.319
M1_family_help_family_n_members_scaled	0.3420	0.235	1.455	0.146	-0.119	0.803
water_demand_met_scaled	0.2968	0.258	1.152	0.249	-0.208	0.802
water_future_confidence_scaled	-0.0484	0.264	-0.184	0.854	-0.566	0.469
impact_severity_scaled	0.2585	0.270	0.959	0.338	-0.270	0.787
water_responsibility_scaled	-0.2808	0.235	-1.193	0.233	-0.742	0.181
extra_effort_irr_gen_scaled	-0.1819	0.266	-0.683	0.495	-0.704	0.340
extra_effort_irr_micro_scaled	-0.0079	0.344	-0.023	0.982	-0.682	0.667
irrigation_productivity_scaled	-0.2299	0.334	-0.687	0.492	-0.885	0.426
irrigation_micro_productivity_scaled	0.4785	0.240	1.997	0.046	0.009	0.948
willing_to_pay_scaled	0.4043	0.211	1.917	0.055	-0.009	0.818
proportion_irrigation_select_scaled	0.3882	0.248	1.566	0.117	-0.098	0.874
approval_scaled	0.1829	0.285	0.642	0.521	-0.376	0.741
importance_irrigation_efficiency_scaled	-0.3444	0.229	-1.503	0.133	-0.793	0.105
confidence_buying_maintaining_irrigation_micro_confidence_scaled	-1.2338	0.414	-2.977	0.003	-2.046	-0.421
confidence_installing_irrigation_micro_confidence_scaled	1.3674	0.844	1.620	0.105	-0.287	3.022
confidence_operating_irrigation_micro_confidence_scaled	0.7384	0.809	0.912	0.362	-0.848	2.325
extra_time_irr_gen_scaled	0.3466	0.230	1.508	0.132	-0.104	0.797
extra_time_irr_micro_scaled	-0.4386	0.341	-1.286	0.198	-1.107	0.230
difficulty_water_scaled	-0.3390	0.266	-1.272	0.203	-0.861	0.183
limit_shortage_scaled	-0.0891	0.231	-0.386	0.700	-0.541	0.363

Appendix D

Interview summaries

In this Appendix, the summaries of the transcripts of the field interviews with farmers can be found.

D.1 Interview 1

She is 30 years old and the highest education level she completed is the 8th grade. She is fully paid for her work on the farm and she does farming only throughout the full year period, i.e. 12 months. She is helping out at the farm of her husband, and the farming area is of 3.5 acres. On the farm they grow cotton and tur dal. They have 4 family members in their family (she, husband, son and daughter of 9 and 10 years, respectively). Young children of them are financially dependent on the parents. Their annual income is 30 000 rupees during the time period of 8 months, while during the rest (4 months) they have no income, so they are taking loans for the rest. She would like to use sprinkler irrigation system since it is comfortable for her and it is affordable. With sprinkler everything would be done properly on the farm. When it comes to the drip systems, there are money constraints, since it is costly and thus more money is needed in order to get it. She needs more money for farming she says that the help is needed from the government. She is facing water problems, because while water is available, they cannot use it properly. The reason for this is because in the rainy season water is stored in the field (i.e. there is too much water in the field). For the proper management, more money is needed. They are facing problems in every rainy season because of climate. In other seasons, farming goes well. They get everything they can in the period of 8 months. Government is not providing anything; they feel bad and they need help. Produce selling rates are at the down level. This means that the investments are larger than income (25loss is felt). Help needed is thus money, because knowledge is not a problem. Whatever they are using, they are only facing loss. She says that most of the people are dying because they are taking loans and cannot pay them back she sees no hopes. Every year they need to take the loan for the farming. They want the systems, but they are getting no facilities. They need to apply fertilizers so that the crops do not get damaged. She feels very much angry because of her situation, but she is still willing to do everything. The problem for getting a drip system is a big capital investment.

D.2 Interview 2

He is 47 years old and the highest education level he completed is 10th grade. His family has 3 members: a son, a wife and him. Only wife helps him with farming, kid not. He has only 1 acre of farming area which yields 10 quintals. On his farm he grows cotton as his main and only crop. He gets 8000 rupees per quintal, which make his seasonal (yearly) earning 80000 rupees. Cotton season occurs from June to March. He invested 50000 rupees, thus profit is 30000 rupees per 1 acre he has. He does not irrigate. He relies on rainfall and water from the canal. He is just using a canal water and pays 1200 rupees yearly for it (it is a part of 50 000 rupees investment). He would like to use irrigation systems, but before that he needs a well. He is getting 10 quintals based on rainfed water supply. After getting a well (proper facilities), he would like to use a drip irrigation system. He would like to use it because he is aware of water scarcity and does not have enough water for his crops. He is facing the problem of water source, for that reason he needs a well. If he had a well, he would be able to connect it with a drip system. However, he needs money for that. He would have been using drip irrigation if he had no money issues. He says that government is giving a 90% subsidy for the drip system, but not for the well. Main issue is the water source, because he cant afford to buy the well. There is a lottery system where someone will be chosen to get the money for drilling and installing the well, but he must have at least 3 acres of farmland to be able to apply. The amount that the government is giving at the moment is not sufficient. Even though productivity is high (10 quintals per acre compared to an average of 7 quintals per acre), he must earn money from the other farms. He does 7 hours of work for 300 rupees in total during the period 12 months. Cotton does not need attention every day, so he can be absent and work on other farms as well. He would have been able to maintain and operate the drip irrigation system (even if it blocks, there is no lack of confidence to operate it). He has confidence in his ability to maintain and operate the drip system because of the experience from the work on other farms that already have it.

D.3 Interview 3

He is 25 years old (check) and the highest education level he completed is 10th grade. He has 2 acres of farming area. On his farm he grows cotton and tur dal (kind of lentil). The yield of cotton is approximately 7 quintal cotton per acre, meaning he has 14 quintal of yield in total. He earns 110 000 rupees, while he invests 70 000 rupees, thus his profit is 40 000 (from both crops, on 2 acres). He does not irrigate. He relies on rainfall and water from the canal. Canals are not accessible to all the farmers (they are 500m 1km away from their farms, meaning that farmers have no water source). If he was closer to the source, he would be using sprinkler irrigation system. The reason for choosing sprinkler system is because he must cover all the farm area. He wants to plant crops that are close to each other. i.e. dense canopy, and for that cropping pattern the drip system is not appropriate. He wants to plant all the green leafy vegetables and onions because of the profit (security against loss). He wants to diversify his crops so to establish the certainty of profit. Drip system may not be useful if a lot of crops are planted, but when the plants are the same. Preferably he would like to have a combination of the drip and sprinkler system (on the laterals). Sprinkler system is cheaper while drip system conserves more water. In his case he wants to achieve coverage and not precision. He thinks that the government is responsible to provide farmers with proper facilities. The price of digging a well is 280 000 rupees. To get the financial help for that, 3 acres of farm area are needed. He is sometimes taking loans for a living (a loan of 100 000 rupees). The money he earns he uses to pay back the loan and to utilize for the family. When it comes to the influence of the other farmers, he says that if the benefit they are achieving is visible, he would do the same activity. If he does not see the benefit, then he will not follow the same farming practice (conditional norms). His knowledge on sprinkler systems is gained by working on the other farms (where he is a labour).

D.4 Interview 4

He is 38 years old and the highest education level he completed is Bachelor in arts. His family has 12 members (it is a joint family). Father and his two brothers are farmers, in total 4 of them are working on the farm. They together have 5 acres of farming area on which they grow tur, some vegetables, beans and okra. Brothers have one kid each and kids are not working. He has a wife and two daughters. He was a part-time farmer until two years ago. He stopped with farming because he was not getting benefits from it. He talks about the situation while he still used to do farming. Total earning is 250 000 rupees, while investment is 120 000 rupees. They are growing various crops thus they are using sprinkler system. He needs drip, but it has high maintenance costs. Now they do not have a proper water facility (water source). They have a shallow open well. If it was deep enough, water would be easily available, which would cause less problems. He would like to cultivate more from the crops and earn more money (production yield increase). Drip system would give to the plant only that much water as it needs to be healthy and grow. He believes that overwatering is bad for the plants (flood). Drip system will not be applicable for all the plants he needs sprinkler or flood as well (in addition to drip). Main issue is that the own funds are needed which they dont have so they cant even reach out to the government. Lottery system is there for wells. If you dont have a well on the farm, then you also cant get money for the drip system. You can apply if one well is used by 3-4 farmers (shared well). 82% of farmers are rainfed in Vidarbha. Confidence in installing and operating an irrigation system is not an issue. Drip system has high maintenance costs. The reason for that is because squirrels and rats drink water and damage the pipes during summer, and this causes a problem to the farmers. Sometimes they would need to do the maintenance each and every night, and small plants are completely damaged. Maintenance entails 20% of the cost of the drip system (10 000 rupees). The maintenance entails the following activities: using chemicals to clean the pipes, using the jointers to join the pipes that are cut by rats, the use of chemicals needed to fix the blocked emitters. Sprinkler system has less maintenance and it is easy to handle. It has bigger and thicker pipes, so rats dont tend to bite them as much as drip. To give an example, drip lateral is 16mm, while sprinkler is 63-90mm. 90mm is the main line, 63mm are distributers. In both, rats cant easily damage . Drip line has a higher density, thus more chances of failure. Drip lines are small and light, so they can easily fly off, i.e. move away from the initial position. However, on a small area farmer can put them himself, otherwise the labour is needed. He believes that farmers should get schemes they require, meaning that the government should provide subsidies (ascription of responsibility is not in the farmer). At this point, only big farmers (> 3 acres) can apply for farm pond subsidy (2 ha according to FAO). This means that there is no flexibility in asking for subsidies! The government decides on everything, including the market price of produce. Farmers cannot decide the price, they need to accept it. Problems: there is no flexibility + uncertainty in the weather. Farming is not my cup of tea I realize it only after having so many losses. In the case of a smaller farm only one brother should work on the farm. If everyone works, i.e. jobs are not diversified, there will be empty times of the year. Everyone has to earn through other means in order to survive (in his family, they went to education and transportation sector).

D.5 Interview 5

He is 28 years old and the highest education level he completed is 10th grade. He has 3.5 acres of farming area. On his farm he grows cotton, tur dal and beans (name: popat). Expenditures are as follows. He invests 175 000 rupees and he earns 275 000 rupees a year, meaning that his profit is 100 000 rupees per year. He applies flood irrigation by using water from the canal and rainfed irrigation. However, canal is intermittent and unpredictable, so he has no permanent source of water. Water availability is thus limited. He needs drip irrigation system because that way he will not need more labour, so he can save that part of the money. I can give fertilizers through drip system and that way I will save the costs. He needs a well and a drip system for his farm. The problem arises when everybody needs labour at the same time (labour scarcity). Drip system is one-time cost. If it rains, labour will sit down, but the drip system will not (8min funny). He does not feel that the maintenance costs are high. He has the knowledge on irrigation systems because he has worked not only on his farm, but also on the farms of his neighbours. Next to the lower maintenance costs, yield will also increase with the use of drip system (beliefs about costs and benefits affective beliefs). Climate change affects confidence in having water in the future. He would like to grow more crops (for example turmeric), so that if one crop may go, the other may survive and still bring earning. He wants only drip system, but what is currently stopping him is high investment cost *** He thinks that operational cost of sprinkler system is more than for the drip system. This is due to bigger pipes more people required to carry them, while for drip one person can lay down the pipes. Because he has no saving, he is unable to afford well digging, which consequently affects his possibility to apply for the drip system. He has taken out loans for purposes other than farming. He says: Arm forces are taken care of and he thinks that the same way the farmers should be taken care of, since they are also serving the nation. Because of corruption, if a farmer potentially has more than 3 acres of land and have applied for the well, there is a chance that he may never get it. In this case also local politics comes into play.

D.6 Interview 6

He is 73 years old and the highest education level he completed is graduate (pre-university course). Previously he was working as a divisional accountant in electricity board. His family has 4 members.

No one is financially dependent, because everyone is working on the farm, where they also live. He has 4.5 acres of farming area. On his farm he grows wheat, grains, vegetables, fruits, spices, oil seeds (different varieties); all required for the family (all needed in the kitchen). Agriculture is his only source of income; he also has deposits in the bank. They first complete the need as much as possible, then processing. He is doing organic farming, which involves no use of pesticides, herbicides, gem seeds. Investments are 1.5 2 lakh (150 000 200 000 rupees), while earning is 2.75 3.2 lakh (it varies, because it depends on the crops). He has not taken out loans, because he does not want to get into that circle, he depends only on himself. He would take a loan for the development of business and agriculture. He does not have an infrastructure on the farm. He uses sprinkler and flood irrigation system (for crops that require them). He does not use drip system because crop variety is much; drip needs some distance. If you cultivate different crops at a time, it is difficult to use drip system. However, he is thinking of utilizing 50% under fruit trees. Drip would be used to save the water and its proper use would get the resources to have money. He has developed his own planning with his own resources. He became a farmer: he purchased a land and built a house. He has money, but no infrastructure (land, water irrigation systems). 80% of the people have the land, 20% are labour. Due to wild animals coming to the farm (wild animals, pigs, monkeys, blue bull, parrots), he needs fencing. Same as the other farmers, but living in the farm. Other farmers live in villages, they just build a small house to keep the fruits and vegetables (they build a hut). His farming practices are based on deep thinking about lifestyle and applying imaginative power and innovative ideas. He prefers to face problems, but he wants a pure lifestyle. He mentions purity in every basic need: health, mind, emotional balance and utilizing the resources. He thinks that financial planning should be worry-free, and that family members should be convinced in that. That way they can keep on going for the generations. He was a part of capitalism, but then he went away to have a good lifestyle for generations to come (he thinks that is the only sustainable and quality lifestyle). Even if the system breaks down, or there is no good yield, he will still keep on going, because he wants to find out the ways to tackle the problems. There is no such field where there are no problems. In a city, problems are more severe and beyond our control. Why the lifestyle should be costly? Nature suffices basic needs, not the desires. Todays problems are related to the desires. Why does it matter if you get money when you do not have a peace of mind?

D.7 Interview 7

He is 56 years old and the highest education level he completed is double graduate (commerce, philosophy; so he is not an engineer). His family has 4 members. All family members are financially dependent on him (2 children, one in the 12th grade and the other one in the final year of engineering). He has 12 acres of farming area. On his farm he grows tur dal, soyabean, cotton, wheat and black gram. He invests 2 lakhs (200 000 rupees), while he earns 3-3.5 lakhs. Therefore, his profit is 1-1.5 lakhs (around 1.25 lakh rupees). He is taking out loans. Till now he managed to repay everything, and again he will take loans. He uses sprinkler irrigation system because he thinks that he can save the water that way. He is not using drip system because of the high costs and because of the fact that it is not suitable for the crops he is growing. However, he used to have a drip system in the past (for 8-10 years). The rats were coming and making holes in the system, so his main issue was the maintenance of the pipes. In addition, his crop pattern changed. For these two reasons he stopped using a drip system. So the reasons to stop using the drip system are summarized as: maintenance issues, crop pattern change and costs. In the earlier time he could afford it, he took the loan for that and got benefits. Government helped him with the subsidy. In addition to that he got a loan, which he had to repay later. Because of the crop shift, the system was not useful for him anymore. On the other hand, he would not change sprinkler (because of less maintenance). He is one of the progressive farmers (various people are joining him). The water source that he is using for his farming is an open well. His idea on what he would like to improve on his farm is a fence (he does not have it at the moment). It can protect a farm from wild animals and that would result in less damage (25-30%). Second improvement is a fruit tree plantation. He does not perceive the water scarcity: his farm is near the dam and rainfall is good in the region (annual rainfall 1000mm). He is not planning to stop with farming; however he is not sure if his children are going to continue with farming. Farming is his main income source, that is why he is going to continue. He is doing organic farming, which involves no use of pesticides, herbicides or gem seeds, while the other farmers are using chemicals. He thinks that most important factor for irrigation is finance: It is more challenging in farmers life. When it comes to the use of irrigation systems, he knows the installation and he can tackle the problems (knowledge is there). He would like to keep on developing and getting the price for his produce. His view on climate change is that it is a problem to farming: At this time of the year it should not be raining. If it does, the wheat will get damaged. With cloudy atmosphere, the number of insects increase this leads to the increase of the expenditures for insects. Government policies are not favourable for the farmers because government gives favourable conditions to industrialists . Government keeps the prices in control. If farmers are getting a loan, they need to spend money for the officers (non-efficient system). Rates of produce are the same for the last 10-12 years, while insecticides, pesticides, labour, technology, electricity prices have risen. This means that the profit margin is reducing. Due to climate change you cant produce enough profit. I have to run a family. My son has to be educated. Europe and US take care of farmers taxes on import and expenditure, they give subsidies. On the other hand, India keeps the prices intact (through the government policies). The goods are imported and the produce has a minimum price, which is very unsuitable. while the input prices increase. The main issue is that We, as farmers, cannot fix our own price of our crops and the government is not taking care of us.

D.8 Interview 8

He is 30 years old and the highest education level he completed is diploma in engineering (graduate). His family has 9 members, out of which 3 are financially dependent. He has 13 acres of farming area. He does only farming. On his farm he grows cotton, soyabean, tur (pulses), wheat and green gram (pulses). He invests 2.5 lakhs, while he earns 7-8 lakhs. He has taken out loans for the development of land, purchase of land and vehicle. He uses a sprinkler irrigation system because it is not too costly, it requires low maintenance compared to drip system. Drip system is too hard to maintain because of rats and squirrels that constantly damage the drip pipes. He knows how to install and maintain drip system (action and cognitive planning are there), however the crop pattern also does not suit drip system. As a water source for his farm he uses an open well. He is not facing any water issues now, he also perceives that he will not be facing them in the future. In the future he is staying only with sprinkler system. As an improvement on his farm, he would like to put fencing. Later in the future, he would like to introduce automation and use a drip system in the case he changes crop pattern. As far as the government and subsidies are concerned, his opinion is that government provides subsidies only on paper. He wants that his pattern is seen, i.e. he wants to have an influence on other farmers. He will continue with farming, however, he will try to make money from other sources. Due to climate change it seems not to be sustainable to earn 5 lakhs every year. He wants to rely a bit less on farming (because of climate change). He is aware that due to climate change, unfavorable prices, production limit, increased requirements and unfavorable government policies, there are less possibilities to try to find a solution to earn more in farming. He is selling in the market, which means that he is in the hands of the government (market is international). He shifted to the sprinkler system. The reason for this is because it covers more area than flood irrigation in the same amount of time (100 seed; 70 seed). In addition to this, some seeds go away in the flood irrigation (% of germination of seed is more in sprinkler, that is better). For flood irrigation, you have to be alert. If you have sprinkler system, you can turn it on and be free for the next 3 hours. In flood irrigation, there is no water control (in terms of amounts). In order to shift from sprinkler to drip system, he should grow crops with the same crop pattern. Now he grows cotton, and then he grows soyabean (drip does not work). If he starts growing fruits and vegetables, then maybe there is a chance to shift to drip system. Sprinkler you can use anywhere, there are no limitations. If you want to use a drip system, you must also have a sprinkler system. This means that having a drip system entails having drip and sprinkler system together.

D.9 Interview 9

She is 42 years old and the highest education level she completed is 4 th grade. Her family has 4 members, out of which 2 are financially dependent. She has 5 acres of farming area. On her farm she grows cotton, tur and wheat. She invests 120 140 000 rupees, while she earns 60 70 000 rupees. Profit is thus 60 70 000 rupees. She has taken out loans which she repays every year. As the water source for her farm she is using an open well. She is using irrigation systems: sprinkler and flood (sometimes for wheat), depending on the specific situation (for example, crop height). She is not using drip system because of the costs and small animals that could damage it. Even if she had enough money, she would not use drip system because it can get damaged due to 8 types of wild animals in vicinity (monkeys, pigs etc.). Sprinkler system is the hard structure. When it comes to the improvements on the farm, she would like to have fencing. However, the fencing does not work for monkeys. She wants to manage extra water coming from the jungle. She thinks that she has sufficient amounts of water for her farm. She says that water scarcity could be felt in summer and occur due to water level decrease (this is her perception). This problem could be solved by deepening the well. The reason why she shifted from flood to sprinkler system is because of the reduction of time and reduction of the required water amounts. She got to know about this from her neighbours (by seeing what they are doing, she shifted from flood to sprinkler). She thinks she is able to tackle the problems occurring during using of the sprinkler system. She is planning to continue with farming (for her family). The solution to stop taking loans: she has a plan of business in mind (to start making edible products from wheat. That way she can earn 20 000 rupees in 3 months) (this product used to be consumed during summer in the past, when there is scarcity of vegetables, so this is a product to eat instead). She has been doing this business since last 5 years. Limitations are that you cant get more than 20 000 to 30 000 rupees. She has two daughters and both of them are talented (agriculture, operation technician). If the problems of wild animals and labour get solved, farming can improve and they can live in a better way. Working hard, but not getting right price and produce. I want to do farming happily. If she gets an aid for fencing (from one side of the farm only), she can be happier to do farming and produce more. Her limitation is that her farm is near the jungle. She has been facing the same problems for 10 years and she got fed up.

D.10 Interview 10

He is 27 years old and the highest education level he completed is graduate in agriculture. He has been doing farming since the age of 16. He has 12 acres of farming area. On his farm he grows cotton, tur, soyabean, sugarcane, watermelon, green gram, wheat, vegetables (for home consumption), muskmelon, ginger, etc. His expenditures are 3 to 3.5 lakhs, while his income is 7 to 8 lakhs, thus having a profit of 4 to 5 lakhs. He is taking out and repaying loans regularly for already 10 years. As a water source for his farm he is using an open well. He is using drip and sprinkler irrigation systems (as per the need for the crop). He thinks that drip system saves water and time, no labour is needed (because fertilizers are given directly to the plants). He could easily pay for drip system. Government gave him a subsidy (70-80 %) to buy it (68 000 rupees), making him one of the few who got a subsidy from the government for the drip system. Because his farming area is 12 acres, he could apply for a subsidy. Subsidy amount varies according to the land holding. As the improvements on the farm, he would like to plant new types of crops, put fencing (more expensive than the drip system), have both horticulture (add banana plants) and floriculture. He thinks that if water is used less there will be less scarcity in the future and that way the water may be saved. He says that water use is growing as an influence of climate change, so water scarcity comes due to that. He realized that because he did not have enough water, so he shifted to drip system to try to save it. He got the knowledge about this system from advertisements, went to see it in another village and got inspired that is when he decided to get it. He is not planning to stop with farming, because he is doing it as his only job. He says that labour is the problem for any kind of work in the farm, because it became less available. He is inspired to use irrigation by the fact that it can help in saving water, and also earning money from the each drop of water.

D.11 Interview 11

He is 48 years old and the highest education level he completed is bachelor of commerce (check). His family has 5 members, out of which 4 are financially dependent. He has 10 acres of farming area. On his farm he grows orange, cotton, soyabean. He invests 5 lakhs, while he earns 1 to 1.5 lakhs, which means that he is in loss. He is taking out crop loans from national bank. He is using drip and sprinkler irrigation systems due to water scarcity and labour. He is facing problems related to labour and problems in electricity maintenance (blockage), so he needs to have high (maintenance) investments for that. He has knowledge on how to solve that, so he is putting acids. This knowledge comes from the fact that he has a shop of pesticides, which is his part-time business. With this business he earns more money which he can use for the repayment of the loan. The cycle of taking out the loan and repaying it back is going on. He is not planning to stop with farming, because his whole family is doing it, it is their tradition. As his water source on the farm he is using a tube well and an open well. He made his own investment in the drip system, he did not take it out from the government. He is planning to keep on using it. Some farmers are practicing new fashion, which means using drip and sprinkler system simultaneously. On the contrary, old farmers are applying flood irrigation. He needs an improvement in farming, however, he is not sure what it is exactly. The current problem he is facing is the scarcity of labour and its high cost. He feels that he needs more production on his farm. However, he is not sure what exactly he wants to increase. He switched to the drip system due to scarcity of water and due to the fact that drip required no labour, so investment money can be reduced. This change was possible because his crops are suitable for drip (orange) and sprinkler (cotton) system.

D.12 Interview 12

He is 30 years old and the highest education level he completed is bachelor in agriculture, making him both a farmer with practical experience and education. His family has 5 members, out of which 1 is financially dependent (his wife). He has 12 acres of farming area. On his farm he grows orange, groundnut, cotton, soyabean and wheat. He has income from farm, but also a business of pesticides and a dairy farm with 5 cows. He is taking out loans (2 per year, one for businesses and the other one for farm). His expenditure is 2.5 lakhs per crop (for 12 acres; 4 to 5 lakhs include labour). He has 50% of loss, thus no profit from the farm. He is using drip, sprinkler and flood irrigation systems, for watering purpose, time management and labour reduction. The reason to have these 3 systems is the different crop pattern. Drip he is using for orange. If the water requirement increases, then hw uses a flood system. He got a subsidy for sprinkler (12-20%) and drip (30%) systems. As his water source for the farm, he is using a tube well and an open well. Since he is highly educated and has been working on the farm, he has all the knowledge. He is aware that when it comes to the maintenance costs, the drip system has more costs. However, he says that they are still affordable. It happened that rats broke the pipe, which adds up to the maintenance costs. We always need improvement on our farm, he says. There is an ongoing climate change, which brings along the weather change and its varieties, so farmers need to resist weather conditions. He is not planning to stop with farming. Working in farm is giving peace to him. However, weather conditions make him worried. He says that he cannot face that much rain, and the problem with it is its wrong timing. He observes that fungal infections are declining yield of crops. If they last 15 to 20 days, they make stress to the plants and result in a loss of 1 year crop. We cannot do anything about the weather, he says, and We want to manage the things easily. He knows that whatever the crop is grown, it needs to be suitable for the climate. However, climate is changing. On the question of How to manage that situation?, he says that that is a proper question! Knowledge and understanding of the field is needed in the first place. In addition, it should be expanded to other people. We would like to have the information on cropping patterns according to climate change, and on how to bear temperatures and rain. That is needed to defend weather conditions, he says. We need to change practices to overcome challenges related to the changing weather, and for that we just need information. That is why the government should do the knowledge and technology transfer. Since farmers are getting low prices, he would like that they are at least given some assurance for seeds. This is not the case at the moment, and at this point government pays back the loan of farmers sometimes. Reduce cost of seeds!, he says, expressing that his point of view is that the government should rather help farmers with seeds, and not repayment of the loan that farmer has taken out (as in some cases repayment is paid by the government to the bank). In addition, he states that labour problems are common. Furthermore, farmers have enough knowledge but they cannot practically implement it (e.g. which pesticides to use on what type of crops, how much fertilizer to apply). He suggests that on percentage basis farmers do not have a sufficient knowledge. He believes that government has to educate the farmers through, for example, trainings program. Make them independent of you! Increase understanding. He highlights the importance of information to a farmer saying that he will either get 10 or 100 quintals of yield on 1 acre of land this difference farmer can make through attending a field school and by being given high quality seeds. Farmers are not getting the proper money of how much they should invest and rates are decided by local governments. There are two seasons according to the monsoon: Kharif and Rabi. In the rainy season, soyabean, cotton and groundnut are grown, during the period of 4 months. After that, the winter season starts, in which 2 to 3 crops are grown. When sowing, land needs to be cultivated, where tillage practices play a role. No farmer will tell you the truth, he says. In addition, the income of farmers is increased only on paper. The reason for this is that ifsomeone is conducting a research, usually it is avoided that the negative impacts are shown, which results in the manipulation of the values. Farmers are not taking proper records on how much they spend. This can bring him into the loss, and to cover it, he is taking a loan, after which he has to do the repayment, on which he gets an interest rate. This farmer has 2 to 3 supporting business, so regular income is there (from poultry or fish), so he has enough to survive. For this reason he is doing a light agriculture business. He states that every problem has a solution, but the solution is unknown to the farmer due to lack of information. Soil technology should be done by knowledge. Farmer is a kind of a man who solves the problem well. He can make a herbicide that is not out there yet, he is such an expert, talented man, yet he needs information for both a problem and a solution.

D.13 Interview 13

He is 45 years old and the highest education level he completed is 12th grade. His family has 6 members, out of which 3 are financially dependent. He has 6 acres of farming area. On his farm he grows leafy vegetables, tomato, cotton, wheat and chana. He invests 160 000 rupees, while he earns 50 000 rupees a year. He would like to grow orange, because his earning can become more (it can go up to 1 to 1.5 lakhs). He is taking out loans only for crops. He has a source of income other than farming, he is doing labour work (driving tractor on other farms). He is using drip and sprinkler irrigation systems. He has various crops, so that is why he needs appropriate systems for that. For orange he uses a drip system. He is using drip irrigation system because of saving water, because it requires no labour and because fertilizers can also be used inside the system. As a water source on his farm he is using an open well. When it comes to the improvements on his farm, he would like to install a wire against animals, to have compounds(fencing so that animals do not damage his crops). There are two types of fencing: solar (requires no electricity) and electric. He says that the government is responsible to keep the animals away from the farms: If government gives proper food to the animals, they wont be coming to our farm!. He is not planning to stop with farming because he is not educated, so he has to rely only on his farm. However, he has to work additionally for a living. Overall, farmers need help from the government: they need to earn more money from selling the crops, and they need a person from the government who can give good information so that they can grow more. At this point government does not provide anything to them.

D.14 Interview 14

He is 65 years old and the highest education level he completed is 10th grade. His family has 2 members (him and son). Son is financially independent. He has 25 acres of farming area, thus he is known as the king of the village. On his farm he grows orange, cotton, soyabean, groundnut and vegetables (onions, tomatoes). His investments are 4 to 5 lakhs, while his earnings are 20 to 25 lakhs (in the case of good crops), or 5 to 10 lakhs (in case if not that good crops) in the last 5 years. He mentions that the income of only 5 lakhs is a consequence of climate change: rain water is destroying the crops. As a water source for his farm he is using an open well. More precisely, he has 5 electrical motors and 5 wells, so he has enough water. He is not taking out loans due to the fact that he has to pay back money for his wife. He is using all types of irrigation systems: drip system for oranges, sprinkler system for soyabean, wheat and cotton (he knows the needs of the crops). He got help from the government to buy an irrigation system: 25% of the money he got in the form of a subsidy from the government, while 75% of the investment he made on his own. He has 50 years of experience in farming, thus also the knowledge on using these systems. As the improvements for his farm, he would like to make his fencing system more protective against forest animals. The main challenges he encountered in the past were electricity supply, because it was not proper (in 24 hours he could get electricity for 8 hours only). The electricity is needed both for irrigation and for getting the water out of the well. During the time of 1 week, for 3 days he was getting it just at night. In the last 5 years, the number of times that he is irrigating is insufficient for him to have his initial production. He mentions 4 reasons for lower production: forest (wild) animals, electricity supply, climate change and labour problem. People working as labour migrated to the cities to go to companies due to bad working conditions. He plans to continue with farming, but he is also considering to start a bigger business to earn more. As far as the help from the government is concerned, he says that a guidance person comes, but he does not really provide a proper knowledge. He is facing a very big loss because of the financial burden from the marriage of a daughter and son from the money he earns. Problems that he anticipates for the future are mostly labour problems. He cannot produce alone on 25 acres, which would be the case without the labour force. He is using the drip system to give fertilizers to the crops. I am working 24 hours in the field. No festivals for me, he says, adding that what made him better farmer than others is a hard work. Nobody shares difficulty. You have to take out your blood and sweat, because farming is not easy, highlighting that hard work is the most important factor for the success in farming. Animals are coming to his farm during the night. The government does not allow to kill animals. But they also do not keep them in their own area (jungle), so they are coming to the farm and destroying the crops. His last word is: Give all the time to crops, saying that other farmers are not giving proper attention to crops.

D.15 Interview 15

He is 49 years old and the highest education level he completed is bachelor of commerce. His family has 4 members, out of which 3 are financially dependent. He has 6 acres of farming area. On his farm he grows cotton and soyabean. He invests 1 lakh, while he earns 85 000 rupees. Therefore he does not have any profit, i.e. he is facing loss of 15 to 20 000 rupees. He is taking out loans for crops, i.e. for seeds and insecticides. He is using a sprinkler and a flood irrigation system. He is growing only cotton and soyabean now, so he has sprinkler system. In a year time he is planning to get the drip irrigation system for growing oranges. He would do it without subsidies, by investing money on his own if he has good crop yields with which he can earn that much money. Government has helped him when he faced loss. For every 1 ha of land (2.5 acres), and 1 lakh of loss, he can get 10 000 rupees. If he would get the money needed to invest in irrigation, he could look after his farm later. His water issues consist of the excess amount of water (due to heavy rain) that is causing the damage to the crops. No water scarcity is felt. The soil is poor and it has no sucking capacities, once the water level rises. He says that he cannot do anything about that. He has no water in the well he is using for farming. He gets the water for both farming and himself from the farm pond that he is sharing with another farmers. If there is no water, there is no farming, I am sitting at home, he says. In that case the government is providing some amount of food. He is getting a ration card, which allows him to get 2 kg of food per month, which is very insufficient. I only eat dal and rice, he adds. He gets only bad feelings about this situation. There is a nearby dam that serves as a water supply, but the water is only coming downstream, leaving his upstream village without water. He thinks that there is no possibility of building another dam, which means no possibility to store water. This makes him completely dependent on rain. He sees no solutions to improve the current situation, he relies only on what water is available. Rice and wheat are grown, and their patterns are adapted. He found another sources of income, so he is selling the milk from the cows. He himself is a labourer. He is completely dependent on climate, no improvements on the farm are planned. With the ongoing climate change he does not know when the rain will come and how to deal with that. He will take out the crops when the rain is coming. If the farming stops, he will migrate to a city. If crops are grown rapidly, wild animals come and destroy everything putting fencing for while the crops are in the field would potentially solve the problem. He says that drip system could not help him with cropping it is not suitable for cotton growing (since drip pipes need space), even though it saves water.

D.16 Interview 16

The highest education level he completed is graduate. His family has 2 members (him and his mother). He has 5 acres of farming area. He grows orange trees (on 1 acre). As a water source for his farm he is using an open well. He is using a sprinkler irrigation system. In his farming he is facing water problems related to climate change: when there is a necessity for water, then there is no water available. On the other hand, seeds get vanished due to excessive amounts of water. He is facing problems with growing soyabean due to the inappropriate climate for this crop. In some cases he has more, in some cases he has less water, i.e. water has wrong timing. He has not enough money to put fencing around the farm. Then the animals come and the crops get destroyed. He needs 2 to 3 lakhs for fencing of a farm area of 5 acres. He is growing oranges and has no drip irrigation system due to money issues. Government wants to provide money, but first farmers need to invest. Drip system is applicable for oranges only, while sprinkler is applicable for orange, soyabean cotton, i.e. it is applicable for multiple cropping. He is investing 82000 rupees to 1 lakh, while he did not report his income. He mentioned that his profit is 20 to 50000 rupees (and he uses it for the next season farming). His actual living condition is surviving from breakfast to dinner. He does the season-wise cropping: in rainy season (from June till October) he grows cotton and soyabean, while in winter season he grows wheat (from October till March). Tomatoes and red chili he grows all the time. The income from the soyabean he uses to invest into the next season. For cotton growth he uses fertilizers. However, fertilizers and seeds get flushed away because of rain. About farming improvements, he says that government should provide subsidies (for well, fencing) and he feels that he needs proper knowledge. People from Baramati (district in Maharashtra) are getting proper facilities (crop loan, bank loans, cars - farmers are living good life and they are getting the good price in the market best price for their crops). He thinks that the government is responsible to provide proper facilities and proper guidance. If governement helps with this, only then he can be a good farmer and live a good life. He believes that same practices from Panjab and Baramati should be followed in Vidarbha. The others are also facing problems, but they have the proper strategies for that. What is thus needed are proper fundings and the proper knowledge on the farm. He says that agricultural officers do not provide proper training and he is feeling sad and frustrated. At the moment, he only does farming, and he does it only for eating. He cannotstart any business because he has no funding at all. His last word: Government facilities in Vidarbha!, Farmers should be capable of living a good life all over Maharashtra!

D.17 Interview 17

The highest education level he completed is 10th grade. His family has 5 members and no one is financially dependent. In the earlier times (10 years ago), soyabean production was a lot in this region. After using pesticides and insecticides, soil quality degraded and its fertility declined, which resulted in less production. Cropping of soyabean used to happen 2 times in 1 season. Now it is only 1 time and in addition to that it is not growing properly. Due to facing huge loss, soyabean farming has stopped. Usually the soyabean plantation is being done between July and October. However, he has not had soyabean for 5 years, thus he has only faced loss. For this reason he is not planning to start again with soyabean. Now he is growing cotton, but in order to make earnings out of it he has to wait for the whole year (from July till March). If focused on cotton, not wheat, other problems occur. Proper amount of cotton growing from the flower is insufficient because of certain insects, so he would still be facing loss. Instead of cotton, he puts wheat (in case cotton does not work) to make sure he has some kind of production. He has an open well in his farm: first 3 months he is using rain water, then other 3 months he is using water from the well, so he has no water problems because of the well. He grows sweet lime (Mosambi) to bring him profit. He invested 2.5 lakhs in his farm, but he cannot earn even 50 000 rupees. He is using flood and drip irrigation systems (flood for planting time and drip in the summer season when water level drops, so that he uses minimum amount of water only as much as plant needs). In case he plants wheat, he uses a sprinklersystem. The type of soil he is having is not capable for growing other plants. In summer season no plantation is done. If he has more water he plants groundnut. Water source (water availability) is the problem and he has no solution for that. He does not have a water well. A well requires 3 to 4 lakhs of expenditure and he is not able to invest that much. If he would take that much as the loan, he would be facing loss in the next 10 years to get that loan back, so he wants government to provide him facilities. Government helps with digging the well, but money it gives is insufficient to dig the well (it provides 2, but 3 to 4 lakhs are needed). The government gives not enough money because there are too many farmers. In Panjab there is a river, so they do not depend on the rain. However, Maharashtra state has not so many rivers.

D.18 Interview 18

He is 52 years old and the highest education level he completed is bachelor. His family has 4 members. He has 40 acres of farming area from the combined family. On his farm he grows rice, cotton, chili plantations and pulses. He has taken out crop loan, then he has repaid it (he is using it for labour work and to buy the seeds), He is taking out water from an open channel and applying furrow irrigation for rice. He is also using drip and sprinkler systems (cotton taking on drip). In this drip system pipes were damaged, so after having the system for 8 years he replaced them. He got the drip system from the branded company, so the pipes lasted for a long time. If a farmer is getting them from a local company, that could be a problem because they can get damaged way earlier. He gets water in the time he requires it, so he is not facing water problems. He has a problem of electricity in daytime. This results in the problem to run the irrigation system. In addition to this problem, he has a problem with fencing. Electricity is available for 4 days during the day, and then for 3 days during the night, in the period from January to June (including the hot weather season). In the night time there is more waste of water, since he goes to the field, he starts the motor and then goes back home. He has no groundwater problems everything is available. Main problem related to farming is financial (no money for the scheme). He invested money and he is not getting a subsidy for already 1 year. He invested 2.5 lakh and only got 90 000 from the government, while the part of 173 700 is not subsidized. The reason for this is because money is coming in installments. He is a farmer who has capacity to invest and that is why he adopted the scheme. If a farmer has an interest, but no money to invest, he will not get any benefit out of the governmental scheme. He is not following what the other farmers are doing because he has his own practice and he is known as an ideal farmer in the eyes of others.

D.19 Interview 19

The highest education level he completed is bachelor in math (educated farmer). He believes that if he gets a drip system, his yield would double (or he would have 1.5 to 2 of the yield amount he currently has). Now his rainfed yield is 10 quintals per acre. With drip system it would increase to 15 to 20 quintals per acre. He knows that fertilizers are given both manually and through the drip system and as in rural areas there is a labour problem, drip system with fertigation would help to overcome the labour problem. In this case, there is no cost saving, but only the labour problem is overcome (20 grams fertilizer compensation he can apply 5 times through drip system, or manually apply to match the quantity). Yield is affected by the timing of fertilizer. Drip system is capable of water and fertilizer simultaneous application. In the village of Amadi there are 200 to 250 farmers, but only 4% have adopted drip or sprinkler system. The ones who adopted are usually educated, from better family, with good paying capacities in the initial stage. Only these farmers take benefits of the government scheme. In order to adopt the facilities, farmers should have money in the initial stage. He thinks that government should give loan facilities at the initial stage (subsidy amount to be transferred to his account). Earlier, government used to give subsidies at the initial stage, but then service providers started malpractices. In order to control them, they adopted direct benefit to the farmer system, but then farmers started using money for other things than technology adoption. This farmer thinks that the solution is to receive loan at initial stage. Major problem is thus availability of funds at the initial stage for execution for drip and sprinkler system according to this farmer. He has no money for agricultural purpose (no money for seeds) due to late payment from the government. He suggests that the solution for this could be that if the government does not pay this money on time, then it should pay it with an interest rate.

D.20 Interview 20

He has 24 acres of farming area with the combined family. On his farm he grows cotton, chili, petty, rice and gram. He has land holding issues, for the reason that 5 people share the land, approximately having 4.8 acres per person. Because of the reason that family members are sharing the land, they are getting facilities and surviving easier. He reports the benefits of the combined farming in the form of a family support. If he goes somewhere for 2 days, someone will look after his plants, which would not be the case if he was an individual farmer. Marketing problem is also not there. If a farmer is individual, he grows vegetables, but at some point he also needs to go for marketing of his vegetables, in that time he can encounter problems in the farm (because he is not there). As the water source for his farm, he gets water from the canal. He is using flood irrigation and a tube well. He is not using drip and sprinkler irrigation systems due to financial conditions. During the period of 12 months, his total yield is 8 metric ton (8000 kg) per year. For this yield he gets 18 to 20 rupees per kg. In the terms of increasing profit, drip system would increase the yield and he would go from metric ton to 10 metric tons per acre. In addition to this he would save water and be able to do fertigation through drip system. If he is using flood irrigation, he can irrigate 5 acres of land. With the same amount of water, he would be able to irrigate 8 to 10 acres by using drip system. The benefits of drip system for him would therefore be more land coverage with the same amount of water. He notices that he is facing problems due to climate change: rain is coming heavily, it affects soil and plants, so he is facing 50 % loss in the recent years. Additionally, the use of pesticides has grown due to climate change effects felt throughout the rainfall events. Due to plant disease, yield is affected and there is a loss (reduction) in yield. In the time period of 1 year, he spends 60 000 rupees per acre for the pesticides. He needs 100 labour per acre per year, with 250 rupees per person per day. He needs 40 000 rupees for fertilizers and 1600 rupees per acre for seeds. Electricity (for the irrigation pump) costs him 2000 rupees a month (taking into account the price of 500 rupees per acre per month). He also uses open tube well to lift the water. The transition from flood to drip system would mainly benefit him in 20% increase in income, water saving and would help solve the labour problem in fertigation (by automated application of fertilizers through the system itself).

D.21 Interview 21

This interview presents the discussion with a key informant about problems of individual farmers versus benefits of the group. For an individual farmer, the input cost is higher. A group of farmers purchase at a time for the whole group and that way lowers the rate. When the seeds are applied once at a time, the virus is not transferred from field to field (and the time for virus to come again is longer). This affects the costs of pesticides. Due to non-application of group farming, the farmers are not getting benefits in India. Groups should be formed crop wise (in order to reduce the input and labour cost, and raise funding for the adoption of government schemes). The group of farmers has increased holding capacity. They can store the quantities required for businessmen and that way they increase their bargaining power (and get higher rate for selling the produce). Farmers think that if the agricultural officers give proper advice, new technologies could be adopted and yields could be increased. Instead of that, farmers are getting useless visits (when 80% of the sowing is completed). Timing of the visits of officers can bring more benefits. The officers give generalized guidance, whereas farmers need specific guidance of each and every crop. In relation to technology, they need to know about the period of sowing, application of fertilizers and application of water. Pesticides and fertilizers company producers give pesticides to the farmers for the first time. Second time they give also the products that farmers do not need, but they still have to pay in case they want to have the suitable fertilizer again. Which fertilizer is useful to the farmer, cost of that increases. In addition to that, the producers give another compulsory pesticide with the one needed (even though there is no reason to purchase that). Green revolution: production increased by the application of fertilizers and pesticides, however, the result of excess application is the decrease in the land carbon content every year. Once the fertilizers and pesticides should be applied, the input cost increases, which is very unfavourable to the farmers.

D.22 Interview 22

The key informant described the process where the government gives schemes for farmers to help them adopt micro irrigation technologies. Even though this process is meant to help them, in reality, they face a lot of obstacles with it, and that way become reluctant to adopt the micro irrigation systems. To begin with, farmers are mentally prepared for the financial year, and it is very hard for them to deviate from their plans and practices. In addition, cropping patterns dictate what kind of irrigation system a farmer needs. Once a farmer decides to apply for a subsidy from the government, he needs to be able to invest in it first, and he also needs to be prepared to install the system on his farm. That installation cannot happen suddenly, since he is growing crops on the farm. The government gives a subsidy to farmers through the lottery process. In order to apply for it, farmers need to make a lot of effort. In order to get the benefit of the scheme, they need to plan for money and plan to empty the field, in other words, a farmer has to arrange everything, and then the question is What is the purpose of a subsidy then?. The farmer goes to a taluk, a place for administrative purposes. In registration, he takes a lot of effort, time, and money. After doing all the steps, he may be chosen in the lottery, or maybe not. If he gets chosen, he still has to arrange 100% of the costs on his own. In addition to this, he has to alter the field to be barren. Only if he had done that, the agent would give 55% of the money. This leaves poor farmers in a position where they cannot even try to apply for the subsidy (except for farmers who are prone to corruption). To sum it up, farmers have to arrange for the money and keep their fields empty. Due to a lottery system, farmers have no confidence in getting a subsidy. They are dealing with uncertainty. How are you going to execute the scheme?, How will you arrange for the money? are becoming important questions in this situation. What else can be done to use micro irrigation, aside from governments help (in the case there was no subsidy)? Farmer has to be taught of economical use of water. He has to take advantage of irrigated crops. In Maharashtra, most areas are with no irrigation facilities. Annual rainfall varies between 1000 and 1600 mm in the districts of this state. Only 30% of the surface area is under irrigation, and 70% of the surface area is rainfed. Out of 30% area that is under irrigation, only 5% area belongs to micro irrigation. Farmers who have micro irrigation are usually farmers who are growing horticulture crops. Specifically, drip irrigation has no practical use with traditional crops, while flood irrigation is suitable for them. This makes farmers going for a change in cropping patterns the ones who usually adopt drip irrigation systems. To give an example, if a farmer grows cotton, every year he needs to take out the irrigation pipe. This process takes a lot of effort and is considered to be a tedious job. Because of that hassle, farmers would be getting tired. In addition, for anything they have to harvest and replant, there is no guarantee of success. Only horticulture crops give assurance. We have to motivate farmers to change the cropping patterns, he said. This could be done, for example, by keeping traditional crops on 4 acres, while on 1 acre farmers could try to plant new types of crops. On the question of who is changing the cropping pattern, he says that those are mainly farmers who have high investing power. If a farmer is surviving only on farming, he would most probably not take the risk of changing his cropping patterns. In addition to the risk related to the stability of yields, when growing new types of crops, the challenge would be to find a proper market to sell them. Before the new product becomes recognized, its purchase is not assured. Furthermore, with horticulture, a farmer can wait for many years before he collects the produce from the farm. The whole process of micro irrigation technology adoption is meant for the farmers who can invest a lot. Schemes unfortunately do not work for the poor farmers. However no one is raising problems at the governmental level, people act blind and ignorant. One of the potential solutions to the financial obstacles of farmers is working in a group of farmers, where there is a collective working mentality, and farmers could arrange finance through groups. If an individual farmer is working on 5 acres of land, that is equivalent to 20 farmers working on 100 acres of land. However, with united efforts, they can develop a processing industry (e.g. for lentils), or build a holding capacity. The idea of collectivized agriculture could thus bring benefits to all the individuals in the group. More farmers could also have easier access to a water source, for example, a river. Subsequently, water could go from its source through the farm pond towards the fields, where either a sprinkler or drip system is applied. Lift irrigation could therefore increase the yield and enable the growth of 2 types of crops instead of only 1 type. Another difficulty in diverting cropping patterns is the lack of road facilities, which makes farmers unable to have a continuous supply of seed inputs to the field. The dream of every farmer is to have a dirt car that runs in mud then he could take inputs to the field at any given moment. I dont want your facility! What I can get myself, I will get, says a farmer, driven by his bad experience and by having developed a low self-confidence mentality. There is a lack of trust that the system works. Trust building cannot be built from a paper form. Sending a paper form should be followed by a phone call and personal conversation that way farmer will get engaged in a process more easily. While farmers often hear that everyone is going to come and teach them, they have no time for experiments. Farmers are time-limited people. The key informant also says that while this situation may seem sad, is purely how the system is. He adds that farmers normally work considering all the points (not only technology). According to him, the acceptable formula would be that if something is easy, the mindset changes instantly. An easy and pleasant process would result in acceptance. Once you make something simple and socially acceptable, everyone will adopt it. He highlights the technology transfer problem rather than the technology itself for the reason that the mind of the accepter is not taken into account. An agricultural officer has knowledge of inputs, cultivation, soil, water, and environmental conditions in fragments (pieces). On the other hand, farmers are in need of an integrated system of teaching.