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The Role of Climate Information and Advisory Services in Drought Resiliency: A Comparative Case Study in Tamil Nadu, India

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Abstract

Beginning in 2016, the southern Indian state of Tamil Nadu began to suffer from its worst drought in the past 140 years. Due to climate change and the El Niño Southern Oscillation, both the northeast and southwest monsoons failed decreasing the amount of summer and autumn rainfall. Farmers are especially vulnerable to this climatic variability. Using resilience as a conceptual framework and empirical findings from semi-structured key informant and farmer interviews, this paper analyzes the consequences of the 2016 drought on farmers across two sites in the Erode District, as well as explores the role of Climate Information and Advisory Services (CIS) in building agricultural farm-level resilience. This paper finds that CIS did not help communities cope with the 2016 drought due to issues relating to short-range forecasting, access, and reliability. The expectations of CIS producers did not align with end-users' reality.

Keywords: *climate information services, agro-met advisories, forest-dwelling scheduled tribes, drought, resilience, adaptive capacity*

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List of Abbreviations and Acronyms

AAS – Agrometeorological Advisory Service

AMAS – Agro-Meteorology Advisory Service

ATREE – Ashoka Trust for Research in Ecology and the Environment

CBO – Community-Based Organization

CCAFS – CGIAR Research Program on Climate Change, Agriculture and Food Security

CD Block – Community Development Block

CIS – Climate Information and Advisory Services

CSA – Climate-Smart Agriculture

Dept. – Department

EDCCB – Erode District Central Cooperative Bank, Ltd.

ENSO – El-Niño Southern Oscillation

FRA – The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006

FRC – Forest Rights Committee

IMD – Indian Meteorological Department

NGO – Non-Governmental Organization

NTFP – Non-Timber Forest Products

PA – Protected Area

SES – Social-Ecological Systems

SST – Sea Surface Temperature

ST – Scheduled Tribe

STR – Sathyamangalam Wildlife Sanctuary and Tiger Reserve

SMS – Short Message Service

TN – Tamil Nadu

TNAU – Tamil Nadu Agricultural University

WTO – Watershed Organisation Trust

1 Introduction

1.1 Background

The frequency of severe weather events is expected to increase globally as a result of climate change (Gummadi et al., 2016). Climate change is caused by the atmospheric accumulation of greenhouse gases, which trap heat, causing a cascade of effects worldwide. Greenhouse gases are emitted through land use changes, the burning of fossil fuels, and the application of inorganic fertilizers and pesticides, among other causes (Raj, 2016). This phenomenon is responsible for changes in rainfall, tropospheric temperatures, sea level, sea surface temperatures (SSTs), and jet streams (Naidu et al., 2015). Due to its impact on SSTs, climate change is predicted to increase the occurrence of extreme El Niño Southern Oscillation (ENSO) events (Cai et al., 2014). Both climate change and ENSO events contribute to climate variability worldwide by influencing global processes, such as the Indian monsoon system.

Every year, India experiences the southwest and northeast monsoon systems. These systems are products of fluctuations in land and ocean temperatures (Naidu et al., 2015). The southwest monsoon, which begins in June and ends in September, supplies India with 70 percent of its annual rainfall (Gummadi et al., 2016). Climate change threatens the southwest monsoon, as it weakens the SST gradient in the equatorial Indian Ocean during the summer months. In turn, the southwest monsoon has decreased in strength producing less summertime rainfall. Similarly, ENSO affects the southwest monsoon through decadal variations in SST patterns and inter-annual SST anomalies, as well through the weakening of its own intensity (Naidu et al., 2015). The northeast monsoon, which lasts from October to December, is also impacted by climate change (Varadan et al., 2017). During this autumn event, southern India demonstrates increases in both low and extreme rainfall events (Naidu et al., 2015). Due to climate change and ENSO, India has begun to experience frequent and intense floods and droughts (Varadan et al., 2017). While both types of climatic events have far-reaching impacts, this paper will focus on the consequences of droughts in agricultural systems.

Approximately one-third of India's geographical area suffers from water stress and drought conditions (Manikandan and Tamilmani, 2015). Monsoon variability and failure have significant implications for India’s agricultural industry, which employs 70 percent of the total population (Gummadi et al., 2016). Of particular concern are India’s rainfed agricultural systems, which cover two-thirds of the country’s total cropped area and provide a source of livelihood for millions (Pradhan et al., 2017). The crop-growing season is impacted by the shifting, weakening, and delay of monsoon rains (Sivaraj and Philip, 2015). Climate variability also increases the incidence of pests and diseases (Shukla et al., 2016). In 2016, farmers in the southern state of Tamil Nadu (TN) experienced its worst drought in 140 years (Kannan, 2017).

The causes of the 2016 drought have been attributed to weakened southwest and northeast monsoon rains and poor water management (Venkatesh, 2017). The drought coincided with one of the strongest ENSO events in the last 60 years, which caused record high temperatures and water shortages in India (Blunden and Arndt, 2017). In addition to ENSO, rains failed due to climate change. Last year, the state experienced a 66 percent rainfall deficit in the northeast monsoon (Mariappanl, 2016). TN is most dependent on this autumn monsoon to meet its annual water requirement (Kedia, 2017). The southwest summer monsoon also waned. Between the two systems, there was a total rainfall deficiency of 81 percent (Venkatesh, 2017). Only 550 mm of rain fell over TN as compared with mean annual rainfall of 945 mm (Kannan, 2017). As a result, combined storage of TN’s key irrigation reservoirs were at 15 percent of their total capacity (Mariappanl, 2016). With insufficient monsoon rains, storage, and groundwater levels, farmers suffered losses in yield and profit.

Farmers have a variety of tools at their disposal to adapt to climatic risks, like the 2016 TN drought. Adaptation strategies often include the use of irrigation technologies and water conservation measures, reductions in acres sown, and the implementation of sowing rules that take into account timing, and soil and climatic conditions (Hochman et al., 2017). Only recently has the use of climate information and advisory services (CIS) gained traction (Tall et al., 2014). CIS provide farmers with information about weather, climate variability, and climate change. The most common type of services are agro-advisories, and hydro-meteorological, disaster (i.e. flood or drought early warning systems), and long-term regional climate forecasts (Singh et al., 2017). The service includes rainfall and temperature data, seasonal climate variables relevant to agricultural risks, historic climate trends, and future projections, which farmers can use to time planting, harvesting and application of irrigation, fertilizers, pesticides, and insecticides. Moreover, farmers can use CIS to determine which crops to select and whether to leave land fallow, diversify their livelihoods, and purchase land and irrigation technologies. CIS are delivered to farmers through mass media, agricultural extension agents, workshops, and mobile phone services (CCAFS, n.d.). In order to minimize the devastating effects of droughts and build farm resilience to climatic risks, CIS must be further explored.

1.2 Research Focus

The research questions explored are: 1) How do CIS contribute to farm-level resiliency to climatic risks; 2) How were CIS accessed and used during the 2016 drought; and 3) Do CIS producers and end-users' expectations align? The overall aim of the research project was to explore and gain a better understanding of the ways in which tribal and non-tribal farmers in Tamil Nadu (TN) respond to droughts through the use of CIS to build resilience. I argue that CIS are largely inaccessible to farmers, particularly those living in forested areas who are illiterate, remote, and lacking in technology and government support. Moreover, CIS in their current form – short-range forecasts – were not useful to farmers to prepare them for the 2016 drought, despite claims by CIS producers that they were. Thus, the expectations of CIS producers and end-users do not align.

In order to achieve the research aims, I performed an extensive literature review and conducted semi-structured interviews with key informants and farmers in two distinct communities. The interviews were carried out over a 10-day period from 16th June to 6th July 2017. Both of the farming communities resided within the Erode District of TN. One sample population was located in the remote Sathyamangalam Wildlife Sanctuary and Tiger Reserve (STR), while the other was located in the rural, semi-arid town of Bhavanisagar. The key informants belonged to various government bodies and NGOs, including but not limited to Tamil Nadu Agricultural University (TNAU), Keystone Foundation, and the Bhavanisagar Horticulture Department. The literature review was used to answer the first research question, while the other two were explored through empirical data. The farmer interviews helped to further understanding of farmer's access to, attitudes, and use of CIS, while the key informant interviews provided context of the case study sites and farmers' responses.

The dissertation has been divided into seven chapters. Chapter 1 above has provided an introduction into the research topic and project. Chapter 2 includes a comprehensive literature review that critically engages with recent literature in the areas of climatic risks, marginalization of forest-dwelling STs, resilience, and CIS. Additionally, it identifies the gaps in the literature that the research project aims to fill. Chapter 3 provides a thorough background about the case study sites and populations. Chapter 4 details and justifies the methodology employed in the research project, as well as addresses limitations and challenges. Chapter 5 describes and analyzes the research findings from the key informant and farmer interviews. Chapter 6 synthesizes the results within the context of the broader literature, as well as provides personal reflections on the research process. Finally, Chapter 7 summarizes the research findings, argument, and contributions to the academic literature.

2 Literature Review

2.1 Climate Variability

In India, climate change has reduced rainfall during the summer months, as well as delayed the arrival of the monsoon (Naidu et al., 2015). By using Z-statistic to calculate and test changes in mean rainfall from 1951 to 2008 using data from 1,803 weather stations across India, Naidu et al. (2015) found that the nation experienced increased dry days and extreme rainfall events. Additionally, moderate rainfall events declined over this period as a result of climate change (Naidu et al., 2015). Within agricultural systems, climate change is predicted to impact crop production, input supplies, and hydrology (Raj, 2016). More specifically, the consequences of climate change include changes in crop nature (e.g. harvesting time, growing season, and losses), pest and disease incidence, and water availability and salinity (Sivaraj and Philip, 2015). Within Tamil Nadu (TN), Varadan et al. (2017) used statistical tools, including Pettitt's Homogeneity Test, Cumulative Sum Charts, Mann-Kendall Rank Statistic, and a box-and-whisker Plot, to approximate the effect of climate change on rainfall trends. The southwest monsoon was impacted by climate change in that rainfall decreased with less dispersion. Consequently, the growing season for crops shrunk during the southwest monsoon. In contrast, the northeast monsoon increased with more dispersion. During the northeast monsoon, fledgling crops faced flood risks (Varadan et al., 2017).

In addition to climate change, the El Niño Southern Oscillation (ENSO) also contributes to extreme weather events, and is the main cause of episodic droughts (Wang et al., 2014). In a study by Azad and Rajeevan (2016), it was found that due to ENSO there would not only be less rainfall over India, but that the frequency of ENSO events would increase from every 3 to 5 years to every 2.5 to 3 years by the end of the century. These findings are concerning given that 5 of the last 7 El Niño events between 1980 to 2016 resulted in droughts (Azad and Rajeevan, 2016). Like Azad and Rajeevan's (2016) findings, Cai et al. (2014) found through the use of Coupled Model Intercomparison Project phases 3 and 5 multi-model databases and a perturbed physics ensemble that the frequency of extreme El Niño events would increase as a result of climate change and its impacts on sea surface temperatures (SST). In the Indian Ocean, SST are increasing and so are temperatures over the Indian landmass, thus decreasing the land-sea thermal gradient. This decline results in less rainfall and weakens the southwest monsoon Hadley circulation (Roxy et al., 2015). Due to the combination of factors from climate change and ENSO, droughts in India are expected to increase (Azad and Rajeevan, 2016).

Droughts are classified as water shortages due to poor rainfall, increased evapotranspiration, and/or mismanagement or overuse of water resources (Manikandan and Tamilmani, 2015). Van Loon et al. (2016) identified three types of droughts driven by a confluence of climate variability and anthropogenic causes (e.g. land use, water abstraction, etc.): meteorological drought, soil moisture drought and hydrological drought. Meteorological drought is defined by a decline in rainfall below normal levels (Manikandan and Tamilmani, 2015). Soil moisture drought is defined as abnormally low soil moisture levels, while hydrological drought is characterized by abnormally low river discharge, and surface water, reservoir, and groundwater levels (Van Loon et al., 2016). In addition to the three aforementioned drought classifications, the combination of meteorological and hydrological droughts can be categorized as sociological droughts in which water shortages limit socioeconomic activities (Choudhury and Sindhi, 2017). Conditions that affect drought severity are length, geographical area, and water or moisture deficit (Rao and Gopinath, 2016).

In India, periods of major drought are classified by nationwide negative rainfall anomalies that last throughout a monsoon season (Naidu et al., 2015). At the district-level, they are defined by a 51 percent deficiency in rainfall (DT Next, 2016). The impact of droughts includes irrigation cutbacks, decreased reservoir levels, groundwater exploitation and crop losses (Manikandan and Tamilmani, 2015). The Erode District of TN only received 28 percent of normal monsoon rains (DT Next, 2016). The amount of rainfall began to decrease in 2013, along with groundwater levels. Last year, however, was markedly worse than those before it. In 2015 the Erode District received 600 mm of rainfall, but by November 2016 only 88 mm had fallen (TNN, 2016a). Additionally, the Bhavanisagar Dam's reservoir levels dropped to 3,000 mcft (million cubic feet) in 2016. During the same period in 2015, the Bhavanisagar Dam contained 10,000 mcft of water (Mariappanl, 2016).

The drought also extended into the forested areas of the Erode District. The Sathyamangalam Wildlife Sanctuary and Tiger Reserve (STR) suffers droughts annually given its location in the rain shadow of the Western Ghats. In March and April, surface waters dry with the exception of the Moyar River (Sathyamangalam Tiger Reserve, n.d.). In 2016, however, the drought became so severe that little water remained in its ponds and lakes. The drought was attributed to weakening southwest monsoon rains that failed to deliver enough rainfall to the reserve. In a Times of India article dated 20th October 2016, a Forest Department authority and a trustee of the Wildlife Nature Conservation Trust had remarked that the drought was noticeably worse in 2016 than in 2015. As a result, wildlife ventured into human settlements looking for water. Approximately half of the wildlife, including elephants, tigers, leopard, deer and Indian gaurs, traveled to the surrounding states of Karnataka and Kerala (TNN, 2016b).

2.2 Forest-Dwelling Scheduled Tribes

Following Independence in 1949, the Indian Constitution established Schedules 5 and 6 to protect marginalized Scheduled Tribe (ST) populations (Springate-Baginski et al, 2013). STs are classified by their 'primitive traits,' unique culture, remoteness, limited contact with outsiders, and socio-economic or political 'backwardness' (Adhikary, 2014). Gupta (2009) added that an ST must be indigenous, have a shared ancestry or display groupism, and largely reside in one 'territorial habitat.' Unlike other groups within India, STs fall outside the caste hierarchy (Majumdar, 2016). In the most recent census, over 104 million individuals were identified as STs, accounting for 8.6 percent of the nation's population (Chandramouli, 2013). Communities categorized as STs are eligible for targeted welfare schemes aimed at improving their economic wellbeing (Bose et al., 2012). Despite constitutional protections and benefits, many ST communities remain marginalized and disadvantaged today. In 2011 through 2012, 44.8 percent of rural STs lived below the poverty line (Majumdar, 2016). Additionally, STs have inadequate access to healthcare, employment, education, economic resources (e.g. land ownership), and government schemes (Majumdar, 2016). Political participation is also limited.

Patnaik (2013) conducted 173 district-level personal interviews with elected representatives and focus groups in Odisha to examine the representation of STs within the context of decentralized local government. The sample site was selected given its relatively high percentage of STs compared with the national average. Elected officials at each branch of local government were interviewed across different caste and tribal groups, ages, occupations, education levels, and gender. The researcher found that of the 173 respondents, only 18 were STs. The low representation was attributed to systemic injustices that exclude ST populations from decision-making processes and bodies. Instead, decentralization strengthened the power and authority of elites. The author concluded that rather than empowering marginalized populations, devolution reinforces the status quo to the detriment of STs (Patnaik, 2013).

Forest management and protection is also decentralized, with various consequences for forest-dwelling STs. Of the 275 million Indians dependent upon forest resources, approximately one-third are STs (Mundoli et al., 2016). In addition to the aforementioned struggles STs face, those living within forests suffer land alienation, natural resource degradation, displacement, and potential legal recourse for alleged encroachment (Bose et al., 2012). Further, forest-dwelling STs living in protected areas (PAs), such as wildlife sanctuaries and tiger reserves, are often antagonized by forest authorities and blamed for biodiversity losses (Hussain et al., 2016). Due to these challenging conditions, Harihar et al. (2014) found that residents in the Rajaji National Park and Corbett Tiger Reserve – PAs of Uttarakhand – would prefer to be resettled elsewhere than continue to live within the parks. Through socio-economic surveys conducted with 158 respondents, it was revealed that all but two were unsatisfied with the living conditions within the PAs. Villagers struggled with livestock depredation, forest unproductivity, and insufficient access to education and healthcare, among other problems (Harihar et al., 2014). In an attempt to address these issues, the national government passed The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (FRA) (Mohanty, 2015).

The FRA, which was officially notified in December 2007, allows individuals and communities to claim forest and land rights, which are subject to verification by a local Forest Rights Committee (FRC) (Barnes et al., 2016). STs and other traditional forest dwellers were also given power to conserve and protect forests and natural resources (Barnes et al., 2016). While the FRA devolved certain rights to forest-dwelling ST communities, ultimate authority lies with the states (Perera, 2014). Ownership of forests came under state control in 1980 with the passage of the Indian Forest (Conservation) Act (Sundar, 2013). The efficacy of the FRA has since been widely debated. Kumar et al. (2015) published a paper analyzing the potential effects of the FRA via an analysis of primary and secondary data, including empirical evidence from Odisha. They concluded that the FRA has a far better potential than other measures (e.g. the Joint Forest Management Program) to improve the wellbeing of forest-dwelling STs. By affording rights to village assemblies, and through the inclusion of STs in local democratic processes, forest officials are held accountable to do right by STs. With decentralization, power is also distributed more equitably, and the control of the Forest Department is constricted (Kumar et al., 2015). Other researchers, however, have been far more pessimistic about the outcomes of the FRA due to its unsuccessful implementation in several states (Veeresha, 2016).

Even with the enactment of the FRA, there are instances across the country of its provisions being ignored or implemented carelessly. Perera (2014) writes that state officials may be more inclined to side with development projects (e.g. mining) that clear forests than with the forest-dwelling ST populations that rely on the them for their livelihoods and traditions. In Springate-Baginski et al.'s study (2013) covering six villages in Andhra Pradesh, the authors also found that the election of FRCs was completed haphazardly to the displeasure of ST villagers. Through key informant interviews, focus group discussions, and household questionnaires, they learned that villagers who criticized the elections were threatened with the rejection of land title claims. During the implementation of the FRA, it was also found that authorities failed to explain community rights and the application process for land rights, as well as improperly conducted land surveys needed to grant tenure. The Forest Department overrode other rights too, including forest-dwellers' right to appeal rejected claims (Springate-Baginski et al, 2013).

Implementation is also stalled in ten states where claims to individual and community land rights are still being processed (Mundoli et al., 2016). TN is one of the states in which the FRA had not yet been implemented (Mohanty, 2015). As of 31st January 2017, none of the 21,781 land title deed claims – 18,420 of which are individual forest rights claims and the rest are at the community-level – have been distributed (Arasu, 2017). Through desk research, Mohanty (2015) cites the causes of FRA stagnation as states lacking trained, on-the-ground personnel and having to face civil insurgencies. In northeastern states, the FRA was not implemented, as they already had existing provisions for forest-dwelling STs and found the FRA extraneous. Troublingly, some states' Forest Departments were also found to purposely resist recognition of tribal rights (Mohanty, 2015).

The News Minute published a four-part series from 31st May to 26th June 2017 to better understand why TN failed to implement the FRA since its establishment over a decade ago. For the piece, Arasu (2017) interviewed forest-dwelling STs residing in PAs across TN, including the STR, as well key informants. One interviewee with the Ashoka Trust for Research in Ecology and the Environment (ATREE) was quoted as stating that the FRA has not yet been implemented as the Forest Department fears losing control of the state's 56,000 acres of forest. In contrast, forest officials blame implementation on insufficient manpower. Finally, STs in the STR believe that the impasse is a result of government apathy. Without FRA implementation, STs are restricted in their livelihood strategies, such as fishing and collection of non-timber forest products, and risk arrest. Villagers are also barred from developing their land. While some residents are able to get away with installing water supplies and power connections, MS Selvaraj states, "But even though this is there, now and then the forest department says, 'don't develop here, this is our land.' So the problems are still there" (Arasu, 2017). Without implementation, it is at the discretion of forest officials to cherry-pick which FRA provisions to permit within PAs (Arasu, 2017).

2.3 Resilience: A Conceptual Framework

Resilience is characterized by a unit's buffer capacity, self-organization, and adaptive capacity and learning (Milestad and Darnhofer, 2003). It has also been framed as one's disaster preparedness, adaptive capacity, and recovery (Bhamra et al., 2011). Adaptive capacity refers to the long-term coping mechanisms to phenomenon (Gallopín, 2006). It involves learning and feedback mechanisms (Milestad and Darnhofer, 2003). Social resilience, more specifically, is defined by a unit's ability to adapt to and recover from external threats (i.e. climatic variability) (Gallopín, 2006). In farming systems, Milestad and Darnhofer (2003) write that individual farm-level agricultural resilience includes awareness of climatic events, diversified livelihoods, socio-ecological management, political participation, information exchanges between farmers, and local support networks. Resilience must account for both long-term and sudden changes across geographical and temporal scales (Folke et al., 2005).

The concept of resilience has been examined through several frameworks, such as social-ecological systems (SES) theory, which came about in Holling's 1973 paper on ecological resilience (Welsh, 2014). SES theory is defined by Redman et al. as:

> 1. a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner; 2. a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked; 3. a set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of

ecological and social systems; and 4. a perpetually dynamic, complex system with continuous adaptation (2004, p. 163)

The components of an SES include resource systems and units, governance systems, and users. Within these components, other factors include resource system size, unit mobility, and user's knowledge (Ostrom, 2009). SES are complex, dynamic, and involve cooperation or collective action (Anderies et al., 2004).

Resilience and the concept of SES are not without their faults. After undertaking a thorough analysis of SES normative assumptions and related epistemology, Cote and Nightingale (2012) write that SES failed to take into consideration power dynamics or culture. Welsh (2014) adds that resilience has become devoid of politics since the 1970s, ignoring issues of social justice and power relations. Therefore, Cote and Nightingale (2012) have proposed an alternative to SES called situated resilience, which recognizes that impact of tradition and political marginalization in one's adaptive capacity. Cretney (2014) also provided an alternative to resilience over similar concerns about the concept's inability to account for power, marginalization, and agency called socio-ecological resilience. Under this framework, ensuring that society is resilient also ensures that the environment is resilient and vice-versa (Cretney, 2014).

2.4 Resilience and Climate Information and Advisory Services

Climate Information and Advisory Services (CIS) can help build agricultural and farm-level resilience by lessening climate-related losses and improving social benefits (Adams et al., 2015). In India, CIS includes agrometeorological advisories and early warning information systems, and are developed by an assortment of national, state, and district-level agencies. In 1945, the Indian Meteorological Department (IMD) created the Agro-Meteorology Advisory Service (AMAS). Farmers were unsatisfied with the service, as the weather advisories were provided only one-day in advance, leaving farmers with an insufficient lead-time for decision-making (Tall et al., 2014). As a result, the IMD further decentralized the program in 1976 to state and district-levels during its Eleventh Five Year Plan. The IMD's AMAS is supported by an array of institutions, including the India Council of Agricultural Research, non-governmental organizations (NGOs), community-based organizations (CBOs), and agricultural universities (Tripathi and Mishra, 2016). Another program developed was the Integrated Agrometeorological Advisory

Service (AAS) in 2008, which has since benefited three million farmers nationwide. Unlike AMAS, AAS is run by the National Centre for Medium Range Weather Forecasting. The AAS relies on local Agro Meteorological Field Units based at agricultural universities, like Tamil Nadu Agricultural University (TNAU), to disseminate climate information and weather forecasts. The data produced provides farmers with a four to five-day lead-time to anticipate and respond to changes in weather. The data includes rainfall, relative humidity, wind speed and direction, maximum and minimum temperatures, and cloudiness. Importantly, this CIS is delivered in several local languages and through mass media, meetings, the Internet, mobile phones, and posters. Through SMS and voice messages (i.e. Kisan) approximately 2.5 million farmers and 30,000 farmers, respectively, have accessed AAS (Tall et al., 2014).

CIS has improved the resilience and security of Indian farmers. Farmers in the state of Maharashtra receiving CIS produced by the Watershed Organisation Trust (WTO) and the Indian Meteorological Department (IMD) had increased agricultural productivity by 30 to 80 percent. Information was delivered through mobile phones, village loudspeakers, word-of-mouth, and walls in public areas. Additionally, the WTO and IMD's CIS focused on farm-level weather forecasts providing information in the local language on rainfall variability, among other climatic and agricultural information (Singh et al., 2017). Feedback mechanisms were also adopted (Lobo et al., 2017). Balaji and Craufurd (2011) found more broadly that farmers living in the Indo-Gangetic Plains receiving AAS reduced cultivation costs by up to 5 percent. Yields also increased by up to 25 percent. Moreover, AAS helped to increase farmers' knowledge of crop and soil management and build resilience to climatic variability (Balaji and Craufurd, 2011).

Despite these successes, several challenges have been identified regarding CIS production, accessibility, and use. In a study by Belakeri et al. (2017), the following issues identified were: 1) CIS production and delivery costs; 2) Distortion of information; 3) Time consuming process; 4) Ineffective communication of services; 5) Generic state- and district-level information; and 6) Mode of delivery (i.e. mobile phone and cell signal access). Joseph et al. (2017) also analyzed the accuracy of CIS (i.e. five-day weather forecasts) in TN using various statistical tools like categorical and quasi-continuous variables. In the Thoothukudi District, for example, the weather forecasts had a 64 to 78 percent accuracy (Joseph et al., 2017). Finally, access does not equate use of CIS. Even in communities with high mobile phone access and, therefore, CIS services (i.e. the Garo ST farmers of the northeastern Himalayas), CIS is not necessarily used (Lahiri et al., 2017).

In order to increase use, Meinke et al. (2006) suggests involving communities in the co-production of climate information, so that they feel that they 'own' the services they produced. It is necessary to address these challenges in order to build farm-level agricultural resilience.

2.5 Gaps in Literature and Research Importance

This research fills a gap within the literature. Currently, there is a dearth in the academic body of work analyzing farmers' access to and use of CIS in India, particularly that of forest-dwelling STs, as well as the disconnect between CIS producers and end-users. Additionally, given how recent the ongoing 2016-2017 drought is, research has not yet been published analyzing how CIS was used to build resilience to this historic event. Aside from their contribution to the academic literature, the findings may prove useful to CIS producers in the production and delivery of CIS. By gaining a better understanding of on-the-ground challenges in CIS accessibility and usefulness, producers can then begin the process of reforming their services to build the climate resilience of at-risk farming communities.

3 Case Study Sites

3.1 Sathyamangalam Wildlife Sanctuary and Tiger Reserve

The two case study sites selected within the Erode District were the Sathyamangalam Wildlife Sanctuary and Tiger Reserve (STR) and Bhavanisagar (Figure 1). The STR is located within the Western Ghats and is the largest tiger reserve within the southern state, consisting of 1,400 km^2 of forest. Its coordinates are 10°29'15" to 11°43'11" north and 76°50'46" to 77°27'22" east (Sathya and Jayakumar, 2017). In November 2008, it was declared a wildlife sanctuary (Kedlaya, 2013). Five years later, on 15th March 2013, the national government officially recognized it as a tiger reserve (Gurung, 2013). The reserve lies between 250 m to 1,450 m above mean sea level (Sathya and Jayakumar, 2017). Temperatures range from 21.54 to 32.84 degrees Celsius. Average annual rainfall measures 824 mm, with rainfall varying greatly across the protected area (PA) due to an east-west rainfall gradient (Sathyamangalam Tiger Reserve, n.d.). As a result, the STR consists of diverse forest types, including evergreen, deciduous, thorn, savanna and riparian forests (Sathya and Jayakumar, 2017). The STR receives 70 percent of its rainfall from the northeast monsoon (Swaminathan, 2016). This rainy season occurs from September to November, while the dry period is from January to April. Other months are characterized by intermittent rainfall (Sathyamangalam Tiger Reserve, n.d.). The two rivers that feed into the STR are the Bhavani and Moyar Rivers (Swaminathan, 2016).

The STR consists of 900 households across 138 villages. The two forest-dwelling STs residing in the PA are the Irulas and Kurumbas (Kedlaya, 2013). Interviews were conducted in the Mavanatham and Bejalatti villages of the STR's buffer zone (Table 1). Buffer zones are areas for habitat restoration protected from encroachment, grazing, poaching, timber felling or thinning, head loading, and biotic interference (Ramasubramanian, n.d.). In both villages, 99 percent of households belong to STs. In Mavanatham, 99 percent of households farm, while 95 percent farm in Bejalatti. Villagers in Mavanatham do not hold land rights, while in Bejalatti average land holding size with tenure was 0.5 acres, and 0.4 acres without tenure. Villagers in the STR farm finger millet, beans, mustard, and maize, among other crops. Additionally, they collect non-timber forest products (NTFP), like honey, gooseberry, myrobalan, and *Phoenix loureiroi* (Kodandapani et al., 2014). Literacy rates for the STR are unavailable; however, of the 189,661 Irulas living in Tamil Nadu (TN), 49.1 percent are literate. Of the 6,823 Kurumbas in TN, 61.5 percent are literate (Ministry of Tribal Affairs, 2013). However, remote forest-dwelling STs are generally characterized by their low literacy rates (Swaminathan, 2016).

3.2 Bhavanisagar

Bhavanisagar lies at the base of the Western Ghats in the rain shadow region approximately 23 km away from the STR. The rural town measures 282.5 km^2 (Prabhakar, 2017). It lies 256 m above mean sea level at 11°28'15" north and 77°6'50" east (CSTI, n.d.). The climate is semi-arid tropical, with average annual rainfall measuring 667 mm across 42 rainy days (TNAU Agritech Portal, 2013). Rainfall ranges from 600 mm to 800 mm, with 40.6 percent of rainfall deriving from the northeast monsoon (CSTI, n.d.). Temperatures range from 11.7 to 39.2 degrees Celsius. Irrigation in Bhavanisagar is supplied by the earthen Bhavanisagar Dam located on the Bhavani River (TNAU Agritech Portal, n.d.). The dam is supplied by both the Bhavani and Moyar Rivers (Sathyamangalam Tiger Reserve, n.d.). In the Community District (CD) Block of Bhavanisagar, 8.63 km^2 are irrigated by government canals, while 32.855 km^2 are irrigated using borewells and tubewells (Census of India, 2011). Borewells are vertically drilled wells cased with PVC pipes that extend to an aquifer. These wells are generally pumped using electrical pumps (India Water Portal, n.d.).

At the CD block-level, Bhavanisagar consists of 26 villages across 15 wards with a total population of 77,313 people (Census of India, 2011). The town itself comprises 2,134 households consisting of 7,710 residents (Chandramouli, 2011). The percentage of STs is 0.19 percent of the total CD block population. According to the 2011 census, 33.11 percent are farmers (Census of India, 2011). Crops grown include banana, coconut, paddy, sorghum, maize, peanut, turmeric, cotton, and tobacco, among other crops (TNAU Agritech Portal, 2013). The net sown area is 97.026 km^2, while the total irrigated area is 41.483 km^2. The remainder is rainfed. Approximately, 64.63 percent of CD block residents are literate (Census of India, 2011).

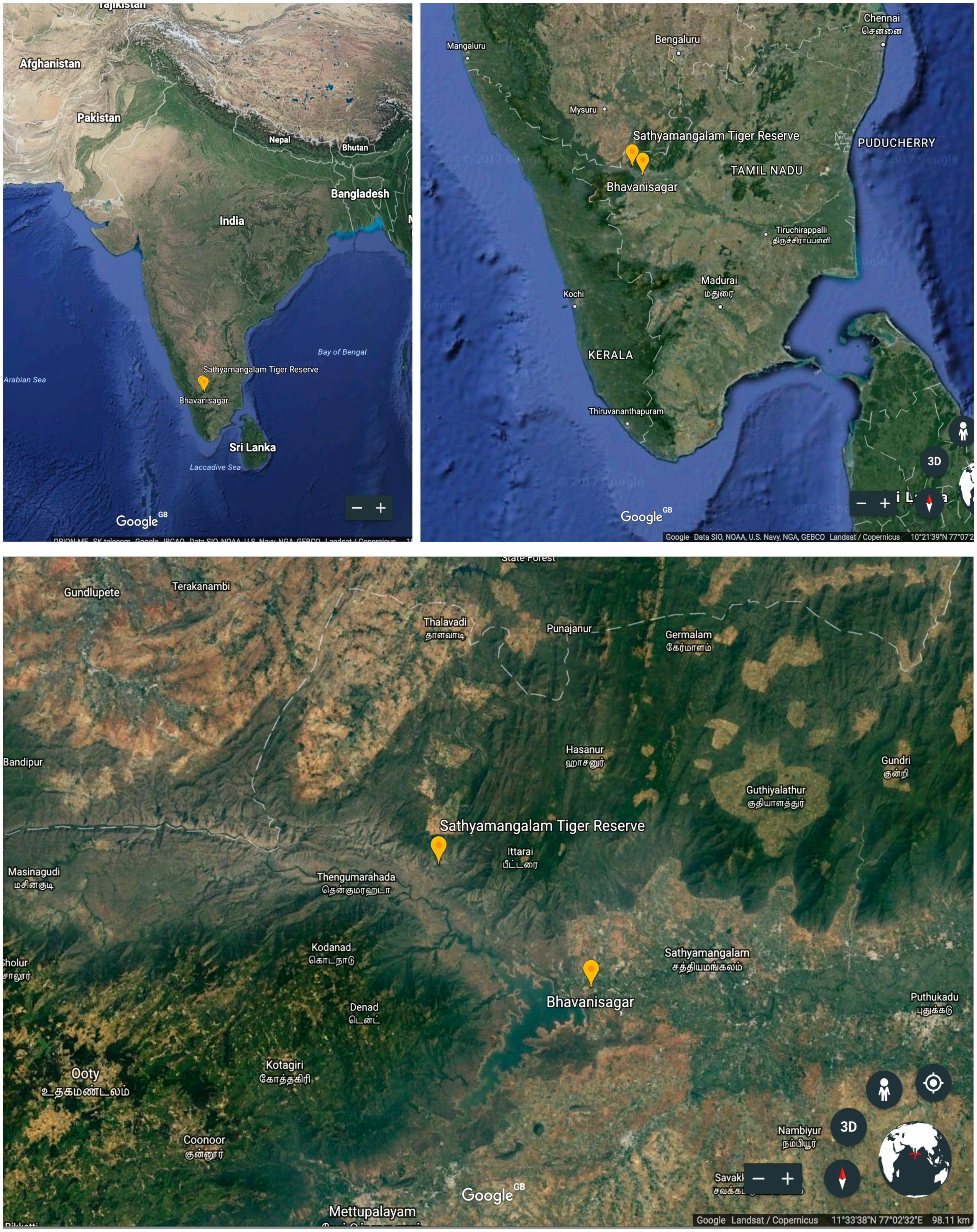

Figure 1: Map of case study sites Sathyamangalam Wildlife Sanctuary and Tiger Reserve and Bhavanisagar, Erode District, Tamil Nadu, southern India (Google Earth, 2017).

4 Research Methodology

4.1 Introduction

The dissertation seeks to answer the following questions: 1) How do climate information and advisory services (CIS) contribute to farm-level resiliency to climatic risk; 2) How were CIS accessed and used during the 2016 drought; and 3) Do CIS producers and end-users' expectations align? In order to answer these questions, an extensive literature review along with fieldwork were undertaken. Question 1 is answered through the literature review in Chapter 2. Questions 2 and 3 were explored through the collection and analysis of empirical data in Chapters 5 and 6. The fieldwork involved two components and was conducted over a 10-day period from 16th June to 6th July 2017. Firstly, farmers in two case study communities – Bhavanisagar and the Sathyamangalam Wildlife Sanctuary and Tiger Reserve (STR) – were interviewed using a general interview guide. Chapter 3 provides a comprehensive overview of the case study sites, including their geography and demographics. Secondly, semi-structured interviews were conducted with key informants across various government, non-governmental, and academic institutions. In total, 34 in-depth semi-structured interviews were conducted with 22 farmers (11 in each site) and 12 key informants. By examining both the existing literature and empirical evidence, this paper will provide a better understanding of the issues farmers face relating to access and use of CIS. In Chapter 4, the research strategies, site and sample selection methods, data collection techniques, frameworks for data analysis, and research limitations and problems will be discussed.

4.2 Research Strategy

A qualitative case study approach was selected to investigate the research questions given the focus on farmers' perceptions of climatic risks (i.e. 2016 drought) and CIS. Unlike the quantitative approach, qualitative data involves human interactions to produce information (Cleary et al., 2014). Qualitative researchers seek to comprehend the meaning behind phenomena and actions (Ercan and Marsh, 2016). Consequently, qualitative research has been criticized for its replicability, validity, representativeness, and reactivity (Katz, 2015). For an interpretivist, however, replicability and generalizability are irrelevant. The interpretivist epistemological position centers heavily on understanding, rather than explaining phenomenon (Ercan and Marsh, 2016). Interpretivism recognizes that participants and researchers' understanding and interpretation of the topic is influenced by their experiences (Schwandt, 1998). Additionally, it rejects theories and concepts for their reductionist nature. Rather, complexity is favored (Isaeva et al., 2015).

Additionally, a case study approach was selected to examine the 2016 drought event and CIS in Tamil Nadu (TN) amongst two vastly different farming populations. This approach is best used for research studying in-depth correlations and causal relationships (Gerring, 2004). Baxter and Jack write:

> According to Yin (2003) a case study design should be considered when: (a) The focus of the study is to answer "how" and "why" questions; (b) you cannot manipulate the behaviour of those involved in the study; (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context (2008, p. 545).

The case study design process involved the selection of the unit of analysis and the 'binding' of the case (Baxter and Jack, 2008). For this research project the unit of analysis were Scheduled Tribe (ST) and non-ST farmers, and the case was bound by location (i.e. drought-prone Erode District, TN) and time (i.e. 2016 drought event). Underpinning the research strategy is the interpretivist research paradigm (Baškarada, 2014). The case study approach has been critiqued for the context-dependent information it produces, its generalizability, and bias confirmation; however, Flyvbjerg (2006) refutes many of these concerns. The author, for example, argues that context-dependent information is invaluable as it provides depth to one's understanding of a phenomenon (Flyvbjerg, 2006).

4.3 Site and Sample Selection

The case study sites were selected based on their climatic and socioeconomic differences. As the case studies were not intended to be representative of the population at-large, case selection procedures did not apply (Seawright and Gerring, 2008). The STR population was characterized by its forest-dwelling ST status, rainfed agriculture, organic and subsistence farming practices, and lack of land ownership. In contrast, the Bhavanisagar population was characterized by its non-tribal status, use of irrigation technologies, choice in water-intensive cash crops, land ownership, and access to government services and schemes. Some of these differences are expanded upon in Tables 1 and 2. The case study sites – both of which were greatly affected by the 2016 drought – also varied climatically as described in Chapter 3. These differences allowed for interesting insights into how non-tribal farmers and forest-dwelling ST farmers responded to the 2016 TN drought, as well as the barriers both groups face in accessing and using CIS to build farm-level resilience.

In total, 11 farmers from each site were interviewed – a total of 22 farmer interviews. Furthermore, 12 key informant interviews were conducted. Participant selection followed key guidelines laid out by Cleary et al. (2014), in that participants must be selected intentionally with the theoretical or conceptual framework in mind. The population from which the participants were selected from were able to provide me with interesting and critical information about CIS, resilience, and the 2016 drought. Little research has been conducted in the locations given their remoteness, which allowed for an opportunity to fill the gap in the literature. The communities in the STR, for example, are difficult to reach as they require government permission to enter the protected area (PA).

Interview respondents were selected using snowball sampling. Objectivity is not necessary in qualitative research; therefore, non-random sampling methods were appropriate to use (Longhurst, 2003). Snowball sampling is used to access populations that are difficult for researchers to contact without a list of population members (Heckathorn, 2011). According to Heckathorn (2011), snowball sampling is recommended for sample populations that are small, spread-out, difficult to reach, and/or stigmatized. This method, however, has been criticized ethically, as snowball sampling threatens the anonymity of research participants as the recommender is aware of their identity (Brace-Govan, 2004). Additionally, this sampling method often leads to sample homogeneity and requires recommenders to have good quality social networks (Fossey et al., 2002). Aside from snowball sampling, researchers can recruit or select participants through other means including cold-calling and group membership lists (Longhurst, 2003). Like farmer participants, key informants were also selected through snowball sampling by asking expert interviewees for referrals. In this case, snowball sampling was an effective means to build one's network (Brace-Govan, 2004). All 12 interviewees agreed to partake in the interview process and answered all questions asked without hesitation. Table 3 includes detailed information about each key informant interviewed.

Table 1: Farmers interviewed in the Sathyamangalam Wildlife Sanctuary and Tiger Reserve.

Code	Village	Sex	Acreage	Water Source	Farming Practice
FKT1	Mavanatham	M	2 acres	Rainfed	Organic
FT1	Bejalatti	F	2 acres	Rainfed	Organic
FT2	Bejalatti	M	-	Rainfed	Organic
FT3	Bejalatti	M	1 acre	Rainfed	Mixed
FT4	Bejalatti	M	1.5 acres	Rainfed	Organic
FT5	Mavanatham	M	3 acres	Rainfed	Organic
FT6	Mavanatham	M	4 acres	Flood Irrigation	Organic
FT7	Mavanatham	M	2 acres	Rainfed	Organic
FT8	Mavanatham	M	2 acres	Rainfed	Organic
FT9	Mavanatham	M	3 acres	Rainfed	Organic
FT10	Mavanatham	F	2.5 acres	Rainfed	Organic

Table 2: Farmers interviewed in Bhavanisagar.

Code	Sex	Acreage	Water Source	Farming Practice
FKB1	M	13 acres	Drip Irrigation	Organic
FKB2	M	3 acres	Drip Irrigation	Mixed
FB1	M	-	Drip Irrigation	Organic
FB2	M	2.5 acres	Flood Irrigation	Non-Organic
FB3	M	3 acres	Flood Irrigation and Drip Irrigation	Non-Organic
FB4	M	6 acres	Rainfed and Drip Irrigation	Non-Organic
FB5	F	1.5 acres	Flood Irrigation	Mixed
FB6	F	20 acres	Rainfed, Flood Irrigation, and Drip Irrigation	Non-Organic
FB7	M	3.5 acres	Drip Irrigation	Organic

FB8	M	12 acres	Drip Irrigation	Mixed
FB9	F	4 acres	Flood Irrigation and Drip Irrigation	Organic

Table 3: Key informants interviewed.

Code	Organization	Job Title
FKB1	Model Learning Farm, Tamil Nadu Organic Certification Dept.	Organic Farmer
FKB2	Erode District Central Cooperative Bank, Ltd.	President
FKT1	Keystone Foundation	Social Worker
K1	Meteorology Dept., Tamil Nadu Agricultural University	Agronomist
K2	Forestry Dept., Forest College	Dept. Head
K3	Forestry Dept., Forest College	Assistant Professor
K4	Ashoka Trust for Research in Ecology and the Environment	Research Fellow
K5	Ashoka Trust for Research in Ecology and the Environment	Researcher
K6	Bhavanisagar Horticulture Dept.	Horticulture Officer
K7	Bhavanisagar Horticulture Dept.	Horticulture Officer
K8	Erode District Central Cooperative Bank, Ltd.	Bank Secretary
K9	Rivulis Irrigation India Private, Ltd.	Salesman

By collecting both farmer and key informant interviews, it is possible to then triangulate the data (Wilson, 2014). Triangulation is the process by which more than one type of research approach is used to answer or explore questions (Heale and Forbes, 2013). The types of triangulation involved in the study were methodological triangulation (i.e. semi-structured key informant and farmer interviews) and data triangulation (i.e. Bhavanisagar farmers, STR farmers, and key informants) (Adams et al., 2015). Data triangulation of multiple sources improves the reliability, validity and objectivity of one's research and helps achieve data saturation sooner (Fusch and Ness, 2015). The use of data saturation is discussed in section 4.4. Moreover, data triangulation promotes depth and reliability of the data and its methodologies (Wilson, 2014). Through data triangulation, findings may converge, diverge, or complement one another providing interesting insights and increasing the validity of the research findings in the case of converging results (Heale and Forbes, 2013).

4.4 Data Collection Techniques

In-depth semi-structured interviews were conducted with 12 key informants and 22 farmers across two case study sites – Bhavanisagar and the STR. On average, interviews lasted approximately 45 minutes and were facilitated by an interpreter. Semi-structured interviews, unlike structured interviews, are flexible allowing the researcher to gather additional responses beyond a pre-defined set of questions to explore new concepts (Baškarada, 2014). The sample size, interview questions asked, and duration of interviews helped to ensure that the data was of high quality. If using an interview approach, a smaller sample size is preferred if the intent is to conduct in-depth interviews and an analysis of a given phenomenon. A large sample size does not generally equate to better results or analysis (Cleary et al., 2014).

Given the semi-structured nature of the interviews, a general interview guide was produced for key informant and farmer interviews (refer to Appendices A and B). Farmer interview questions were divided into four categories: 1) background; 2) climatic risks, impacts, and resilience; 3) access to and use of CIS; and 4) government and/or NGO involvement in CIS delivery and other services. Key informant questions were divided into similar categories: 1) background and experience; 2) understanding of the climatic risks, impacts and resiliency of farmers; 3) production and/or delivery of CIS; and 4) farmers' access to and use of CIS. The interview responses were hand-recorded in a notebook and reviewed by the interpreter for accuracy during daily debriefing sessions. Notes also included daily weather observations from the field. The data was stored and protected as per CUREC guidelines. Additionally, it is important to note that local terminology was used during the interview process such as *agro-met advisories* in place of climate information service and *patta* for land title deeds.

Interviews were collected until data saturation was achieved. Data saturation is the point at which no new information can be learned (Mason, 2010). Information and coding saturation must be reached for each category in depth and breadth (Creswell and Poth, 2017). Fusch and Ness (2015) add that data saturation is achieved when there is enough data available for replication. As data collection involved long in-depth interviews with farmers from homogenous communities, data saturation was reached within the 10-day period (O'Reilly and Parker, 2013). Additionally, in research that focuses on exploring local phenomenon rather than making generalizations, such as this dissertation study, data saturation is more quickly achieved (Charmaz, 2006). In order to determine whether saturation has been reached, the researcher must analyze responses after each interview. It can be difficult for the researcher to know for certain that no new information will appear in subsequent interviews (Cleary et al., 2014). The concept of data saturation has been critiqued for its limitless possibilities. While a category may appear to be saturated, more information may come from it if explored though another lens (Mason, 2010). Moreover, biases from the researcher's personal lens are also of concern when determining whether data saturation is achieved. To ensure that my personal lens was minimized, I recognized my biases, views, and motivations beforehand to ensure that the data did not reflect my worldview (Fusch and Ness, 2015). Data saturation was the most useful principle by which to determine my sample size and minimize concerns about data validity and reliability

Other qualitative approaches, such as focus group discussions, were deemed inappropriate means by which to answer the research questions. Focus group discussions are used by researchers who seek to understand their research questions through group dynamics (Cleary et al., 2014). These interactions between heterogeneous populations provide additional insights into the ways in which socioeconomic, cultural, religious or political status relate to or influence a given phenomenon (Kamberelis and Dimitriadis, 2013). Given the homogeneity of the populations in each site, as well as the types of questions asked, it became clear that one-on-one interviews were the best means by which to gather detailed information. Moreover, the participants lived far apart from one another – particularly those in Bhavanisagar – and were busy with farming given that it was the kharif cropping season, which occurs from July through to October. Many farmers are restricted in how they move around without cars or motorbikes. This posed logistical challenges that contributed to the selection of an interview approach. It had been attempted to form focus groups after my arrival to India; however, due to these difficulties, only 3-4 individuals agreed to partake. In focus group discussions with under 5 participants, a researcher may face problems in data quality. With small discussion groups, it is difficult to achieve a sufficient amount of information pertinent to the research questions. Additionally, participants may be reluctant to speak or may engineer their responses to be socially correct when around others (Cleary et al., 2014).

4.5 Framework for Data Analysis

The basic framework for data analysis involves five main steps: 1) Data collection; 2) Electronic data transcription; 3) Data coding; 4) Data description; and 5) Data analysis (Figure 2). As discussed in Section 4.4, data collection involved fieldwork in TN. Semi-structured in-depth interviews were conducted with key informants, as well as with farmers in two case study sites. Upon returning to the UK on 15th July 2017, data was transcribed electronically and then coded using NVivo. NVivo is a qualitative data analysis computer software package that allows for the analysis of qualitative data to be completed more quickly freeing up time for the researcher to "discover tendencies, recognize themes and derive conclusions" (Hilal and Alabri, 2013, p. 182). NVivo was also selected as a way to minimize human error in data analysis given the complexity and number of interview responses. Software like NVivo ensures that the data analysis is far more accurate than manual analysis, as coding guarantees that no data are missed during the analysis phase (Welsh, 2002). The software is appropriate for various research strategies and data analysis methods (Zamawe, 2015). Compared with other software like Leximancer, NVivo was found to best code and analyze data (Sotiriadou et al., 2014).

Thematic coding is an important process in qualitative research analysis (Castleberry, 2014). Thus, key informant interviews were coded into three main categories or 'nodes': 1) Key informant characteristics; 2) Climatic risks and resilience; and 3) Agricultural systems. Each of these nodes were then further divided into sub-categories (Appendix C). Farmer interviews were coded into five nodes: 1) Demographic factors; 2) Climate variability; 3) Farm characteristics; 4) Irrigation and water sources; and 5) External support. A more detailed figure displaying the sub-categories can be found in Appendix D. After coding was completed, data was described and then analyzed. Key informant interview findings were compared against farmer interview findings. Interview results between Bhavanisagar and STR farmers were compared. Additionally, the literature review results were compared against the case study results. Data was analyzed using an interpretive approach for qualitative data. The interpretive approach requires that the researcher interpret the meaning of interviewees' responses (Welsh, 2002).

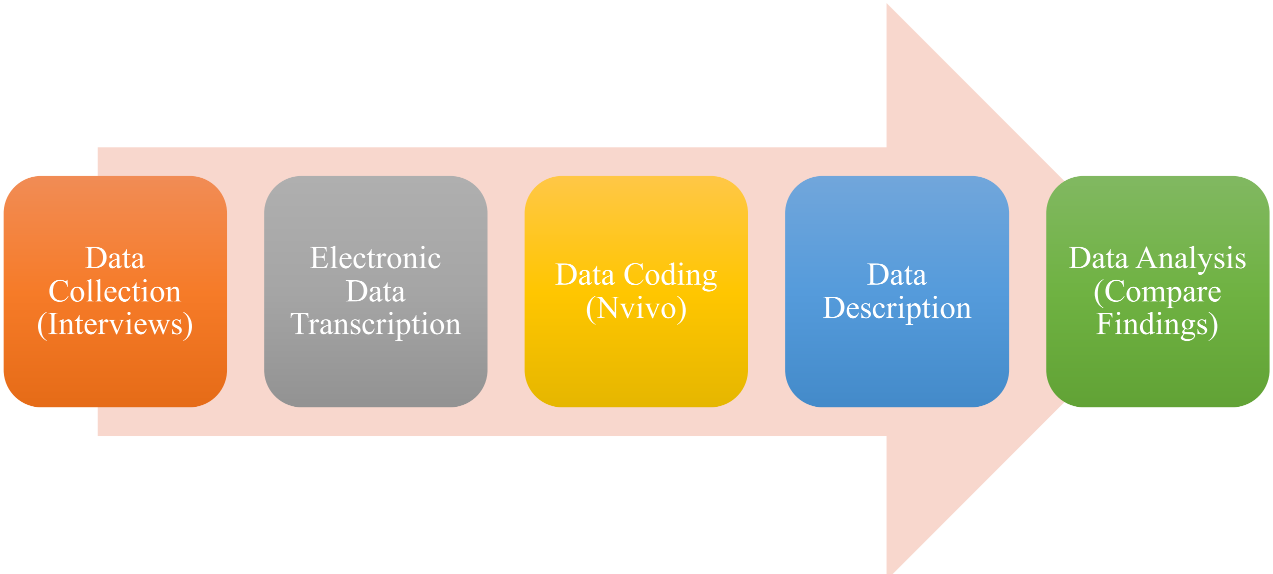

Figure 2: Qualitative data analysis process for STR and Bhavanisagar case study.

4.6 Limitations and Potential Problems

My main limitation as a qualitative researcher was the language barrier. Without any knowledge of the Tamil language, I was completely reliant on an interpreter. Given financial constraints, the Ashoka Trust for Research in Ecology and the Environment (ATREE) generously provided me with one of their researchers to serve as my interpreter free-of-cost. Temple (2002) reminds researchers that they should not ignore the limitations of interpreters, as they are "active producers in the research process" (p. 846). Bujra (2006) identified the following limitations in using an interpreter, such as the ways in which: 1) A researcher and their research is introduced to interviewees; 2) Responses are translated either literally or colloquially (and consequently risk losing sociological data); 3) Content is filtered by an interpreter, who decides what information is important without consulting the researcher; and 4) Power dynamics play out between the researcher, interpreter and interviewee. I attempted to minimize these interpretation issues by conducting daily debriefing sessions with my interpreter. During these sessions, we explored nuances, revisited and expanded upon concepts, and defined local terminology that does not necessarily have a direct English translation.

5 Results: Description and Analysis

5.1 Observations

While conducting fieldwork in the Sathyamangalam Wildlife Sanctuary and Tiger Reserve (STR) and Bhavanisagar, I observed stark differences in climate and vegetation between the two case study sites. The densely forested STR was noticeably cooler and greener than Bhavanisagar. In contrast, Bhavanisagar was far more arid. The vegetation consisted largely of cacti and short shrubs. During the nearly two-week period that I was in the field, it only rained once in Bhavanisagar and twice in the STR. The impact of the drought was observed in the Bhavanisagar canal and a watering hole in the STR. During a 2-mile long drive alongside a canal connected to the Bhavanisagar Dam, I observed that certain sections had completely dried up. I was told by farmer FB7 (2017), whose farm ran parallel to the canal, and K7 (2017) from the Bhavanisagar Horticulture Department that it was the first time they had seen it dry. As for the STR, the interpreter assisting in the research project remarked that a watering hole at the periphery of Mavanatham Village was noticeably drier than it had been when he had last visited in March 2017 (Vivekh 2017, personal communication, 05 July).

5.2 Semi-Structured Interviews

Farmers in both Bhavanisagar and the STR receive climate information and advisory services (CIS) largely through the television (Figure 3). The services are conveyed as short segments on the state or national news networks. The information presented is short-range weather forecasts that provide daily or weekly rainfall data at the state- or district-levels. Due to the type of information presented and how it is delivered, the services have been criticized as inaccurate, inaccessible (due to language, geographical and/or technical barriers), non-targeted (e.g. CIS is not tailored to organic farmers), and infrequently and unpredictably delivered (Figure 4). In its current form, the CIS accessed and used by Bhavanisagar and STR farmers is only useful for day-to-day activities, such as irrigation, fertilizer and pesticide application, plowing, sowing, weeding, and harvesting (Figure 5). More specifically, farmers stated that the decisions were whether to act on the aforementioned activities the next day or to hold off for another day when weather conditions were more favorable. For farmers in the STR who are unable to install irrigation technologies due to lacking land rights, the short-range weather forecasts have less use. Short-range forecasts are unable to assist farmers in farm-level decision-making during droughts.

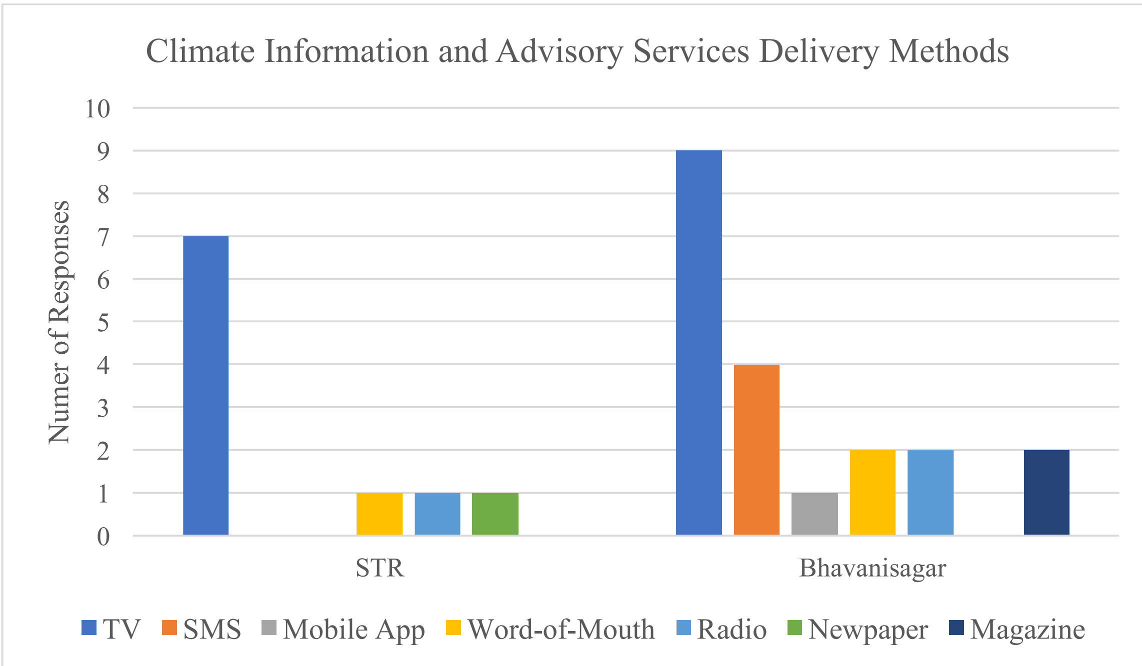

Figure 3: Farmer responses in STR and Bhavanisagar on how they access CIS.

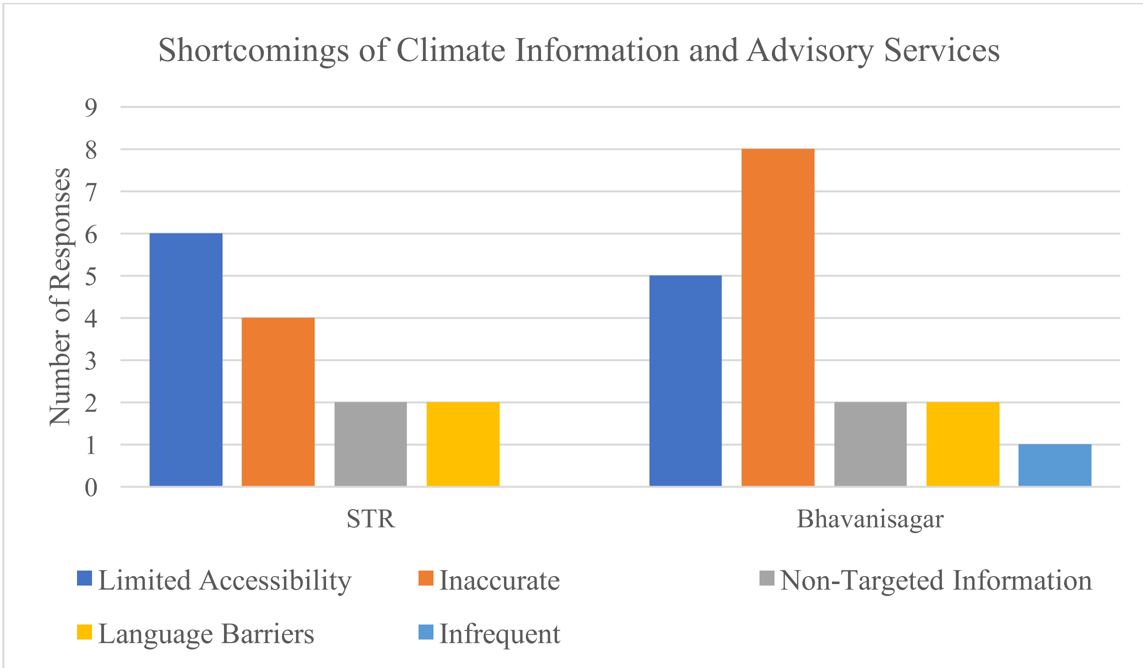

Figure 4: Farmer responses in STR and Bhavanisagar on the shortcomings of CIS.

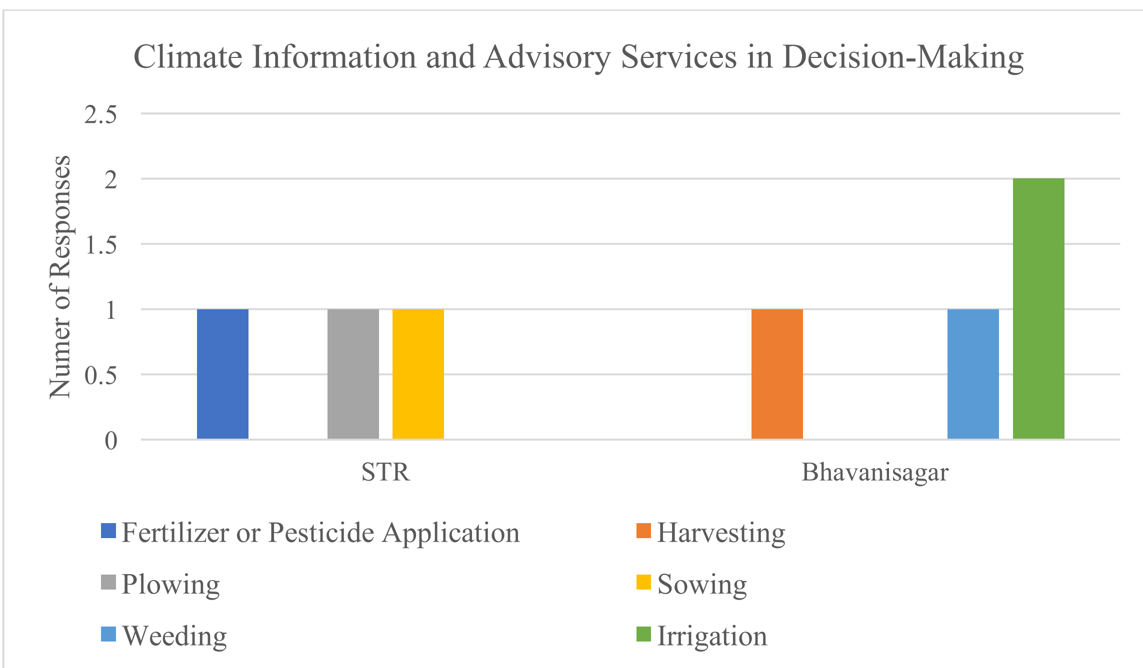

Figure 5: Farmer responses in STR and Bhavanisagar on uses of CIS in farm-level decision-making.

CIS must not only provide enough lead-time for end-users to make use of the information they provide, but must also address the shortcomings the farmers identified in the interviews discussed above. Due to limitations in language, geography and technology, information must be delivered so that it will reach the greatest number of farmers. Of greatest concern are marginalized rainfed farmers like the forest-dwelling scheduled tribes (STs) residing in the STR. CIS producers do not typically consider rainfed farmers when designing CIS services, as they do not contribute to large-scale food security (K4, 2017). While farmers in both communities raised similar concerns about CIS and drought impacts, forest-dwelling STs face additional challenges that exacerbate their vulnerability to climatic risks.

As discussed in Chapter 2, forest-dwelling STs residing in the STR are unable to claim individual land rights due to a stall in the implementation of The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (FRA). Without land rights, farmers in Mavanatham Village are unable to install irrigation systems. The only STR farmer interviewed with irrigation had installed the technology 20 years ago with the assistance of an NGO no longer operating in the area (FT6, 2017). The installation occurred before the park was declared a protected area (PA) in 2008 (Kedlaya, 2013). While land rights were not raised in the interviews in Bejalatti Village, FT3 (2017) cited government inaction in the construction of a small irrigation dam. He, along with 40 to 45 farmers, lobbied the local government to build a dam, but the government has not yet approved it for fear of its potential impacts on local wildlife (FT3, 2017). Consequently, unlike the farmers interviewed in Bhavanisagar, all but one farmer in the STR depend upon rainfall rather than irrigation technology to water their crops. Even with irrigation, Bhavanisagar experienced crop losses, as groundwater and reservoir levels dropped. Therefore, without reliable access to water resources in both communities, it is important that these farmers access CIS for effective farm-level decision-making.

Given the remote geography of the STR and high rates of illiteracy amongst forest-dwelling STs, CIS should be delivered through TV. TVs were delivered to each farmer in the STR five years ago as part of a government scheme (FT8, 2017). Other modes of delivery, such as SMS and the Internet, are inaccessible given the poor cell and data signals. While Bhavanisagar farmers have more modes of delivery available to them given their higher literacy rates and access to technology, they too prefer TV news to receive information. CIS delivered through TV programs are more engaging than their alternatives given their visual component. As weather forecasts are typically delivered between commercial breaks, farmers are more likely to be exposed to CIS. Some of the farmers interviewed recommended that the state create a television channel solely dedicated to CIS. Unfortunately, however, the farmers have not yet had an opportunity to express these views to the government, as none were solicited for feedback about their access to and use of CIS. The importance of end-user feedback became clear in K1's interview.

When asked about illiterate and socially marginalized farmers' access to CIS, K1 (2017) responded, "the only marginalized group in India are farmers, all of whom receive SMS [Short Message Service] messages. Now, even illiterate people can access the services." The on-the-ground farmer interviews contradicted K1's (2017) statement and highlighted a lack of awareness and disconnect between the CIS producers and end-users. While K1 (2017) proclaimed that SMS texts are accessible to all farmers, the empirical evidence demonstrates that this is incorrect. In the remote STR, cell signal does not work (FT5, 2017). Many of the STR farmers are also illiterate and/or do not have access to mobile phones. Moreover, despite an overwhelming preference by farmers for rainfall data, Tamil Nadu Agricultural University (TNAU) is developing targeted CIS centered on *agricultural information*, such as pest and disease incidence, fertilizer application, and market prices. The Bhavanisagar Horticulture Department also fails to train or provide farmers with weather or climate information in its annual Kisan SMS training (K7, 2017). In fact, there are no government departments or organizations operating in Bhavanisagar that train or raise farmers' awareness on weather or climate (K7, 2017). Similarly, there are no government institutions or non-governmental organizations in the STR that provide CIS training, services, or awareness to farmers (FKT1, 2017).

While farmers expressed interest in accessing and using CIS to build resilience to droughts, some key informants were skeptical of their willingness to use the services. Due to the deficiencies in CIS and short-range forecasts, farmers living in the STR are more likely to predict daily rainfall using traditional knowledge (K3, 2017). For example, FT1 (2017) prefers to use her own knowledge and experiences than short-range forecasts from the TV, which she finds inaccurate. Access to services does not guarantee use of services (FKT1, 2017). In the following chapter, I will explore in greater depth the role of CIS in drought resilience. For a more comprehensive summary of the findings, please refer to Tables 4 and 5.

Table 4: Farmer responses and selected quotes.

Topic	FB	FT	Selected Quotes
Perceived droughts to be increasing over the past three years	11/11	9/11	FKB2: "Last year was the first time in the past 20 to 30 years that we had a water shortage. The level of my open well decreased, although my crops survived. Unfortunately, my neighbors' crops dried." FB2: "Over the last 2 to 3 years, there has been a decrease in rainfall resulting in water shortages. Last year's drought was worse than the others." FB7: "For the past 2 years, I have had to leave between 1 and 1.5 acres fallow because of water shortages. The shortage has affected an additional 1 to 2.5 acres of crops." FT8: "I have noticed a decrease in rainfall over the last 2 years. It is the first time we have had water shortages in the past 50 to 60 years."
2016 drought impacts	6/11	8/11	FB3: "I use flood irrigation to irrigate paddy daily, but with the drought I have had to reduce the amount I grow. Due to the water shortage, the Bhavanisagar Dam authorities have had to cut the water supply. They only give a 1 to 2-day warning in the newspaper." FB6: "I normally make between ₹400,000 and ₹500,000 per year, but last year I only made ₹300,000. 10 years ago, we had a water shortage issue. The one that began 1.5 years ago is even worse. I lost 100 percent of my crops across 4 or 5 acres. It is the first time that this many acres of jasmine have dried." FB8: "I use the Bhavanisagar Dam to irrigate my paddy, but for the past two years the dam has gone dry. Last year, I needed to use the water from my open well for the paddy. Therefore, I grew less paddy this year." FKT1: "In 2016, all the villagers lost half of their crops. This affected income and food consumption."

			FT1: "My crops lost half their value last year. I was not compensated by the government as I live in a settlement area." FT8: "Last year, I lost half of my crops and profits to the drought. I had to borrow money from a local moneylender. If I had access to irrigation technology, I would not have to worry about water shortages. I cannot drill a well, however, as I do not have *patta* [land title deed]. Neither the Forest Department nor the *panchayat* [local government] will not allow me to. It would also be expensive to do so." FT9: "For the past two years, my profits have dropped from ₹100,000 per year to ₹20,000 due to drought."
Accessed CIS	9/11	8/11	FKB2: "I do not trust 90 percent of the weather information I receive from TV. I also had been using the Kisan mobile app for the last 2 years, but a few months back the app suddenly stopped working. I do not know what happened or how to fix it." FB2: "I have received rainfall and temperature information through TV every day for the past 20 years. I do not use this information though, as it is unreliable. If they say it will rain here, it rains instead in another village." FB5: "I prefer to access rainfall information on the TV, as I do not know how to use a mobile phone and cannot read." FB6: "I watch the weather news occasionally on TV, but the information is too general. I do not know where else I can find this type of information." FB7: "I learned about the Kisan SMS through TNAU, but seldom use it. As an organic farmer, I do not find the service applicable to me, as the information is too focused on non-organic farming. Also, it is unpredictable when I will receive a message."

			FB8: "I sought agro-met advisories 5 years ago, because I thought it would be helpful. I am satisfied with the information I receive, although it is not correct 25 percent of the time. My only other issue is with Kisan SMS, as the messages are mostly in English. Most of us do not know English." FT1: "I occasionally watch TV weather news, but the information is too basic. I rather use my own traditional knowledge to predict rainfall." FT7: "I am only able to access the information on TV, as I do not have access to a radio and cannot read. If the information were more reliable, I would use it to plan farming activities." FT9: "If the short-range forecasts were more reliable, I would be able to use them to decide when to plow and apply manure."
Used CIS to prepare for 2016 drought	0/11	0/11	FKB2: "The short-term information I receive does not help anticipate droughts. I would need longer-range forecasts to plan ahead of the season. The information last year about the drought came too late to be useful." FT2: "The information I receive through TV and radio is too general. To prepare for droughts, I would like village-level information and for information to be delivered to me with enough time to make preparations." FT5: "I did not know about CIS or agrometeorological advisories, but would like to have access to monthly or seasonal rainfall information so that I can better prepare for water shortages like last year's. I think it would be most convenient to access it through SMS, but the cell signal is very bad. We also do not have Internet access." FT8: "The daily and weekly rainfall information I currently get only helps plan some day-to-day activities. Information that looks further into the future would be more useful."

Table 5: Key informant responses and selected quotes.

Topic	Selected Quotes
Climate Variability, Impacts and Resilience	FKB1: "Last year the drought was particularly bad, as we did not get proper rainfall. This year, even drinking water availability was impacted. Of all groups, farmers are most impacted by climate change." K1: "Consecutive droughts are happening more frequently, and rainfall is shrinking. The onset of the monsoon is right, but long dry spells have been occurring afterwards." K6: "Horticulture crops are most sensitive to droughts and are not grown in rainfed farms. Despite the drought conditions, farmers will not switch crops to less water-intensive crops due to sentimental or labor issues. These droughts impact farmers by reducing their yields and incomes; however, most farmers impacted live outside Bhavanisagar. Bhavanisagar farmers are less affected by climate variability, as they have access to the Bhavani River and the Bhavanisagar Dam for irrigation." K8: "Guideline Order (Ms) No. 59 was introduced last year as a loan forgiveness scheme for marginal and smallholder farmers due to the 2016 state-wide drought." K9: "Farmers in the Erode District are not aware of climate change."
Farmers' access to and use of CIS	FKB1: "Forecasting technologies are not made readily available for members of the community. For example, information is available on the Internet, but it is not accessible to the farmers here. Additionally, data is not provided on the farm-level. If farmers had access to farm-level rainfall information, they would use CIS to plan their farming activities." FKT1: "TV is the best way for farmers here to receive CIS, as many of the farmers are illiterate and the signal is poor. Only my generation [20s] is literate, so we have a responsibility to convey climate information to our parents. I think that another option to transmit information could be self-help groups, but we do not have any currently

	established here. While the information is available to farmers on TV and word-of-mouth, farmers do not use this information." K1: "Extreme weather events increase awareness of climate change amongst farmers. Now, farmers want to use CIS whereas beforehand, they made jokes about weather forecasts. Farmers are using CIS for farming and even property development purposes. We conducted a study 3 or 4 years ago looking at the economic benefits of seasonal climate forecasting for paddy, tomato, and banana farmers. We found that profit increased by 8 to 15 percent. Farmers are generally happy with CIS." K3: "In Bhavanisagar, farmers can visit the center of town to get information from a met office bulletin board that displays daily temperature and rainfall or through the TNAU met website. As for farmers in the tiger reserve, I do not think that they would use CIS, as they have long relied on traditional knowledge to determine daily rainfall. According to them, the short-range forecasts are just as effective as their traditional knowledge." K4: "CIS targets irrigated farmers, not marginalized rainfed farmers." K6: "Farmers in Bhavanisagar are using the Kisan app for weather forecasts, availability of fertilizers, and market prices." K7: "Bhavanisagar farmers rely largely on TV for weather forecasts to plan their farming activities. Admittedly, farmers do not find the information to be 100% accurate given how general it is at the state- or district-levels. We provide training for 300 farmers each year on how to use the Kisan SMS. We have provided the training for the last three years. We do not discuss weather or climate, nor are there any government departments in Bhavanisagar that communicate climate information. "

6 Discussion

6.1 The Broader Context

Adaptive capacity to climatic risks are found to be lowest amongst those that are marginalized, illiterate, poor, and own little to no land (Tripathi and Mishra, 2016). These communities lack the information and economic resources needed to reduce climatic vulnerabilities and build agricultural resilience (Howe et al., 2014). Additionally, due to the speed at which the climate is changing, local knowledge is also becoming less relevant (Tall et al., 2014). As a result, van Etten et al. (2017) put forth the data revolution as a solution of which Climate Information and Advisory Services (CIS) is one component. For smallholder rainfed farmers who previously relied on traditional knowledge to predict rainfall patterns, CIS can create a new reservoir of knowledge from which to make safer and more efficient decisions (van Etten et al., 2017). However, CIS producers must design CIS so that issues of equal access and use are taken into consideration. The data revolution must be both effective and ethical. Adams et al. (2015) stress that CIS producers must: 1) Co-produce knowledge through public participation; 2) Consider climatic and non-climatic vulnerabilities; 3) Communicate CIS clearly; 4) Easily be able to revise their services; and 5) Be targeted and village-specific. In addition to these guidelines, Tall et al. (2014) propose that CIS: 1) Have sustained interaction between institutions and farmers; 2) Be delivered locally; 3) Have diverse products with various lead times; 4) Allow for farmer feedback; 5) Integrate scientific and local knowledge; 6) Include face-to-face dialogue; 7) Have diverse communication channels; and 8) Target women and marginalized groups. These CIS best practices should be considered by CIS producers in Tamil Nadu (TN) to increase farmers' access to CIS and to bridge the divide between CIS producer expectations and farmer realities.

Furthermore, in order to improve access to CIS, the Indian government will need to adopt a user-centered design reliant on user feedback (van Etten et al., 2017). According to van Etten et al. (2017) this will require significant financial and regulatory investments to create sustainable, accessible, and useful CIS. CIS should also promote climate-smart agriculture (CSA). CSA is defined by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) as an agricultural approach that:

1) sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and development; 2) adapting and building resilience of agricultural and food security systems to climate change at multiple levels; and 3) reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries) (CCAFS and UNFAO, 2014).

CIS can scale-up CSA to ensure that populations increase their adaptive capacities and agricultural resilience (Rodríguez et al., 2017).

During the 2016-2017 drought event, new and promising CIS were developed. In TN, satellite data analytics company, Satsure, offered to provide satellite information that "can calculate the actual availability of water in the plants; determine the strength of the crops and identify the stressed and the non-stressed areas; and accordingly schedule your irrigation" (Kedia, 2017). The production and delivery of CIS from a private company may provide a suitable alternative to that of public institutions which are in a poor state. Balaji and Craufurd (2011) found in an analysis of agricultural extension services and climate information in the Indo-Gangetic Plains that government CIS producers are poorly organized. Additionally, a program similar to that of the Watershed Organisation Trust (WTO) and the Indian Meteorological Department (IMD) should be considered. While the WTO and IMD program centers on short-range and not seasonal forecasts, it still has positive results. Their short-range forecasts were localized and delivered every hour of every day. Moreover, it sought the feedback of its users, which consist of 6,300 households. As a result, 93 percent of farmers thought the services were reliable and used the information to make farm-level decisions, and 57 percent thought that timeliness in CIS delivery improved (Lobo et al., 2017).

6.2 Reflections

The research requires further exploration into drought resilience in the STR and Bhavanisagar farming communities. At the conclusion of this research project, certain questions still exist particularly: 1) To what extent do CIS improve resiliency as compared with other measures (i.e. irrigation, organic farming practices, crop selection, livelihood diversification, etc.); 2) Which community is more resilient to climate variability than the other; 3) How can public participation improve CIS production, delivery, access and/or use; 4) and What is the role of NGOs in delivering CIS? In order to respond to these questions, it is important to spend an extended period at the study site and increase the number of farmers and key informants interviewed. Additionally, it would be of interest to follow-up with the research project within the next few years given the dynamic status of the communities and climate. For example, once implementation of the FRA is underway in the STR, it could dramatically change the STs' ability to cope with droughts. K1 (2017) also stated during their interview that Tamil Nadu Agricultural University (TNAU) is developing targeted farm-level advisories and seasonal climate forecasting tools. The historic TN drought is also still ongoing with increasing civil unrest and political pressures.

7 Conclusion

The 2016 drought event impacted 25 percent of Indian citizens across 10 states (Choudhury and Sindhi, 2017). The drought has continued to persist into 2017. In Tamil Nadu (TN), 8 of its 32 districts are classified as drought-prone (Manikandan and Tamilmani, 2015). On 1st April 2017, it was reported that reservoir levels in TN's major reservoirs sunk to 8 percent of their total storage capacity. In response, the Tamil Nadu Water Supply and Drainage Board limited the water supply by 75 percent (Mariappanl, 2017). Farmers relying on the dam for irrigation suffered lower productivity as inflow decreased and reservoirs dried. Groundwater levels in the Erode District also dropped from January 2016 to May 2017 by 7 m. Compared with other districts in TN, the Erode District saw the sharpest declines in groundwater levels. This decrease in groundwater is attributed to increased drilling of wells in response to the drought, as well as a preference for water-intensive crops like coconut, sugarcane, and maize (Vaitheesvaran, 2017). Without rainfall, the water table is unable to recharge. Consequently, farmers have begun to sell livestock and farmland leaving many economically depressed (Kannan, 2017). Due to devastating crop losses, many farmers have resorted to taking their lives since the drought began in 2016 (DT Next, 2016). The Sathyamangalam Wildlife Sanctuary and Tiger Reserve (STR) also experienced drought beginning in February 2017 (TNN, 2017). Wildlife living in the STR were dying from food shortages brought on by insufficient rainfall. As a result, the Forest Department invested in artificial water-bodies for wildlife (Kotteswaran, 2017). In desperation, villagers residing in the STR began to drink from elephant water troughs. It was not until 22nd June 2017 that residents and wildlife of the STR began to receive some respite from the months-long drought (TNN, 2017).

In order to bring attention to the crisis and to request assistance, TN farmers traveled north to Delhi to conduct a strike demanding the creation of a drought relief package, a farm loan waiver, and a Cauvery Management Board. The protests began in late March 2017 and extended to August 2017. On 23rd April 2017, the chief minister of TN promised to meet the strikers' demands resulting in a hiatus in May; however, the minister did not follow through on his promise (Kapoor, 2017). The farmers have since resumed their protest (Mani, 2017). As recently as 21st August 2017, the farmers began requesting to meet with the Indian president and prime minister about their situation, as they felt ignored by state politicians. In a memorandum to the president, the farmers have asked for permission to commit suicide if their demands are unmet (Express News Service, 2017). It is imperative to understand not only how TN farmers arrived at this situation, but, more importantly, what adaptation strategies exist to minimize similar crop and profit losses in the future.

This paper sought to better understand climate information and advisory services (CIS) as an adaptation strategy to build farmers' resilience to droughts. The paper explored: 1) How CIS contribute to farm-level resilience to climatic risks; 2) How CIS were accessed and used during the 2016 drought; and 3) Whether CIS producers and end-users' expectations aligned. As evidenced in the literature review and the empirical data, CIS can build agricultural resilience to droughts by supporting farmer decision-making and management of climatic risks (Tall et al., 2014). In order to design effective CIS, CIS producers must proactively solicit feedback from end-users to identify challenges and solutions to access and use (Chattopadhyay et al., 2016). The dissertation identified a disconnect between CIS producers and farmers resulting in poor access and use of CIS by the sample populations. Some of the issues leading to farmer dissatisfaction were that CIS were inaccessible, delivered infrequently or unpredictably, and were inaccurate as they were district- or state-level forecasts. Additionally, short-range forecasts proved useless to farmers in mitigating the impacts of the 2016 drought. Farmers preferred to receive seasonal climate forecasts that can inform their decision-making of what to sow, whether to leave land fallow, and whether to diversify their livelihoods, among other decisions. Instead, CIS producers have continued to deliver short-range forecasts focused heavily on agricultural production than on meteorological conditions.

The implications of these findings go beyond the case study sites and India itself. As addressed in Chapters 1 and 2, the research contributes to the body of work on CIS, which lacks empirical data on CIS challenges in the case study sites, its populations, and in similar communities in India. Additionally, research has not yet been published exploring how CIS were used in the historic 2016-2017 Indian drought. The empirical findings in this paper have produced new knowledge relevant to CIS producers within TN and in other regions suffering from climate variability induced by climate change and the El Niño Southern Oscillation (ENSO). Other than India, regions like the Sahel, southern Africa, central and southwest Asia, and parts of South America experience devastating climate change and ENSO-related droughts that are expected to intensify in the upcoming decades (Wang et al., 2014). Additionally, with the predicted 2-degree

Celsius increase in global temperatures as a result of climate change, crop yields worldwide are expected to decline. Rice yields, for example, are expected to drop by 0.75 ton/ha (Sivaraj and Philip, 2015).

The need to adapt extends beyond the individual level. Climate change and ENSO threaten agrarian livelihoods, as well as agriculture-based economies and food security (Cashin et al., 2017). Globally, demand for major crops like maize, wheat and rice is expected to rise by up to 110 percent beyond that of 2005 (Iizumi et al., 2014). CIS should be used as a tool to protect the economic wellbeing of farmers, as well as national GDP and food security. CIS can help farmers and governments respond to climatic risks thus minimizing malnutrition and economic crises, as well as improving resilience (Iizumi et al., 2014). There is need for further investigation into CIS's benefits at the community, state and national levels. Additionally, researchers and governments must explore ways to improve CIS' efficacy in improving resilience to droughts and other climatic risks. CIS is not a substitution for other adaptation strategies. Rather, it should be used as a tool for farmers in decision-making and selecting adaptation strategies like intercropping, soil moisture and water conservation measures, re-seeding, transplantation, or mulching, (Rao and Rao, 2016).

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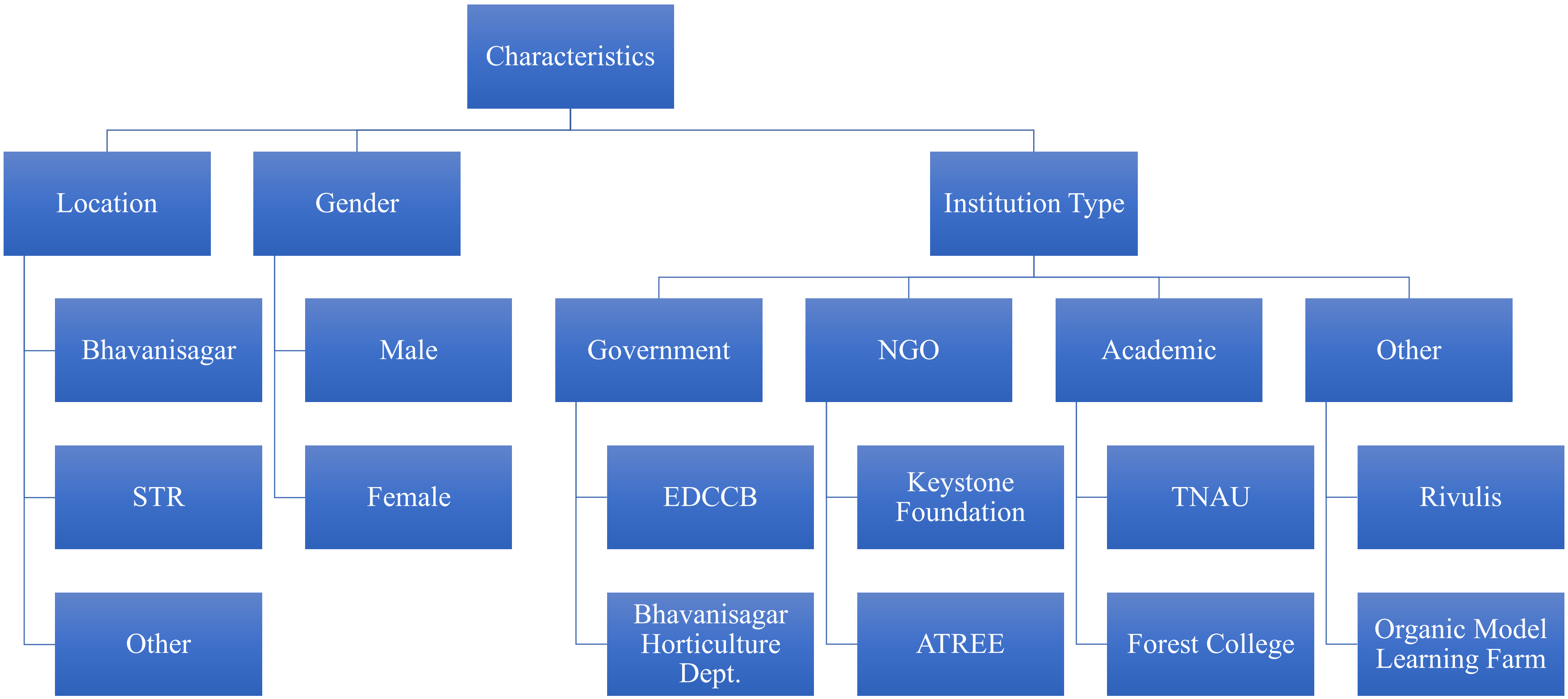
Appendices

Appendix A: General Key Informant Interview Guide

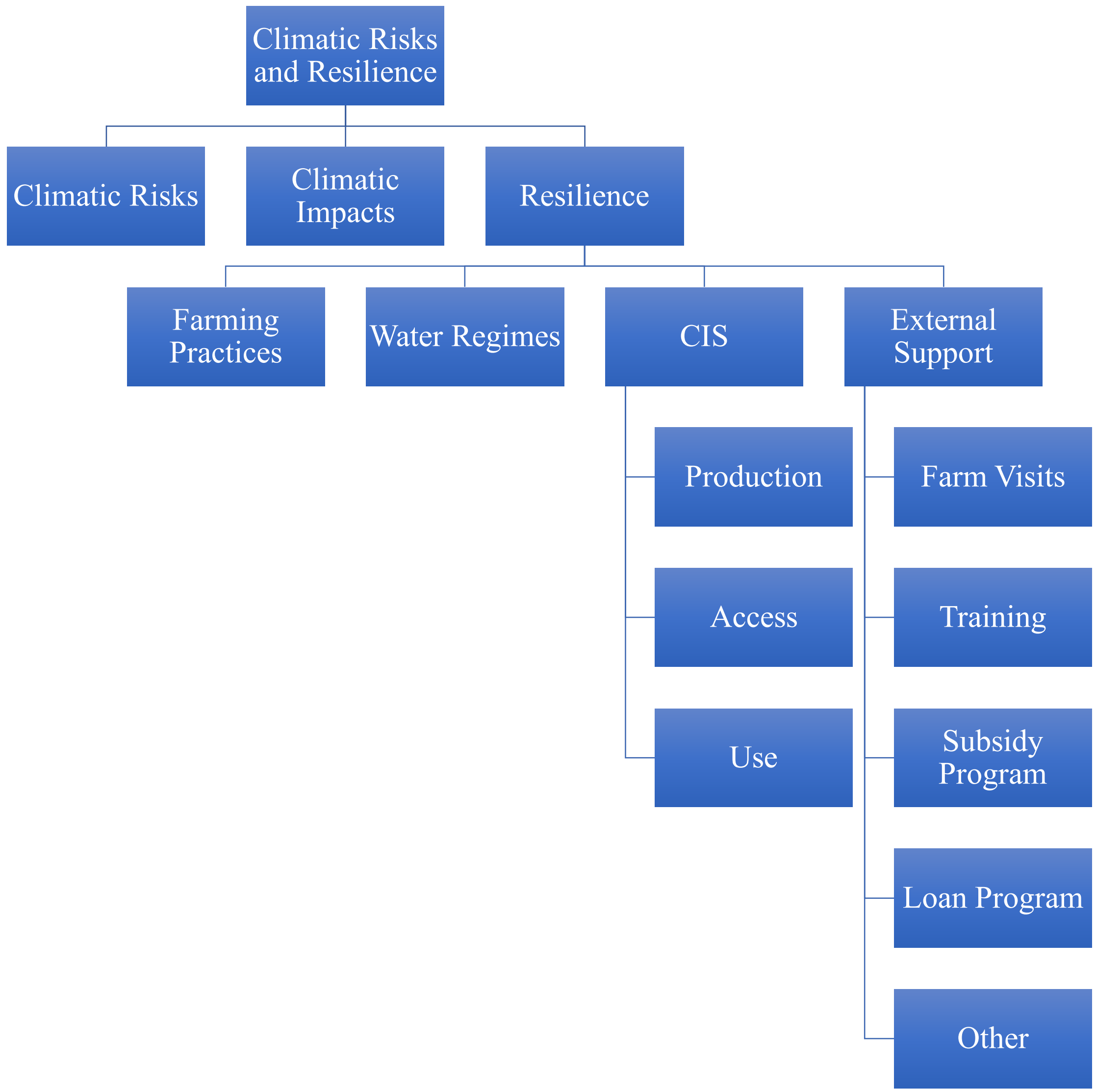
Appendix B: General Farmer Interview Guide

Appendix C: Classification Nodes for Key Informant Interviews

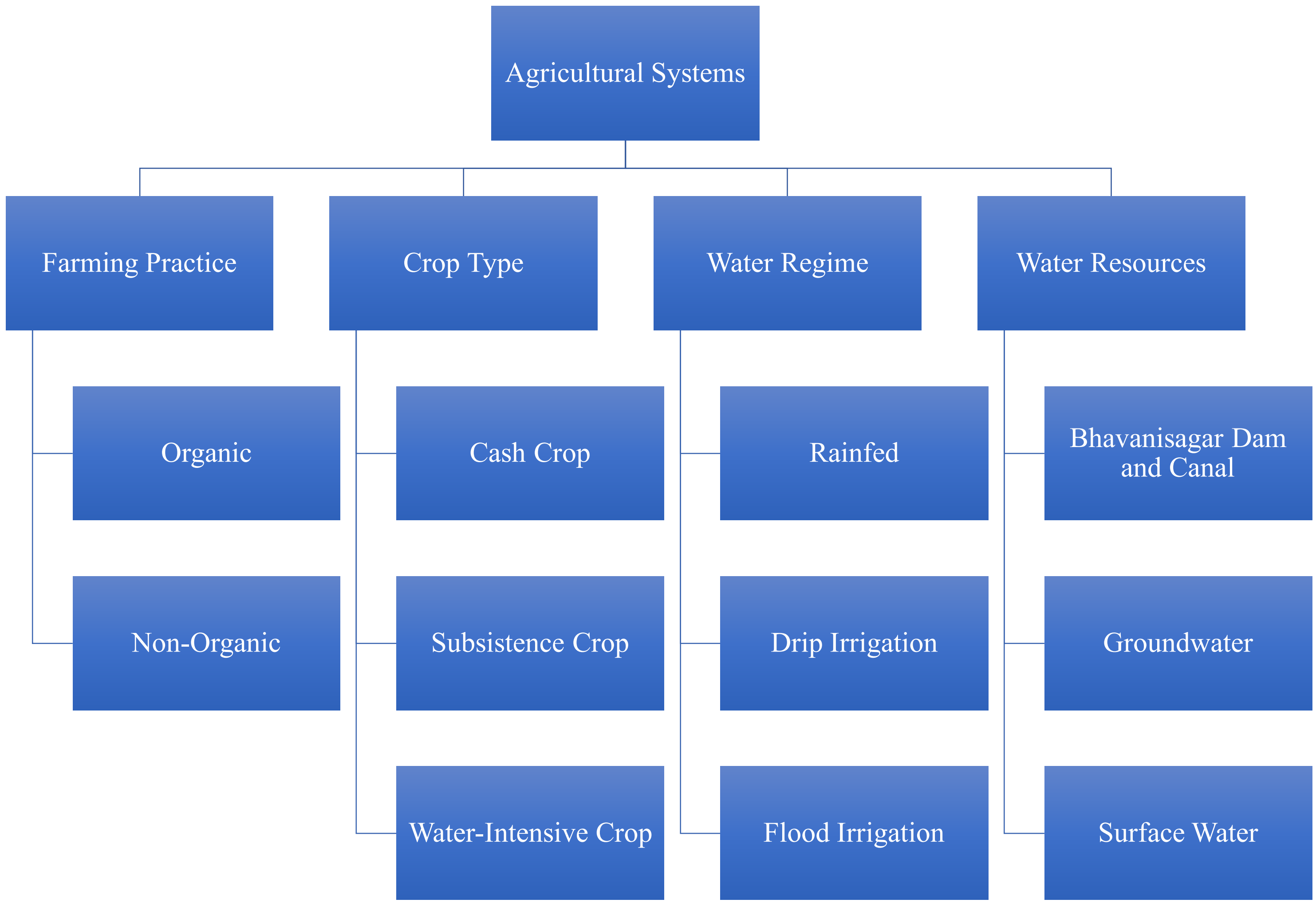
Node 1: Key Informant Characteristics



Node 2: Climatic Risks and Resilience

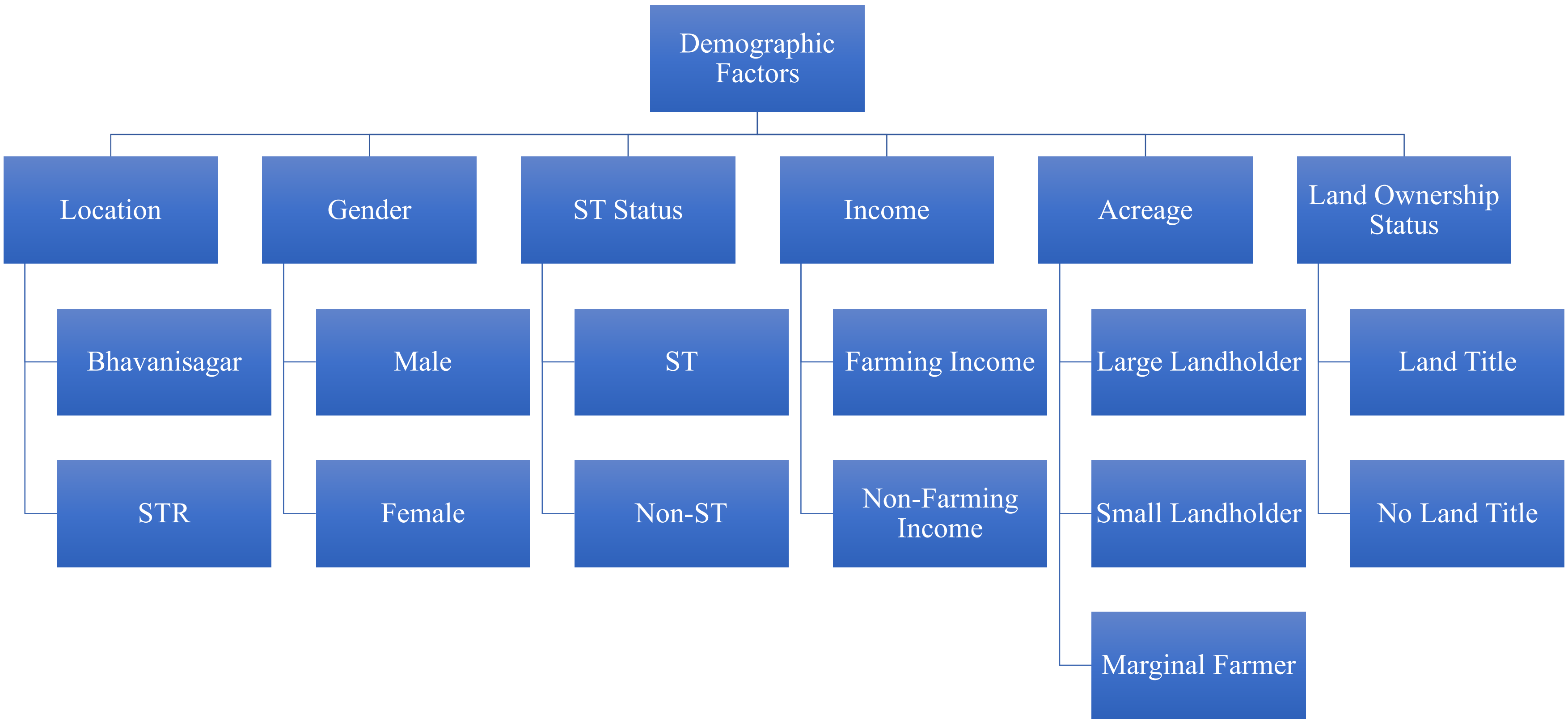


Node 3: Agricultural Systems

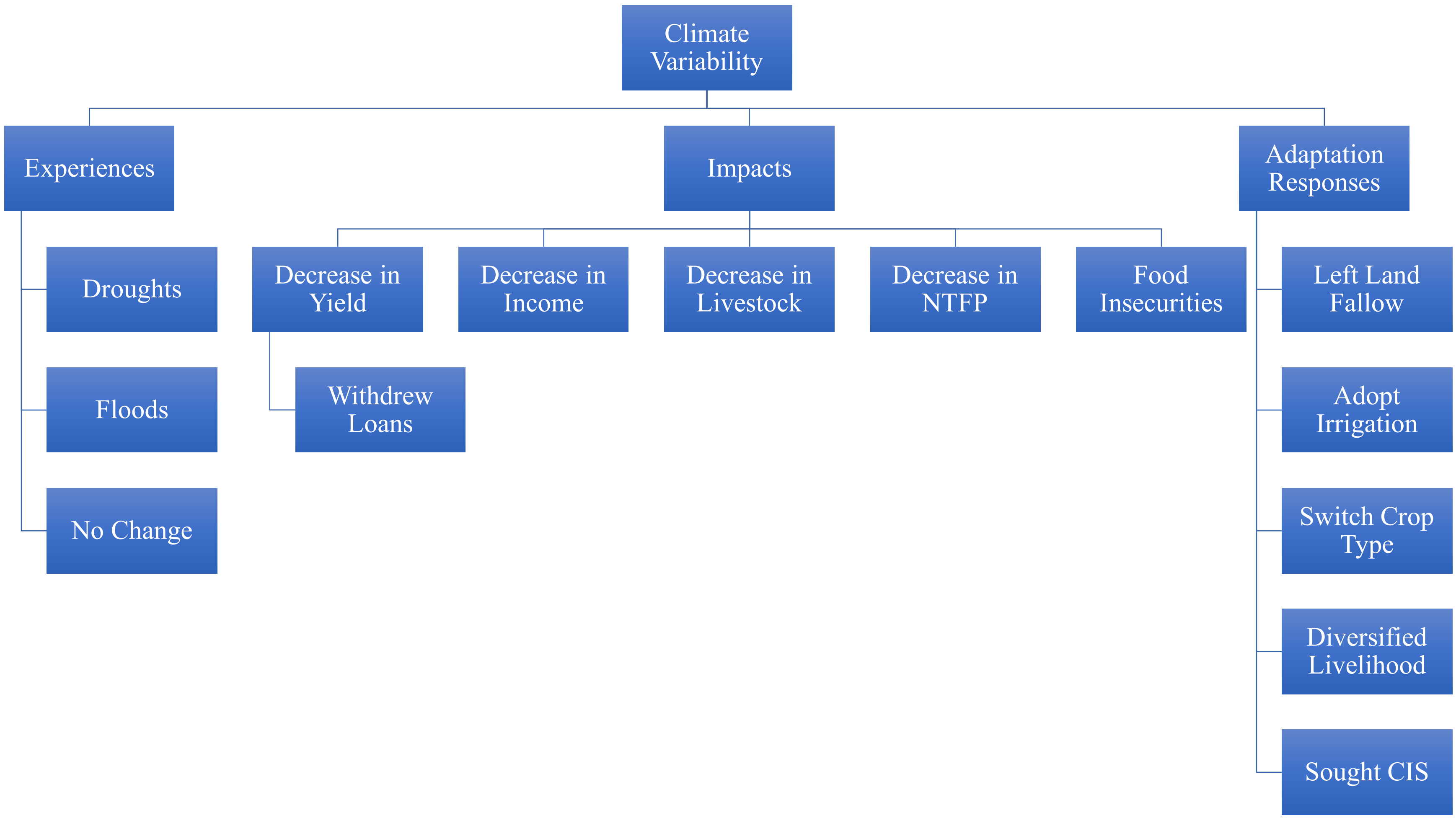


Appendix D: Classification Nodes for Farmer Interviews

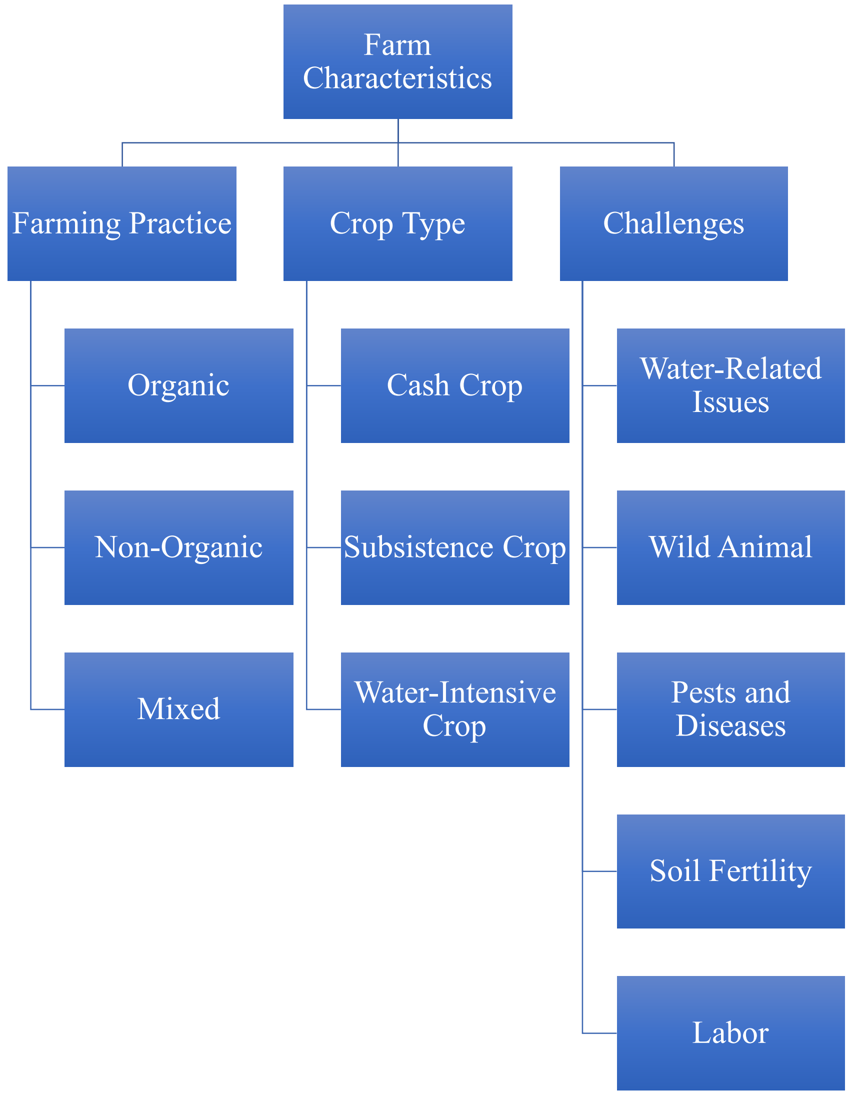
Node 1: Demographic Factors



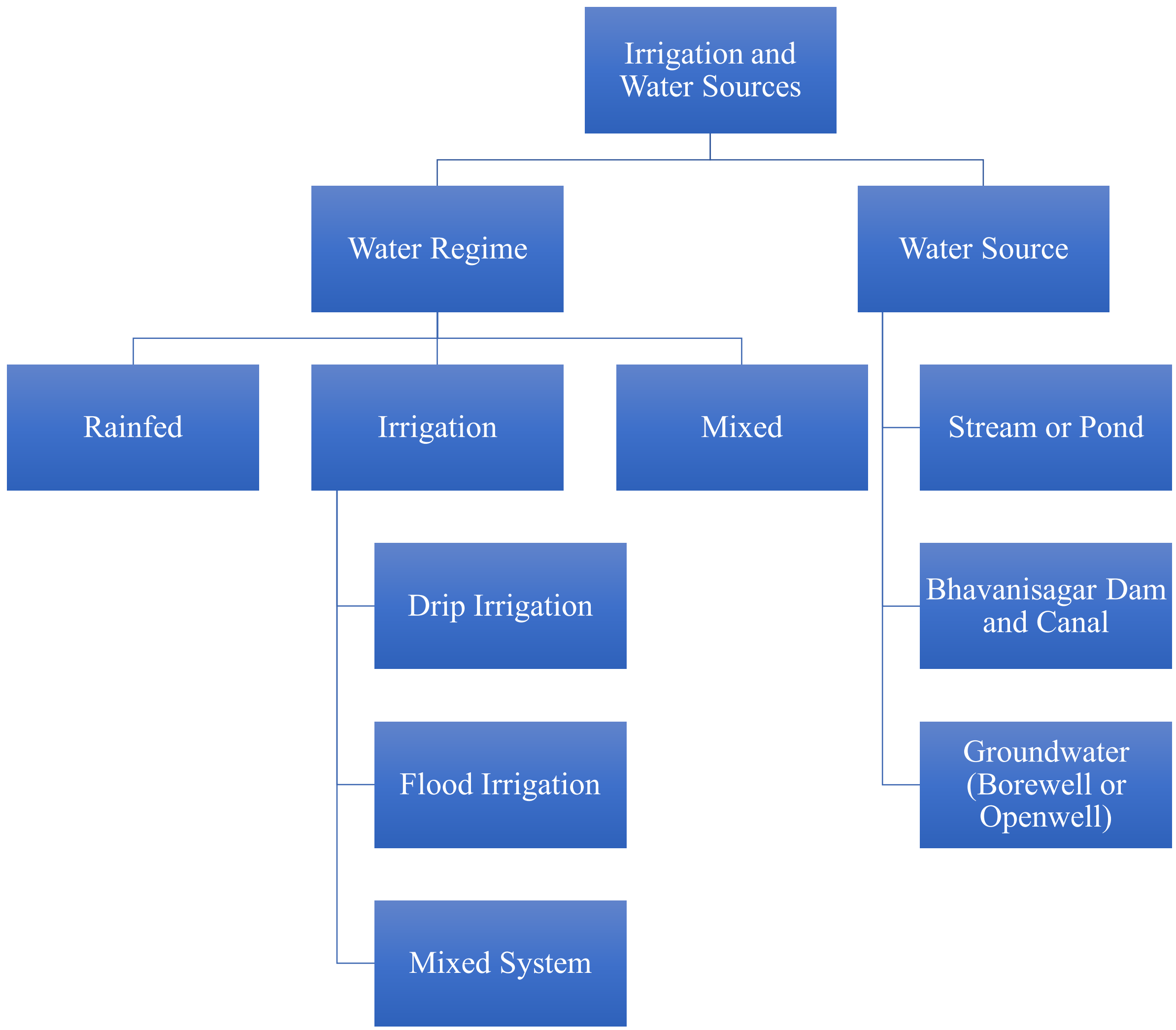
Node 2: Climate Variability



Node 3: Farm Characteristics



Node 4: Irrigation and Water Sources



Node 5: External Support