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Exploring smallholder farmers' climate change adaptation intentions in Tiruchirappalli District, South India

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Abstract
Smallholder farmers are disproportionally vulnerable to climate change, and knowledge on cognitive factors and processes is required to successfully support their adaptation to climate change. Hence, we apply a qualitative interview approach to investigate smallholder farmers' adaptation intentions and behavior. The theoretical Model of Private Proactive Adaptation to Climate Change has guided data collection and analysis. We conducted twenty semi-structured interviews with smallholder farmers living and working in Tiruchirappalli District in South India. We applied a qualitative content analysis by combining a content-structuring with a type-building approach. The systematic analysis resulted in four types of smallholder farmers that differ in the formation of adaptation intentions. Three of these types intend to adapt and follow different adaptation plans: (i) innovative measures that are new to the farm or region and are considered effective to overcome the detriments experienced from past efforts, (ii) contractive measures such as selling land or livestock, and (iii) retaining past measures they consider effective while relying on their access to resources. Only one type does not intend to adapt, emphasizing that rain is absolutely necessary to continue farming. We conclude that public efforts could focus on education and training programs adjusted to the farmers' needs, measures to maintain or increase the fertility of land and farmers' livelihood, flexible water conservation technologies and regular checking of dams, fostering combined adaptation and mitigation measures, providing access to loans up to debt cancellation, and offering physical and mental health programs.

Keywords Agricultural adaptation behavior · Climate change perception · Qualitative analysis · Farmer types · Drought · India

Introduction

Smallholder farmers are particularly vulnerable to climate change because of their high susceptibility to mostly detrimental impacts and their limited capacity to adapt (IPCC 2019). Climate change impacts are likely to increase in severity in the next decades and are projected to be prevailing where vulnerable people live and work, particularly in South Asia (Byers et al. 2018). For India, which represents a large share of South Asia (IPCC 2022), projected increases in average temperatures, summer heat waves, daily precipitation extremes, variability of monsoon precipitation, and severity of drought conditions (Krishnan et al. 2020) will likely result in declining agricultural production and amplify food insecurity (Mendelsohn 2014; Cai et al. 2016).

These projections underline that climate change adaptation is critical for smallholder farmers in India, suggesting to conduct research that may finally enable adaptation behavior. While individuals and households are critical to implement adaptation measures on farms, governments and regional organizations can support smallholder farmers if they know about their formation of adaptation behavior. A recent meta-analysis finds that researchers have primarily investigated risk experience and perception, while other cognitive factors and processes that may motivate adaptation remain underexplored, particularly in countries of the so called Global South (van Valkengoed and Steg 2019). Exploring cognitive factors and processes of adaptation planning may thus lay the foundation for effective interventions of governments and regional organizations and facilitate capacity building.

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Smallholder farmers contribute substantially to food production and food security (Samberg et al. 2016), with varying shares consumed by the individual household or family. However, they manage their farms under structural constraints such as limited access to land, water, labor, capital, markets, technology and education (Khalil et al. 2017). Accordingly, they often suffer from low competitiveness and marginalization, and face disproportionate challenges with respect to climate change adaptation.

Knowledge on climate change perceptions and adaptation intentions is key to successfully empower smallholder farmers. Indian farmers' climate change perceptions have been compared with reported data (Vedwan and Rhoades 2001; Tripathi and Mishra 2017), linked to implemented adaptation measures (Dubey et al. 2017; Funk et al. 2020; Lone et al. 2020) or both (Banerjee 2015; Baruah et al. 2021; Datta and Behera 2021; Dhanya et al. 2021; Dhanya and Ramachandran 2016; Varadan and Kumar 2014). Furthermore, investigations have focused on the availability and (female) farmers' utilization of climate information, crop insurance, training programs and extension services (Kumar et al. 2011; Kakumanu et al. 2018; Rengalakshmi et al. 2018; Dupdal et al. 2020), farmers' willingness to pay for linking wastewater management with irrigation considered as a potential adaptation measure (Saldías et al. 2017), crop production and diversification strategies of female farmers (Connors et al. 2023), the importance of public, civic and private institutions to facilitate adaptation (Banerjee et al. 2013), and on human, social, natural, physical and financial assets and capitals enabling or constraining adaptation (Brown et al. 2019). Data on farmers' climate change perceptions and adaption intentions were predominantly collected with structured or semi-structured questionnaires (Varadan and Kumar 2014; Aryal et al. 2018a, b; Funk et al. 2020; Lone et al. 2020; Bhalerao et al. 2021; Jha and Gupta 2021; Baruah et al. 2021), qualitative methods (Banerjee et al. 2013; Banerjee 2015; Brown et al. 2019; Dhanya et al. 2021; Dhanya and Ramachandran 2016) or mixed methods approaches (Basannagari and Kala 2013; Dubey et al. 2017; Singh et al. 2020). These approaches have been complemented with participatory modeling, for instance, to visualize scenarios focusing on efficient groundwater management (Matham et al. 2023), and with participatory interventions informing farm experiments and crop system simulations to identify adaptation measures that are effective under changing climate conditions, feasible on the respective farms, and popular among the farmers (Hochman et al. 2017a, b).

However, the analyzed literature focuses on demographic and socio-economic factors to explain adaptation intentions and behavior and does not go into detail with respect to cognitive factors and processes. For instance, several studies find that age, gender, education and experience of the farm manager influence adaptation behavior (Aryal et al. 2018a, b; Funk et al. 2020; Lone et al. 2020; Jha and Gupta 2021). Others show that farm and household size (Lone et al. 2020; Baruah et al. 2021), plot characteristics (Aryal et al. 2018a, b), non-farm and total household income (Jha and Gupta 2021; Baruah et al. 2021), and farm endowments (Funk et al. 2020) are correlated with climate change adaptation. Furthermore, the use of extension services (Funk et al. 2020), and access to markets (Aryal et al. 2018a, b), water and financial resources have been identified to impact the likelihood of Indian farmers to adapt to climate change (Baruah et al. 2021).

Though these studies reveal the explanatory power of demographic and socio-economic factors, the relevance of cognitive factors and processes for adaptation intentions and behavior has also been emphasized for countries in the so called Global South (Singh et al. 2016). Cognitive factors and processes influence farmers' adaptation intentions and behavior. They denote that farmers collect, select, structure and interpret information, while operating in a broader socio-environmental context. Such cognitive factors and processes are organized in behavioral theories, which are used to explore, describe and explain how farmers intend to adapt to climate change.

The Theory of Planned Behavior, the Model of Private Proactive Adaptation to Climate Change, the Values Beliefs Norms Theory, the Protection Motivation Theory and the Five Capitals Model are most commonly applied in the agricultural adaptation context (Mitter et al. 2019; Hanger-Kopp 2021; Kropf and Mitter 2022). However, investigations of cognitive factors and processes are rare for Indian farmers, and only few of the reviewed studies were backed by a theoretical model, concept or framework. Banerjee et al. (2013) worked with an institutional framework and grounded theory, Brown et al. (2019) applied the Five Capitals Model, and Jha and Gupta (2021) developed and applied a conceptual framework of farmers' adaptation decisions.

Even though theories can inform the research process in different ways, its value has been stressed for behavioral change research in general, and climate change adaptation research in particular (Nielsen et al. 2021; Lange et al. 2021; van Valkengoed et al. 2021). Furthermore, little is known about the applicability of behavioral theories across cultures in both the Global South and North (Grothmann and Patt 2005). This is of interest because investigations of cognitive processes produce culturally and historically situated knowledge (Noll et al. 2020) that allows for analytic generalizations of how the investigated cases fit into theoretical constructs but not for statistical generalizations, spatial distributions, future predictions or extrapolation beyond the confines of a site or region (Curtis et al. 2000; Tracy 2010). Hence, translation of research results to other contexts, regions, cultures or across time is limited to situations where individuals share experiences or feel that the

produced results are relevant for their own decisions (Tracy 2010; Phoenix et al. 2013).

In addition, the majority of the studies for regions in India has analyzed the collected data quantitatively, while qualitative approaches are still limited. A recent review also demonstrates that quantitative outnumber qualitative methodological approaches, particularly for studying farmers' climate change perceptions in the Global South (Soubry et al. 2020). This review suggests that the choice of methods has an effect on the presentation of results, arguing that *"the lack of in-depth qualitative methods […] may be correlated with the perception of farmers as passive and vulnerable, rather than viably adapting."* (Soubry et al. 2020, p. 210). Despite of this attributed passivity, previous studies focus on intended or implemented adaptation measures and do not describe, specify or analyze avoidance strategies such as denial of climate change and related risks, wishful thinking, religious faith or fatalism (Grothmann and Patt 2005; Mitter et al. 2019). However, enhanced knowledge on adaptation and avoidance strategies can facilitate the development of adequate and tailored support measures, outreach efforts, and empowerment programs (Arbuckle et al. 2014; Mitter et al. 2019). This calls for applying qualitative methods to study cognitive factors and processes and their association to the formation of adaptation intentions and avoidance strategies of particularly vulnerable farmers in order to make their voice heard in academia, the public and private domains (Soubry et al. 2020).

We address these gaps and investigate smallholder farmers' climate change cognitions by applying a qualitative interview approach. We build on and largely follow the approach developed and successfully implemented by Mitter et al. (2019) for a developed country (i.e., Austria) in Central Europe in the so called Global North and test whether it is applicable for smallholder farmers who often operate under resource constraints in a rural region in a developing country (i.e., India) in South Asia in the so called Global South. More specifically, we aim at exploring how smallholder farmers in Tiruchirappalli District in South India perceive climate change and associated impacts; how they appraise climate change adaptation; and how they form adaptation intentions and avoidance strategies. In addition, we aim at forming groups of farmers that differ in their adaptation intentions and at building empirically-based types of smallholder farmer by assigning group-specific attributes of risk and adaptation appraisal.

The article is structured as follows. In Sect. "Data and method", we shortly describe the theoretical model and the process of data collection and analysis. In Sect. "Smallholder farmers' formation of climate change adaptation intentions", we present our empirical results by describing the four identified smallholder farmer types along the theoretical constructs. In Sect. "Discussion", we discuss the obtained results, and in Sect. "Conclusions", we suggest potentials for public interventions and draw conclusions.

Data and method

Study region

Our study region are villages in the rural area of Tiruchirappalli District, which is situated in the center of the state of Tamil Nadu in South India. Tiruchirappalli District is characterized by annual minimum and maximum temperatures between 19.5 and 39.2 °C, and mean annual rainfall of 818 mm (Department of Economics & Statistics 2017). The two monsoon seasons determine everyday work and life of smallholder farmers in the region. The summer monsoon is between June and September with average rainfall of 294 mm and strong southwest winds. The winter monsoon is between October and December with average rainfall of 392 mm and northeast winds (Nathan 1995; Department of Economics & Statistics 2017). Table 1 gives an overview of the annual rainfall and the respective deviation from the mean annual rainfall in Tiruchirappalli District for the last ten years.

Land tenure of the majority of farmers (about 77%) is below one hectare, with an average farm size of 0.78 ha in Tiruchirappalli District. Major food crops grown are paddy rice (29% of the total area of food crops grown), cholam (sorghum, 23%), maize (11%), and groundnut (8%; Department of Economics & Statistics, 2017). Literacy rate in rural

Table 1 Annual rainfall in Tiruchirappalli District (in mm) and deviation of the mean annual rainfall (%) for the years 2012–2021. Data sources: Kaur and Purohit 2013, 2014, 2016a, b; Purohit and Kaur 2017; Yadav et al. 2018, 2020, 2021a, 2021b, 2022

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Annual rainfall (mm)	491	523	536	864	475	**690**	507	635	797	1223
Deviation from the mean annual rainfall (%)	− 40	− 36	− 34	6	− 42	**− 16**	− 38	− 22	− 3	49

The year of data collection for our empirical analysis is marked in bold. The observed rainfall data refer to the district level, while empirical data have been collected in 15 rural villages located in the district. Hence, rainfall patterns in the rural villages may differ from those in Tiruchirappalli District

areas is between 45% for women and 55% for men (Department of Economics & Statistics 2017).

The villages in the rural area of Tiruchirappalli District are comparably small in terms of number of households (up to approximately 70 households per village). The rural population has only limited access to natural resources such as land and water and many residents do not have access to technical infrastructure such as radio, television or internet.

We have chosen the study region for two major reasons. First, it has experienced severe climate change related impacts over the last years. In particular, droughts have posed serious challenges, a risk currently underexplored in the adaptation behavior literature (van Valkengoed and Steg 2019). A recent report summarizes that Tiruchirappalli District has experienced 14 rainfall deficient years (defined as years that receive below 20% of the long-term average rainfall during the summer monsoon season) between 1990 and 2019 (CSTEP 2022). Recorded rainfall was more than 40% below the average in Tiruchirappalli District the year before data collection, and the government declared Tamil Nadu as a drought affected state in January 2017 (Government of Tamil Nadu 2017). Mohanty and Wadhawan (2021) even suggest that Tiruchirappalli is one of the five Indian districts most exposed to droughts and cyclones. Second, one of the authors has worked in an honorary capacity in the study region and has used this time to establish contacts and trust, which has proven useful during the research process. Our primary contact point in the study region is a regional organization that has been engaged in empowering the rural population for more than 25 years. Employees and volunteers organize bi-weekly self-help-groups for farmers and women, they run schools which are free for girls and low in cost for boys, they offer specific trainings for adults, and they provide evidence-based information on topics of interest for the rural population. The regional organization has expressed interest in the research results to improve the opportunities and their offers for the farmers in the region.

Theoretical model

We use the theoretical Model of Private Proactive Adaptation to Climate Change (MPPACC; Grothmann 2005; Grothmann and Patt 2005; Mitter et al. 2019) to guide data collection and analysis (Fig. 1). The MPPACC draws on the Protection Motivation Theory (PMT; Rogers 1983; Rogers and Prentice-Dunn 1997) which centers on 'threat appraisal' and 'coping appraisal' as the two major cognitive processes of individuals. Similarly, the MPPACC focuses on 'climate change risk appraisal' and 'adaptation appraisal'. Climate change risk appraisal refers to the two components of perceived probability of risks and perceived and expected severity of associated impacts. Adaptation appraisal refers to the three components of perceived adaptation efficacy, perceived self-efficacy, and perceived adaptation costs. Perceived adaptation efficacy refers to an individual's belief in the effectiveness of adaptation measures or behavior to reduce potential detrimental impacts; perceived self-efficacy refers to an individual's perceived capability to exhibit a certain adaptation measure or behavior or to achieve a desired outcome; and perceived adaptation costs refer to the resources considered a requirement for implementing adaptation measures such as time and money.

The MPPACC suggests that an individual responds with either adaptation intention or avoidance strategies, depending on the outcomes of the two major cognitive processes. In our analysis, adaptation refers to measures that reduce or avoid adverse physical or monetary impacts of climate change that affect the farm, family or individual. Avoidance strategies refer to responses that reduce or avoid sorrowful emotions resulting from perceived risks or associated impacts, such as wishful thinking, religious faith, and superstition (Grothmann 2005; Grothmann and Patt 2005). Compared to the PMT, MPPACC also considers socio-environmental context factors in terms of adaptation incentives (Grothmann and Patt 2005; Mitter et al. 2019). Social norms

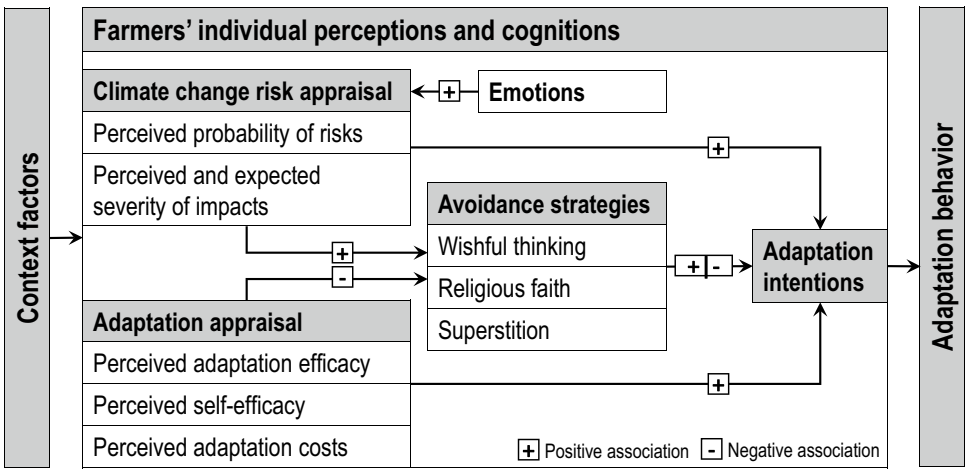

Fig. 1 The theoretical Model of Private Proactive Adaptation to Climate Change (MPPACC, based on Grothmann and Patt 2005; Mitter et al. 2019)

and emotions have been identified as important complements for explaining adaptation behavior (van Valkengoed and Steg 2019) and are addressed as context factors and to affect climate change risk appraisal, respectively. The MPPACC has already been successfully applied for empirical analyses in the context of farming (Kuruppu and Liverman 2011; Frank et al. 2011; Eakin et al. 2016; Burnham and Ma 2017; Woods et al. 2017; Mitter et al. 2019; Zobeidi et al. 2022). However, we are not aware of any applications for smallholder farmers in India.

Data collection

We have conducted a qualitative research approach in order to explore cognitive and behavioral processes of individual farmers. In particular, we have conducted 20 semi-structured interviews with smallholder farmers living and working in the study region. The participants were selected by maximum variation in terms of age, gender, educational level, number of years as active farmer, household size, and farm endowment (see Table 3 in the Appendix) in order to obtain a comprehensive understanding of how smallholder farmers address and deal with perceived risks related to climate change. We were advised not to include caste as a selection criterion, mostly because the caste can be recognized from, for instance, the jewelry and paintings of a person and, hence, asking about caste is considered impolite.

Potential participants were identified and approached by employees of a regional organization enjoying great trust by farmers, because of their engagement for empowering the rural population. The recruitment of female farmers was particularly effortful even though they were approached through the gatekeepers who were also present in the personal interviews to reduce potential distance and to translate. The interviews were conducted on site in the premises of the regional organization in June and July 2017, as suggested by our reference persons at this organization. The location was chosen as a neutral and safe venue and to avoid potential inconvenience for the participants, which may have been caused when meeting farmers at their homes. The farmers may feel ashamed of their houses or they may not be able to offer food and drinks because of lacking resources, while hospitality is considered civil and polite. The participants organized their trips to the venue individually. They arrived from 15 different rural villages, all with a limited number of households (e.g., about 40 in the village where the regional organization is located). The villages belong to three different sub-districts of Tiruchirappalli District in Tamil Nadu. Before the interview, the aims of the research and the research process were described in order to make sure that the participants grasp the potential impact of the research on themselves and on society. It was also made clear that participation in the research is voluntary (i.e., the right to refuse), that participation can be stopped at any time without giving a reason and without consequences (i.e., the right to withdraw), and that non-participation does not bear any additional risk. The interviews were recorded after asking each participant for consent. We refrained from obtaining written consent because of potential illiteracy. Open questions were asked in the face-to-face interviews and were complemented by a structured questionnaire, which focused on demographic, household and farm-specific data, mostly to characterize the sample.

The interview guide is based on the components and processes of the MPPACC. Feedback by experts in agricultural adaptation and the employees of the regional organization was incorporated before the first interview. After the first two interviews, the interview guide was slightly adapted in order to better fit the regional circumstances. Three employees of the regional organization supported the interviewer by translating the interviews between English and Tamil, one of the four major local languages in the region (Department of Economics & Statistics 2017).

The English translations of the interviews were transcribed word-for-word. Pre-defined transcription guidelines were followed. For instance, the speakers (i.e., interviewer, participants and translators) were anonymized using alphanumeric codes. These codes are also used in the results section when using direct quotes. Sensitive information that could allow inferences to be drawn about the individual participant was effaced in order to ensure confidentiality. Emotions of the participants and translator as well as interruptions and background noise were put into square brackets. For instance, it was noted that the [voice gets shaky], that the participant [laughs] or that [somebody enters the room to serve coffee]. This information was used for describing the smallholder farmers' fears and concerns about climate change. Blank lines were inserted after turn-taking for easier identification of speakers. The audio records were available for listening and checking the accuracy of the transcripts during the data analysis phase.

Data analysis

We conducted a qualitative content analysis by following a content-structuring and a type-building approach (as described in Kuckartz 2018 and Matousek et al. 2022). We combined deductive and inductive coding strategies in order to harness their individual advantages. As suggested by Hopf and Schmidt (1993), two team members coded the text material independently and regularly discussed the coding strategies in order to reach consensus and improve reliability.

Deductive codes were built on the MPPACC, the interview guide and the research questions. These thematic codes (i.e., main categories) were assigned to the text material in order to analyze the components and processes considered in

the MPPACC, to understand the linkages between the components, and to link the findings to previous research and other established theories (Nguyen et al. 2022). Deductive codes included, for instance, perceived climate change and associated impacts, future expectations of climate change and associated impacts, perceived adaptation efficacy, self-efficacy and adaptation costs, implemented and intended adaptation measures, avoidance strategies, emotions, and socio-environmental context factors.

Inductive codes were developed based on the qualitative data material and in order to differentiate the main categories into subcategories, as suggested by Kuckartz (2018). For instance, subcategories were developed for the socio-environmental context factors from the empirical data to distinguish between environmental, economic, institutional, and social factors and their interactions. Environmental context factors refer to the availability and accessibility of water and fertile land. Economic context factors relate to access to financial resources and the market situation. Farm characteristics such as farm size, production intensity, type of cultivated crops, kept livestock, managed trees, and workforce are related to environmental and economic context factors and affect the objectively available and subjectively perceived options for adapting individual farms. Institutional context factors refer to different public support programs for farmers or rural poor, and governmental initiatives in the region or country. Village and farmers' community characteristics, household and family characteristics, and personal characteristics are summarized as social context factors. Inductive codes were also developed to classify implemented and intended adaptation measures. We started from the widely accepted categorization of incremental adaptation that maintains the essence and integrity of a farm system or process, and transformational adaptation that changes the essential attributes of a farm system or process (IPCC 2022). The wealth of adaptation measures mentioned by the participants motivated another categorization of transformational adaptation into structural (i.e., change the structure of production and farming efforts), expansive (i.e., expand production and farming efforts) and contractive adaptation measures (i.e., reduce production, farming effort and resource ownership; Kropf and Mitter 2022; Wheeler et al. 2013). However, the data suggested no further categorization but only a specification of incremental into incremental agronomic adaptation measures.

We summarized the empirical data in a thematic matrix, with individual cases (i.e., smallholder farmers) depicted in the rows and relevant themes (such as the components of the MPPACC) depicted in the columns (Miles and Huberman 1994; Miles et al. 2013; Kuckartz 2018). The content-structuring analysis and the thematic matrix provided the basis for analyzing similarities and differences between cases and for identifying patterns of smallholder farmers' adaptation intentions. For building polythetic types of smallholder farmers, we adopted the concept of attribute (or property) space (Barton 1955) and followed four steps (as suggested by Kluge 1999; Kelle and Kluge 2010; Kuckartz 2018; Matousek et al. 2022): (i) specifying the characteristic (i.e., primary) attributes for the components of the MPPACC and each individual case, (ii) ordering of the empirical data to describe regularities and group the individual cases along their adaptation intentions, (iii) defining the number of types of smallholder farmers and describing them along the characteristic attributes of the MPPACC, (iv) describing the characteristic non-type defining (i.e., secondary) attributes such as personal and farm characteristics for the identified types. We assigned each individual case to one type. Iterations helped to ensure that the individual cases assigned to a type show similar patterns and can be distinguished from other patterns and types.

Smallholder farmers' formation of climate change adaptation intentions

We find four types of smallholder farmers, which differ in the formation of adaptation intentions and avoidance strategies. Three types differ in their adaptation plans, following innovative (type I), contractive (type II) or effectively tested adaptation measures (type III). One of the identified types does not intend to adapt their farms in the future, given the currently prevailing climate conditions. We present our empirical results along the components of the MPPACC (Table 2).

Type I: smallholder farmers intending innovative adaptation measures

This type of smallholder farmers intends to implement adaptation measures that are new to the farm or region to overcome the limitations experienced from past adaptation efforts. Such innovative adaptation measures include the implementation of deficit irrigation and greenhouse cultivation following procedures tested in arid countries, the introduction of new techniques for preparing pesticides that come from natural sources, and the processing of raw materials into products for the market to increase their storage life. In the past, farmers of this type have implemented a broad variety of incremental and transformational adaptation measures including adjustments in timing of soil preparation and cultivated crops, increasing water use efficiency, drilling new boreholes, planting new trees, and reducing the cultivated land.

The smallholder farmers belonging to this type share a high risk appraisal, expressed by high concerns about decreasing precipitation over the past years, irregularities

Table 2 Overview of the four empirically based types of smallholder farmers for climate change adaptation, structured along the components of the MPPACC

		Type I	Type II	Type III	Type IV
Adaptation intention	Intended adaptation measures (AM)	Innovative AM	Contractive AM Potentially sell land Migration as last resort	Retain selected past AM	No adaptation intention
Risk appraisal	Perceived and expected risks	Rain deficit Temperature increase Changes in seasons Increasing uncertainties	Rain deficit Temperature increase	Rain deficit Temperature increase	Rain deficit Temperature increase Changes in seasons
	Perceived and expected climate change impacts	Farm Family Region Country	Farm Family Region	Farm Family Personal Region	Farms Family Personal Region
	Reasons for climate change	Global: population growth, emissions Regional: deforestation, fertilization	Regional: deforestation Lack of knowledge	Regional: deforestation, emissions	Regional: deforestation, inoperable water infrastructure Will of God
Avoidance	Avoidance strategies	Wishful thinking	Wishful thinking	Wishful thinking Religious faith	Wishful thinking Religious faith Superstition
Adaptation appraisal	Perceived effectiveness of AM	Awareness of effective innovative AM	AM ineffective	Selected AM effective	AM ineffective
	Perceived self-efficacy	Motivated and capable of implementing innovative AM	Interested in farming Physical power AM impractical Relinquish plans	Build on positive experience Have the ability Heteronomous	Incapable of farming successfully if it remains dry
	Perceived adaptation costs	AM costly Agriculture is income-generating	AM too costly	Adaptation costs increase	AM too costly, have not paid off
Perceived context	Personal characteristics	Male Moderate in age High level of education	Female or male Young Low to moderate level of education	Male Diverse in age and level of education Long-term experience in farming	Female or male Diverse in age Low to moderate level of education
	Perceived social relationships	Strong	Rather weak Low number of household members	Strong	Strong
	Farm characteristics	Endowed with land and with livestock or trees Around to above average in size of land	Endowed with land, livestock and trees Mixed size of land	Endowed with land and with livestock or trees Mixed size of land	Endowed with land and with livestock or trees Below to around average in size of land
	Non-farm work	Not mentioned	Non-farm work NREGA	Non-farm work NREGA	NREGA

Table 2 (continued)

	Type I	Type II	Type III	Type IV
Perceived economic context	No mention of debts No mention of ration shops	Indebted Use ration shops Low product prices	Indebted Use ration shops Decreasing financial authority High input prices Increasing cost for cultivation Low product prices No market for selected products	Indebted No mention of ration shops
Sell products on the market	Yes	Used to or still	Used to or still	Not any more
Perceived access to financial resources	Yes	Not mentioned	Yes	No
Perceived access to water	Mixed	No	Yes	Mixed
Perceived institutional context	Aware of public support programs (PSP) Some mistrust in PSP Suggest new PSP	Aware of PSP	Aware of PSP High transaction costs	Aware of PSP Some mistrust in public support programs High transaction costs

NREGA refers to the "Mahatma Gandhi National Rural Employment Guarantee Act 2005", which guarantees a fixed number of days of paid, unskilled work per financial year for every household whose adults volunteer through the NREGA card (Ministry Of Rural Development 2019)

in the seasons and the *"climate circle" (IP01),* and increasing temperatures and uncertainties. In addition, they perceive and expect only detrimental impacts of climate change on their farms, families, region and even the entire country, as summarized by one participant: *"I guess the effects on the farm are negative, negative, negative." (IP01).* The farmers of this type address water scarcity and decreasing groundwater levels in the region and related impacts on their farms (such as reduced yields and income) and the economic status of their families. They report of rural–urban migration and its effects on labour supply, and they expect a welfare loss for the entire country. These farmers give a variety of reasons for climate change by referring to the global level (e.g., increase in the world population and emissions) and the regional level (e.g., deforestation and mineral fertilization in agriculture). They also express some avoidance strategies, which can be interpreted as wishful thinking, as summarized by a statement of one of the participants: *"We hope that we will get a good rain this year." (IP09).* The smallholder farmers suggesting new adaptation measures appraise adaptation positively. They are aware of and motivated to test innovations. They consider these innovations effective in response to the perceived and expected changes in climate, and they consider themselves as *"hard worker" (IP15),* as *"a very good farmer, a good agriculturist" (IP09)* and as well-equipped to successfully implement new adaptation measures. They also appreciate that *"agricultural activity itself is income-generating, profit-generating" (IP15).* Still, they consider adaption to be costly and think about strategies to reduce costs and develop alternative sources of financial resources. As such, they refer to potentially applying for a loan when implementing innovative adaptation measures and inform themselves about public support programs for farms. In addition, they have clear requests for additional public support programs.

Personally, this type of smallholder farmers can be characterized as male, well-educated, and moderate in age. They live in households of average size and mention strong relationships within the family or with friends and neighbors such as summarized by one participant: *"One reason is, generations together are doing this work, so we want to continue. Second thing, I have lots of relationship, friendship in this area." (IP15).* The farms are endowed with trees or livestock and around or above-average in size of land, which the farmers are not intending to sell. The farmers of this type do neither mention debt issues, nor do they talk about ration shops or support programs of the rural poor. Rather, they sell a particular share of their products on the market or to middlemen in order to earn their living. Hence, they feel dependent on perceived high input and low product prices.

Type II: smallholder farmers intending contractive adaptation measures

The smallholder farmers belonging to this type only plan contractive adaptation measures such as non-farm work, and selling livestock or even land. In the past, they have adopted incremental and transformational adaptation measures. They changed the crops grown, improved the water management and manuring techniques, increased the number of boreholes or planted new trees. In addition, they had to reduce the cultivated land or sell livestock because of lacking water, feed or income. The smallholder farmers of this type also regret that they had to relinquish their plans and dreams for their farms, as summarized by one of the participants: *"Some of the decisions have been given up […]. What I dreamt of, that way I couldn't achieve. […] I wanted to have a dairy farm, at least five or six cows." (IP03).* Instead, they themselves or family members have already started with non-farm work or participate in NREGA, the "Mahatma Gandhi National Rural Employment Guarantee Act 2005", which guarantees a fixed number of days of paid, unskilled work per financial year for every household whose adults volunteer through the NREGA card (Ministry Of Rural Development 2019). So far, they have not sold any land because of the drought but consider this a potential though unpleasant option. Migration is considered a last resort if climate conditions remain demanding as summarized by another farmer: *"if there is no rain for another two to three years, I also have to move from this place, […], leave the family here." (IP06).*

The smallholder farmers of this type appraise climate change, and in particular the shortage of rain and the increase in temperature, as considerable risk for their farms, families and the region. In particular, they say that seasonal crops are no more profitable, that the crops grown have become *"waste" (IP14)* and cannot be used as food or for feeding purposes, and that new viruses and insects attack the crops or trees. They also report reduced milk yields resulting not only from scarce water but also from limited grass and hay for livestock feeding. Combined with price fluctuations, the impacts on the farms have led to reduced farm and family income and lacking resources, for instance, for attending village festivals. Such impacts evoke negative feelings as expressed by one farmer by referring to the mother *"There is a village festival today […] and we cannot attend. My mother is crying because she cannot go and attend. Because to go there, we have to spend some money." (IP14).* Health issues, especially of children, are another reported impact in the context of experienced heat. At regional level, decreases in soil fertility and salinization are considered to be critical. The smallholder farmers of this type mention that they do not know the exact reasons for climate change. However, they believe that deforestation has a decisive effect on the rainfall patterns in the region: *"So the reason for not raining is loss of trees. A lot of trees are cut down by the people." (IP06).* Hence, they are not aware of the global developments and connections but rather blame themselves and their neighbors for the situation they are facing. Avoidance strategies are expressed by these farmers. More specifically, they hope and wish for rain and refer to others who also expect that it will be raining in the near future.

The smallholder farmers of this type appraise the adaptation measures they are aware of as ineffective or too expensive. While they are *"interested in doing the agricultural activities" (IP03),* consider themselves to *have "physical power" (IP10)* and know about selected governmental education and support programs, they think that the proposed water management strategies are *"not practical" (IP06)* for their farms and that lacking water, lacking financial resources, and decreasing product prices restrict their scope of action.

The farms operated by these farmers are endowed with livestock and trees. They have liabilities but no more access to water. Put differently, these farmers and households intend to live off the farm capital and use governmental support programs to make their living. In terms of personal characteristics, farmers of this type are young (up to the age of 40 at the time of the interview), female or male, and with low to moderate education. The number of household members is relatively low.

Type III: smallholder farmers intending to continue selected adaptation measures

This type of smallholder farmers intends to retain selected incremental and transformational adaptation measures they have already used in the past. They plan to continue the field work and adopt the cultivated crops to the level of rain, maintain the fruit and teakwood trees or plant additional tress, and deepen the existing or drill additional boreholes.

The smallholder farmers of this type appraise climate change as a risk. They report perceived precipitation declines and temperature increases with impacts on their farms, their families, themselves, and the region. They appraise the perceived impacts as negative, which becomes evident by their expressed fear, anxiety, and sadness. They describe that their farms are affected of decreases in yields, drying trees that cannot be leased anymore, reduced feed and water availability for livestock, and, hence, reduced income. One famer tells that *"earlier, we got 80 packs of rice when we cultivated, but nowadays not even 40." (IP08).* The families suffer from insufficient food production for their own needs, restricted access to drinking water, and a decrease in economic status. Personal impacts include impairments of individual physical and mental well-being due to high temperatures and lacking water, as described by one farmer: *"When there is no water in the*

field, the life itself will become very questionable." (IP13). At regional level, impacts are associated to environmental and economic conditions such as the decreasing fertility of the land, the decreasing availability of groundwater, and rapidly changing product prices on the regional markets. The farmers of this type believe in human-induced climate change and refer to deforestation, and emissions from traffic and industries as potential reasons for climate change. Except for one farmer, the farmers of this type articulate avoidance strategies of wishful thinking and religious faith. Wishful thinking and religious faith degrade the risk or potential impacts of climate change. The first is expressed by the hope of a *"positive change in the climate" (IP02)*, which is shared with *"many others" (IP08)* in the region. The second is expressed by the belief that God could help and by *"pray[ing] to the Goddess" (IP11)* for mercy and rain. The one farmer not mentioning any avoidance strategies expresses strong destructive feelings about climate change including lost dignity and thoughts of suicide.

Smallholder farmers of this type consider selected adaptation measures effective, while others are considered ineffective. Hence, they suggest to continue only with those measures where they can build on positive experience. They perceive their self-efficacy to be decreasing. While they feel to *"have the ability" (IP13),* they are not the *"boss" (IP02)* anymore and describe that *"even though we'd work hard and would produce a lot of things, it won't be enough" (IP02).* In addition to the perceived decreasing self-efficacy, these smallholder farmers think that their financial authority decreases and their economic dependence increases. They refer to high input prices, increasing costs for watering, low product prices, high transaction costs when applying for subsidies, and the lacking market for organic products as adaptation barriers. To deal with the market situation, the smallholder farmers either ask for governmental support to stabilize product prices or cooperate with private companies that compensate for production costs at the beginning of the growing season to ensure that their company obtains the harvested yields.

This type of farmers consists of men who are diverse in terms of age and level of education but share long-term experience in farming (with a minimum of 20 years) and awareness of public support programs such as subsidies for tree saplings and irrigation. The number of household members ranges between two and seven, and the farmers refer to strong relationships in their families. The farms are endowed with land and with livestock or trees. In addition, they still have access to water or financial resources. Access to financial resources is secured through family members who are working in other regions and regularly send money or through loans given to women by self-help groups, even if they are already indebted. Hence, these farmers do not intend to sell their land.

Type IV: smallholder farmers not intending to adapt

The smallholder farmers of this type stress that rain is absolutely necessary to continue farming and to survive, as outlined in this quote: *"And if it will not rain, how can we survive?" (IP20).* Hence, farmers of this type think that they have reached their adaptation limit and do not intend to continue neither their incremental nor their transformational adaptation efforts if it remains dry: *"If there is no rain, we cannot do anything in the field." (IP12).* In the past, they have worked with alternative crops and seeds, they have improved their water management system and invested in additional boreholes. In addition, they have adopted contractive measures such as reducing the cultivated land and selling livestock. Yet, they have refrained from selling land, adding for consideration that *"no one would buy the land, even if I want to sell. The others would not buy the land if there is no water." (IP12).* These smallholder farmers appraise climate change, and in particular, the long-term rain deficit, the changes in the seasons, and the temperature increases as a severe risk. In particular, they refer to impacts on their farms, their families, themselves, and the region. At farm level, the lack of water is considered decisive for crop failures, more intensive pest and disease pressure and considerable suffering of livestock. For their families, the smallholder farmers of this type refer to detrimental impacts on daily life and postponed family investments. With respect to daily life, they report on their inability to fully satisfy their basic needs and are particularly concerned about the lack of drinking water. One of these smallholder farmers boils it down to: *"No rain. Because of that we are not having enough water for cultivation and also not for drinking." (IP05).* In addition, they feel sorry for the kids who lack the experience of playing in the ponds which have gone dry. Postponed family investments include unfinished houses and lacking resources reduce the educational options for children. The farmers of this type consider their children's education important and mention that they have either sold livestock or have entered liabilities to pay for the fees such as explained by these farmers: *"for […] child education, they charge school fees and for that I sold some goats" (IP04), "for the children's education, so I am in debt" (IP20).* At regional level, the farmers mention lack of water in wells and decreasing soil fertility. They associate the lack of water to the insufficiently maintained water infrastructure which they also consider a reason for climate change, besides deforestation and the will of God.

As avoidance strategies, the smallholder farmers of this type express superstition, religious faith or wishful thinking. They go to church to *"pray to our Lady" (IP12)* for rain.

Superstition becomes evident, for instance, when a farmer talks about a marriage and believes *"if some 1,000 people are coming in one village, at least there will be one good man, or good woman, for them, there will be rain." (IP18).*

Farmers of this type are concerned about climate change. They are not aware of any effective adaption measure and do not feel capable to farm successfully if it remains dry. They report high expenses for adaptation measures, in particular for water management systems, which have not yet paid off.

Farmers of this type are diverse in terms of age and gender. They have low to moderate education and a minimum of 14 years of experience in farming. They are aware of public support programs but also express some mistrust. The farmers complain about the necessary paperwork to qualify for subsidies or criticize the bribe: *"It is 100% free, but in between, for the people, you have to pay." (IP18).*

Their farms are endowed with land and with livestock or trees, but encumbered with debts. Further, they mention that they are not eligible for loans, not least because of the prevailing droughts and their inability to meet their financial commitments, as expressed by one farmer: *"Even if I ask somebody else from outside, they think, how will this lady repay the money, no cultivation. How will she do that? So will I get back my money, like that they think." (IP12).* To deal with the situation, a household member participates in NREGA.

Discussion

Types of smallholder farmers for climate change adaptation

We have identified four types of smallholder farmers, with one not intending to adapt and the other three planning different adaptation measures. Farmer types are gaining in attention in and beyond academia because they are deemed particularly useful to bridge gaps between epistemological positions and methodological approaches (Mitter 2021), to generalize and transfer knowledge between contexts, regions and cultures or across time (Kostrowicki 1977), and to inform the design of policies, programs and instruments that support transformations towards sustainable and climate-resilient agri-food systems (Emtage et al. 2006; Bartkowski et al. 2022). Only recently, other authors have presented types of smallholder farmers for regions in India (Goswami et al. 2014; Shukla et al. 2019; Kaur et al. 2021; Innazent et al. 2022; Sinha et al. 2022). These types have been derived from data collected with structured questionnaires and analyzed with quantitative, statistical methods, a commonly applied approach to derive types of smallholder farmers (Nyambo et al. 2019). These types are formed along socio-economic factors such as farm endowment, household size, predominant farming activities, and farm and non-farm income, with Shukla et al. (2019) also referring to perceived climate change and related impacts. In our analysis, socio-economic factors are used as secondary attributes to describe the farmer types. Based on these descriptions, we discuss similarities and differences between the typologies for Indian smallholder farmers.

Innazent et al. (2022) developed a typology of smallholder farmers who adopt integrated farming systems and identify resource endowment and livelihood strategies as main characteristics of their four types. Similarly, our identified types differ with respect to adaptation intentions and land endowment such that farmers of type I plan for innovative adaptation measures on farms that are around to above average in size, and farmers of type IV do not intend to adapt their farms that are around to below average in size. The access to water and financial resources also differs and seems to be important or even critical to form adaptation intentions for farmers of types I and III. Type I may apply for loans to realize their plans, and type III can retain selected past efforts because they still have access to water or money.

Shukla et al. (2019) find that farmer types characterized by resource endowment and production orientation do not differ with respect to climate change perception, which is in line with our findings. Their five farmer types differ in the perceived impacts of climate change such that high-resource endowed farmers perceive significantly higher impacts on water resources and crop yields, whereas low-resource endowed farmers are more concerned about food self-sufficiency and landless farmers feel stronger impacts on social bonds (Shukla et al. 2019). Our participants perceive a similar variety of detrimental impacts, though the association with resource endowment is less clear. Impacts on yields and income are reported by the four farmer types. Concerns about food and drinking water security are raised by farmers of type III with mixed farm sizes and by farmers of type IV with average to below average farm sizes. Both types refer to their participation in NREGA or mention that basic food like rice and sugar is available and economically accessible from the ration shop. Unlike the results of Shukla et al. (2019) suggest, social bonds are considered strong by the farmers of types I, III and IV and regardless of their farm size. These farmers appreciate family cooperation and joint decision-making in farming and financial affairs or describe the team spirit and solidarity in the village and farmers' community as enabling adaptation. However, farmers of type II cannot count on family support, and farmers of type I would like to improve communication and cooperation between farmers, in particular for introducing new technologies.

The typologies developed by Sinha et al. (2022), Kaur et al. (2021) and Goswami et al. (2014) aim to improve extension interventions and focus on farm and household size and production orientation. Sinha et al. (2022) suggest

to diversify skills and provide access to loans for the farmer type with large land holdings. Interestingly, the considerations of our type I farmers with average and above average farm sizes support these suggestions. They think about borrowing money for innovations and ask for public information and training programs. Sinha et al. (2022) address the need for professionalized extension services in particular for small farms. We agree with the request for such services taking care of the concerns and needs of all types of farmers, because we are neither aware of public institutions nor official agricultural extension services taking care of the farmers in the rural villages of our study region. Kaur et al. (2021) have even implemented farm type specific low-cost interventions with considerable improvements in net income.

Beyond India, farmers types have been developed focusing, for instance, on Scottish dairy farmers to explain their attitudes towards climate change and adaptation intentions (Barnes and Toma 2012), on livestock farmers in Wales to characterize climate change perceptions and the capacity to engage in mitigation activities (Hyland et al. 2016), on U.S. corn belt farmers differing in belief about climate change, experienced extreme weather events, and risk perception (Arbuckle et al. 2014), on Gozitan livestock and crop farmers in Malta and their willingness to adapt to climate change (Galdies et al. 2016), on grassland farmers' climate change awareness and adaptation preferences (Eggers et al. 2015), and on Austrian farmers differing in the formation process of adaptation intentions (Mitter et al. 2019).

Applicability of the applied theoretical model and methods

The MPPACC guided data collection in the rural villages in Tiruchirappalli District in South India and qualitative content analysis. The model was also successfully applied in Europe (Woods et al. 2017; Mitter et al. 2019) and the U.S. (Eakin et al. 2016), suggesting its adequacy and applicability both in the Global South and North. Countries that were less negatively affected from climate change and droughts in the past may learn from our results in order to counteract potential downward spirals in the farmers' willingness, capacities and intentions to adapt.

In the coding and analysis process, we experienced two main difficulties. First, demarcating perceived adaptation costs from institutional context factors raised discussions in the research team. For instance, subsidies for specific measures can be interpreted as a policy instrument or to lower adaptation costs. We decided to code both in order to be consistent with other research guided by the MPPACC and because it allows comparisons or links with (mostly quantitative) results on the influence of demographic and socio-economic factors on adaptation intentions and behavior. Second, we cooperated with non-professionals affiliated to a regionally trusted organization for recruiting participants and translating the interviews. We consciously followed this strategy though being aware that it may have attracted specific farmers who may address or avoid specific topics and that non-professional translation may be exposed to limitations (as nicely summarized by Kruse et al. 2012). Getting in contact with farmers through a gatekeeper proved effective, though convincing female farmers to participate was challenging. The gatekeepers explained that they had to assure female farmers that their views and opinions are valuable and of particular relevance for our research. The translators know not only the language but also the culture and the subject area, which contributed to a pleasant interview atmosphere. Some of the interviewed farmers even showed emotions indicating that they felt safe. We explained the necessity and value of the translation as well as the subsequent method of analysis in order to sensitize the translators, reduce potential misunderstandings to a minimum, and make them aware of the importance of verbatim translation. At the same time, we made sure to avoid the impression of 'methodological hierarchy' (i.e. superiority of methods from the so called Global North; Kruse et al., 2012: 50). Nevertheless, translation remains an interpretative act (Kruse et al. 2012).

Conclusions

The interviewed smallholder farmers operating in Tiruchirappalli District in South India have responded to multi-annual droughts and related impacts with incremental and transformational adaptation measures. Our qualitative content analysis resulted in four types of smallholder farmers, which differ in the formation of adaptation intentions. Three types intend to adapt, suggesting innovative measures that are new to the farm or region (type I), focusing solely on contractive measures (type II) or continuing past efforts they consider effective (type III). Farmers of type IV perceive that they have reached their adaptation limits and, hence, do not intend to adapt.

These results call for long-term public strategies, programs and activities to empower smallholder farmers. Farmers of type I ask for facilities to store agricultural products locally, information and training programs dealing with water management systems, field visits where innovative adaptation measures are tested, programs that foster exchange and cooperation between farmers, and for bans on inefficient irrigation techniques. Farmers of type II ask for easier access to water and the stabilization of product prices. They could potentially benefit of transboundary and regional water management strategies and plans, coordinated soil health initiatives, combined subsidy and training programs for effective adaptation measures with low entry barriers,

easier access to farm inputs to manage adaptation costs perceived as high, and free community events to strengthen social relationships. Farmers of type III ask for affordable farm inputs, stable product prices, sales opportunities for organic products, and easier access to food and water for their own needs. For the continuation of NREGA and ration shops, the farmers stress the preference for food rations over money in order to secure the survival of their families without the risk that the money is spent for festivals or alcohol. In addition, the farmers may benefit of technologies for effective water management, trainings on innovative adaptation measures to increase their perceived self-efficacy, and of physical and mental health programs. Farmers of type IV ask for more efficient governance structures and easier access to financial resources including reduced interest rates. However, publicly supported loans can only serve as temporary solutions and in extreme situations, but do not work for persistent problems. Thus, strategies to relieve farmers' economic tensions need to be developed, for instance, through debt cancellation and affordable risk transfer systems. Farmers of this type also require support for their daily needs including food and water, and for the education of children which they cannot afford any more.

Future research could complement the findings on individuals and their behavioral intentions with larger and more complex social networks as well as in broader institutional and cultural contexts within climate solutions emerge. More specifically, future research could address how individual farmers influence and are influenced by their peers and cultural traditions, how engagement in adaptation behavior affects other and future behaviors through spillover and rebound effects, and how collective behavior emerges in sparsely populated regions experiencing limitations in social and technical infrastructure. In addition, it could focus on the cooperation process between smallholder farmers and with private and public actors, on institutional developments to encourage cooperation and climate change adaptation, and on the application of the empirically based types of smallholder farmers to develop tailored support structures, extension and empowerment programs.

Appendix

See Table 3.

Table 3 Characteristics of participants and their farms

Participant	Age*	Gender	Highest education completed	Number of years as active farmer	Number of household members	Number of acres**	Livestock	Number of cows	Trees
01	48	m	MA	38	6	5	n	0	y
02	35	m	2nd grade	20	7	< 1	y	1	n
03	33	f	8th grade	13	5	2	y	2	y
04	44	m	7th grade	27	5	1.25	y	3	n
05	62	m	5th grade	50 +	18	7–8	y	6	NM
06	40	m	6th grade	20	3	9	y	2	y
07	65	m	9th grade	50	6	3–4	y	2	n
08	57	m	9th grade	20	3	3	y	2	NM
09	36	m	10th grade	14	7	10	y	7	y
10	34	m	10th grade	10	3	4	y	2	y
11	55	m	2nd grade	30	7	4	y	2	y
12	39	f	3rd grade	22	5	2.5	y	4	y
13	55	m	10th grade	38	5	10	n	0	y
14	40	f	3rd grade	25	6	> 10	y	4	y
15	43	m	10th grade	20	6	8	y	2	y
16	70	m	6th grade	45	2	2.5	y	1	y
17	60	m	7th grade	50	2	5	y	6	y
18	43	m	10th grade	14	5	5	y	2	y
19	38	m	BSc	20	3	15	y	NM	y
20	42	m	3rd grade	30	5	8	y	0	y

Gender: *f* female, *m* male, Highest education complete: *BSc* Bachelor, *MA* Master, Livestock and tress: *n* no, *y* yes, *NM* not mentioned in the interview

*At the time of the interview

**1 acre is equal to 0.404686 hectares

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Declarations

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