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Agricultural Voluntary Sustainability Standards and Farming Resilience: Opportunity or Contradiction?

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Author's declaration:

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Furthermore, this dissertation contains no materials previously written and/or published by another person, except where appropriate acknowledgment is made in the form of bibliographical reference, etc.

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List of Abbreviations

5PBR	The Five Principles for Building Resilience
7PBR	Seven Principles for Building Resilience
AMC	Agriculture Market Committees
AT	Municipality of Adoni
AVSS	Agricultural Voluntary Sustainability Standards
BCI	Better Cotton Initiative
BMP	Best Management Practices
BSC	Bonsucro
CDO	Child Development Office
CESS	Centre for Economic and Social Studies
COSA	Committee for Sustainability Assessment
CPO	Chief Planning Office
CSA	Climate-smart agriculture
DAHF	District Animal Husbandry and Fisheries
DAOA	District Agriculture Office Adoni
DC	District Collector
DCAFCS	District Consumer Affairs, Food & Civil Supplies
DFO	District Forest Office
DG	District Groundwater
DH	District Horticulture
DI	District Irrigation
DMIP	District Micro Irrigation Project
DPO	District Panchayat Office
DRDA	District Rural Development Agency
DS	District Sericulture
DWWC	District Welfare Department for Women and Children
ESMP	Environmental and Social Management Plan
FHL	Fairtrade Standard for Hired Labor
FPIC	Free and Prior Informed Consent
FSPO	Fairtrade Standard for Small-scale Producer Organizations
FT	Fairtrade International Standards
GCC	Girijan Cooperative Corporation
HCV	High Conservation Values
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IMWP	Integrated Water Management Program
IPM	Integrated Pest Management
ISH	Independent Smallholder
KVK	Krishi Vigyan Kendra
LEAF	Linking Environment and Farming
MAE	Mandal Agriculture Extension
MAH	Mandal Animal Husbandry
MAO	Mandal Agriculture Office
MDO	Mandal Development Office
MDWMA	Water Management Agency

ME	Mandal Education
MED	Mandal Engineering Department
MNGO	Local NGOs
MPR	Mandal Panchayat Raj
MRO	Mandal Revenue Office
NABARD	National Bank for Agriculture & Rural Development
NGO	Non-Government Organizations
NREGS	National Rural Employment Guarantee Scheme
NRI	Natural Resources Institute
NSC	National Seeds Corp
NTRJS	NTR Jala Siri programme
NWR	Water Resources, River Development & Ganga Rejuvenation
PO	Private Organizations
PRDIS	Climate-Smart Agriculture
PSM	Propensity Score Matching
RA	Rainforest Alliance
RARS	Regional Agriculture Research Stations
RCT	Random Control Trial
RF	Reliance Foundation
RSB	Roundtable for Sustainable Biomaterials
RSPO	Roundtable for Sustainable Palm Oil
SAC	State Agriculture and Cooperation
SAHF	State Animal Husbandry and Forestry
SAN	Sustainable Agriculture Network
SCA	State Commission on Agriculture
SCS	State Civil Supply
SEFT	State Environment, Forestry and Technology
SLR	State Lands and Survey
SPDCL	Southern Power Distribution Company
SPR	State Panchayat Raj
SWR	State Water Resources
UEBT	Union for Ethical Biotrade
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNICEF	United Nations International Children's Emergency Fund
VBAL	Village Ballekal
VBAR	Village Baladoor
VCHI	Village Chinna Harrivanam
VDHA	Village Dhanapuram
VDIB	Village Dibbanakal
VGHO	Village G. Hosali
VMAD	Village Madire
VNAG	Village Naganathana Halli
VPAN	Village Pandavagallu
VSAL	Village Salakalakonda
VSAN	Village Santhekudlur
VSS	Voluntary Sustainability Standards

VVIR	Village Virupapuram
WMB	Water Management Board
WPAR	Ward Parvathapuram

Abstract

As humanity is approaching and surpassing critical thresholds, agricultural production systems will need to become resilient to face more frequent, precipitous and unpredictable disturbances. The COVID-19 pandemic clearly highlights this need. Although focused on sustainable agriculture, Agricultural Voluntary Sustainability Standards (AVSS) have potential for enabling farming resilience as they have grown significantly in number and market share. This research addresses this unexplored potential by tabling and testing the AVSS resilience analytical framework which provides a spatially bounded way of thinking about farming resilience via the following three interconnected resilience dimensions: 1) intelligence – the farming decision maker's mindset, 2) conditions – the farm's tangible features, and 3) collaborations - the farming operation's relationships. These dimensions are further disaggregated into eighteen indicators to assess how AVSS designs and implementation affect farming resilience.

AVSS designs are first examined by benchmarking the eighteen farming resilience indicators against the production criteria of 11 AVSS. The benchmarking effort revealed that very few production criteria require farmers to experiment, develop adaptation strategies and manage the diversification of agricultural production and economic activities supported by the farm. Incorporating AVSS production criteria that support these farming resilience aspects could significantly contribute towards building the general resilience of farming systems. For instance, managing the diversification of agricultural production and economic activities supported by the farm is especially important for dealing with known and unknown disturbances. On the other hand, the AVSS examined also support farming resilience in terms of requiring the conservation of ecosystems within and surrounding farms, the preservation of the growing environment and the continuous capacity building of people involved in the farming operation via training as well as monitoring and recording various aspects of the farming operation.

AVSS implementation is then examined by undertaking a case study of the Better Cotton Initiative (BCI) program in the Adoni Mandal located in the state of Andhra Pradesh, India. The study revealed that the BCI training was largely ineffective as only 13% of the cotton farmers who participated were favorable to implementing the lessons learned. Furthermore, cover crops, potassium application and fertilization based on experts were the only farming practices clearly implemented by more treatment farmers. An analysis of the water and food security organizational networks in the study area, revealed that the BCI program had a limited network function and positioning to enable farming resilience. Consequently, the BCI program was found to have limited effects on capacity building and engagement with external governance structures in the study area. These limitations highlight the need for AVSS capacity building efforts to be effective and oriented toward building farming resilience and to link stakeholders into polycentric governance systems by integrating vertical and horizontal governance structures for resilient agriculture, both requiring a deeper engagement with farmers.

This research provides a stepping stone for AVSS to enable sustainable **and** resilient farming systems by examining how AVSS designs and implementation affect the general resilience of farming systems. It makes an analytical contribution by developing and applying the AVSS resilience analytical framework for assessing their effects on farming resilience so they can be re-imagined for building the general resilience of farming systems. It makes an empirical and methodological contribution by providing a multi-level assessment of the BCI program's resilience effects on cotton farming in the Adoni Mandal using network analysis which has never been used to assess the effects of AVSS on farming community resilience. Lastly, it makes a policy contribution by benchmarking AVSS production criteria against resilience indicators, providing guidance for their revision towards farming resilience.

Keywords: Resilience, Agricultural Voluntary Sustainability Standards (AVSS), Cotton, India

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1 Introduction

Demands on our global agricultural production systems are expected to increase with growing populations and consumption patterns (Mc Carthy et al., 2018). The need for rapidly expanding global agricultural production to meet this demand is alarming as it is an important driver of environmental degradation (Benton, 2017). Natural ecosystems have been lost as large swaths of land have been cleared and drained of forests, grasslands, wetlands and peatlands to give way to agricultural production which has become the largest user of freshwater, a significant greenhouse gas emitter and the most important driver of biodiversity loss (PBL Netherlands Environmental Assessment Agency, 2014). Almost three quarters of global freshwater is appropriated for irrigation and unsustainable water consumption has led to the depletion of groundwater aquifers and the loss of surface water bodies undermining aquatic ecosystems (Varis et al., 2017). The agricultural sector is an important contributor to climate change primarily via clearing natural environments, livestock rearing and rice cultivation (Shukla et al., 2019). "An estimated 23% of total anthropogenic greenhouse gas emissions (2007–2016) derive from Agriculture, Forestry and Other Land Use (Shukla et al., 2019, p. 41)." Agrochemicals has boosted production in some contexts but is undermining the long-term viability of the sector by affecting human health, polluting soils and water bodies, decimating pollinator and pest predator populations and spreading toxic substances to all parts of the globe which are bio-accumulating up our food chains (Leong et al., 2020; Pérez-Parada et al., 2018). Moving the agricultural sector towards more sustainable forms of production is imperative to meet the growing global food security challenge and enhance the natural ecosystems we depend on for our survival (Lal, 2013; McBratney et al., 2014; PBL Netherlands Environmental Assessment Agency, 2014; Tscharntke et al., 2012).

As we grapple with this important challenge, farming is becoming more difficult in many parts of the world as farming conditions become increasingly unpredictable often due to globally driven disturbances such as climate change and pandemics (Masson-Delmotte et al., 2021; Shukla et al., 2019; Stephens et al., 2020). Global climate change is expected to result in the loss of cultivable land due to sea-level rise and render areas unfit to produce certain crops as changing temperature and precipitation patterns become more rapid and erratic (Masson-Delmotte et al., 2021; Shukla et al., 2019). Stephens et al. (2020) report that the COVID-19 pandemic has already significantly disrupted our global agricultural supply chains affecting labour availability and resulting in significant agricultural production waste. Coupled with the need to be more sustainable, our agricultural production systems will also need to become more resilient. Farming systems that are resilient continue to function when faced with disturbances by persisting, adapting and transforming (E. M. Bennett et al., 2014; Meuwissen et al., 2019).[1] The emergence and focus on the concept of climate-smart agriculture (CSA) reflects the need for more resilient farming systems as it focuses on building resilience to climate change (Food and Agriculture Organization of the United Nations, 2014).[2] Nevertheless, farming has historically been a livelihood at the mercy of changing environmental conditions from growing season to growing season and farmers have developed various coping strategies in the contexts where they grow their crops (Thrupp, 2000). Complex and intricate agricultural production systems have been

[1] According to Bennett et al. (2014) resilient farming is defined as "one that meets both food and development needs over both the short and very long-terms, from local to global scales, without destabilizing the Earth system" (E. M. Bennett et al., 2014, para. 1), while Meuwissen et al. (2019) define it as "its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of robustness, adaptability and transformability" (Meuwissen et al., 2019, p. 2).

[2] "Climate-smart agriculture (CSA), contributes to the achievement of the sustainable development goals by integrating the three dimensions of sustainable development (economic, social and environmental) and jointly addressing food security and climate challenges. It is composed of three main pillars: 1. sustainably increasing agricultural productivity and incomes; 2. adapting and building resilience to climate change; 3. reducing and/or removing greenhouse gases emissions, where possible" (Food and Agriculture Organization of the United Nations, 2014, p. ix).

developed over time to provide a range of products and offer more resilience to potential shocks, stresses and changing growing conditions (Shah et al., 2018; Snapp, 2017).

Nevertheless, agro-industrial production systems have moved away from more complex and diverse production systems towards more large-scale uniform ones typically requiring mechanization, fossil fuel consumption and agrochemical inputs to maintain productivity (Landis, 2017; Weyers & Gramig, 2017). These high input dependent monoculture production systems are often more vulnerable to potential shocks and stresses as they are integrated in global markets where geopolitical and market forces dictate agriculture input costs and commodity prices (Birthal & Hazrana, 2019; Blesh et al., 2019; Garibaldi et al., 2017; Osawa et al., 2016). These intensified agricultural production models are likely to persist due to the rapid rate of global urbanization resulting in a vicious circle where the loss of agricultural land necessitates more production from what is remaining to meet growing needs primarily from expanding urban areas (Su et al., 2011). Clearly, more sustainable and resilient forms of agriculture will be required to meet the growing global food security challenge while enhancing the natural ecosystems we depend on for our survival (E. M. Bennett et al., 2014; Gosnell et al., 2019; Meuwissen et al., 2019).

Agricultural Voluntary Sustainability Standards (AVSS) have emerged in the agricultural sector as a market-based instrument to enable more sustainable agricultural production practices. Established to improve socio-economic conditions and reduce environmental impacts associated with agricultural livelihoods, AVSS are voluntary schemes which aim to guide agricultural production towards sustainability in exchange for a seal or certification[3] of standard compliant production (Committee on Sustainability Assessments, 2013; S. D. Elder et al., 2013). AVSS, such as Organic, Fairtrade and Rainforest Alliance, are typically comprised of production criteria,

[3] "Certification (is a subset of AVSS) … has a codified set of standards for production and management practices. Certification programs optimally include third party auditing to confirm that the standard's requirements are being met (Committee on Sustainability Assessments, 2013, p. xii)."

a conformity assessment approach, a traceability system for product integrity and a governance structure focused on addressing various sustainability challenges in specific agricultural sectors (Komives & Jackson, 2014). Borne out of the Organic movement of the 1970s, AVSS have become uniquely placed to enable more resilient agricultural production due to their orientation towards enabling sustainable agriculture which intersects closely with resilience (E. M. Bennett et al., 2014; Folke, 2016; Roostaie et al., 2019).[4] Furthermore, they have been growing in number and in market share in a number of agricultural commodity sectors and this trend will likely continue with public and private sector commitments to sustainable consumption and production (McCarthy, 2016; Meier et al., 2020; Potts et al., 2014; United Nations Environment Programme, 2012).

Sustainability and resilience are normative terms that provide conceptual framing for their application. Sustainability is focused on sustaining systems over the long-term while resilience is focused on maintaining systems in the face of disturbances which includes resisting, adapting and transforming in the face of change. They are compatible since a more sustainable system is likely to be more resilient and vice-versa (Roostaie et al., 2019). Despite their compatibility, they have clear differences which are manifested particularly when applied. For instance, green buildings, which are deemed more sustainable, have been designed to lower their environmental impacts as opposed to being designed to withstand impacts from their environment (Roostaie et al., 2019). The same logic can be extended to agricultural production systems where more sustainable forms of agriculture, designed to be more socio-economically and environmentally beneficial, may not be oriented towards withstanding shocks and stresses as well as more resilient forms of agricultural production (E. M. Bennett et al., 2014). For this reason, agricultural

[4] Since the first major AVSS, the Organic standard, was established in the nineteen seventies, they have expanding significantly especially after the first World Sustainability Summit held in Rio in the early nineteen nineties (Willer & Lernoud, 2018).

production systems need to become more sustainable as well as resilient which go hand in hand (E. M. Bennett et al., 2014).

Ensuring that AVSS build more sustainable and resilient farming systems could offer an opportunity to meet global agricultural product needs while maintaining ecosystem integrity. Despite providing a framework and governance system within agricultural supply chains to support more sustainable consumption and production, AVSS have had mixed sustainability impacts (Bacon et al., 2014; Carlson et al., 2018; S. D. Elder et al., 2012; Komives et al., 2018; Tuck et al., 2014; Vanderhaegen, 2018). For this reason, examining how can AVSS build and impede farming resilience provides a basis to recommend AVSS design characteristics and implementation approaches for farming resilience.

1.1 Background

With rapidly changing conditions driven by socio-economic pressures experienced in every part of the world, agricultural producers need to become more resilient to a broad range of disturbances if their agricultural operations are to remain viable over the long-term (E. M. Bennett et al., 2014; Brondizio & Syvitski, 2016; Zalasiewicz et al., 2017). Despite the potential for AVSS to enable more resilient farming systems, very little research has been conducted in this regard (Verburg et al., 2019a). In fact, AVSS and resilient farming systems can be considered a contradiction of sorts since they can result in farmers adopting less flexible agricultural production approaches to remain standard-compliant. For example, many AVSS prohibit the use of various types of synthetic pesticides which can limit farmers' ability to respond to pest outbreaks in a given production cycle. Where AVSS have addressed farming resilience they have primarily focused on climate resilience as opposed to general resilience which includes building farming resilience to known as well as unknown disturbances. In addition to climate resilience, some AVSS have designed their production criteria based on a continuous improvement model allowing for more flexibility by meeting farmers at their capacity levels and encouraging the adoption of more sustainable agricultural production practices over time (Better Cotton Initiative, 2018; Rainforest Alliance, 2019a, 2019b). Despite these provisions aligned with farming resilience, AVSS have yet to systematically examine what measures that support the general resilience of farming systems can be integrated in their production standards.

AVSS have been focused on enabling more sustainable farming systems by addressing various sustainability challenges affecting agricultural commodity sectors. Nevertheless, previous research findings on their sustainability impacts is context dependent and mixed at best (DeFries et al., 2017; Komives et al., 2018; Meemken, 2020; Oya et al., 2018). Resilient agriculture overlaps with sustainable agriculture, in that they both grapple with developing a more holistic understanding of agricultural production systems so they can be managed for the long-term wellbeing of socio-ecological systems. Viewed by many as a subset of sustainability science, resilience thinking and approaches have evolved into an important field of research and practice to face numerous governance and management challenges that requires dealing with change, uncertainty, unpredictability, and surprise (Folke, 2016; Roostaie et al., 2019). Both sustainability and resilience have ambiguous and malleable meanings by design and are often considered bridging concepts between disciplines to enable common understandings. Although linked, sustainability and resilience have distinguishing features worth noting. Resilience focusses on the capacities of socio-ecological systems to deal with change which includes transformability while sustainable development focusses on enabling beneficial change and preventing detrimental change within socio-ecological systems to meet the needs of present and future generations (Roostaie et al., 2019). Due to its distinctive and sustainability-related features, resilience offers an opportunity to rethink AVSS that can enable more sustainable and resilient farming systems (Roostaie et al., 2019). To do so, focusing on resilience enabling conditions or attributes of farming systems is required to deal with known and unknown disturbances (Biggs et al., 2015; Folke, 2016; Meuwissen et al., 2019).

Nevertheless, measuring resilience remains elusive as it is normative and subjective and therefore highly context dependent influenced by spatial, temporal and subjective specificities (Folke, 2016). Despite this challenge, key questions and resilience assessment frameworks have been developed to assess the resilience of socio-ecological systems including farming systems (Biggs et al., 2015; Cabell & Oelofse, 2012; Meuwissen et al., 2019; Serfilippi & Ramnath, 2018). Resilience of what, to what, for whom, from whose perspective, for what timeframe and for what purpose provides some framing on what needs to remain resilient to what disturbances and why (Helfgott, 2018; Meuwissen et al., 2019). Examining the resilience capacities (i.e. persistence, adaptability and transformability) and attributes (i.e. diversity, connectivity, system reserves) of farming systems can also be insightful (Meuwissen et al., 2019). In addition to framing questions, frameworks have been developed to examine farming system resilience. For instance, Meuwissen et al. (2019) developed a framework to assess the specified and general resilience of farming systems, Cabell and Oelofse (2012) propose 13 behavior based indicators for agroecosystems and Serfilippi and Ramnath (2018) put forward 72 development and food security indicators to assess farming resilience. Despite the existence of frameworks for ascertaining farming resilience, there are currently no approaches specifically developed to assess the resilience effects of AVSS. For this reason, this doctoral research presents an analytical framework and an example of its application to examine AVSS and farming resilience.

1.2 Problem Statement

As our complex global socio-ecological system is approaching and surpassing critical interconnected thresholds we can expect more frequent, precipitous and unpredictable disturbances (Lenton et al., 2019; Masson-Delmotte et al., 2021; Rockstrom, 2009; Steffen et al., 2015, 2018).[5] For this reason, agricultural production needs to become more resilient to

[5] The latest IPCC report warns against surpassing 1.5 Degrees Celsius above the pre-industrial global temperature average as this would result in significant impacts on natural and human systems by stating the following: "All regions are projected to experience further increases in hot climatic impact-drivers (CIDs) and decreases in cold CIDs (high confidence). Further decreases are projected in permafrost, snow, glaciers and ice sheets, lake and Arctic

disturbances which range broadly from climate change to fluctuations in international markets and global pandemics. To do so, interventions in agriculture need to focus on enabling conditions that support general resilience as opposed to narrowly focusing on enabling resilience for specific disturbances (Meuwissen et al., 2019; Steffen et al., 2018). Although, measuring resilience in farming systems remains elusive and context specific, academics have started developing frameworks to operationalize farming esilience (Cabell & Oelofse, 2012; Meuwissen et al., 2019; Serfilippi & Ramnath, 2018). AVSS could potentially offer an opportunity to build farming resilience due to their orientation towards enabling sustainable agriculture and their growth in numbers and market share in a number of agricultural commodity sectors. Originally oriented to address sustainability issues, AVSS must evolve to enable farming systems to respond to disturbances, which are likely to increase in type, intensity and complexity, to achieve their sustainability objectives. Furthermore, their impact on enabling more sustainable agriculture is of strategic and perennial interest to the standards community, but remains insufficiently understood (Angelo & Reilly-Brown, 2014; UNFSS, 2018). Consequently, examining the current suitability of AVSS to build farming resilience provides a starting point to re-imagine the design and implementation of AVSS for farming resilience. Doing so will benefit from an analytical framework designed to examine the potential for AVSS to enable farming resilience. Furthermore, as it is becoming clear that sustainable agriculture also has to be resilient to remain sustainable, ensuring that AVSS are re-imagined to enable sustainable as well as resilient agriculture is paramount (E. M. Bennett et al., 2014).

sea ice (medium to high confidence). These changes would be larger at 2°C global warming or above than at 1.5°C (high confidence). For example, extreme heat thresholds relevant to agriculture and health are projected to be exceeded more frequently at higher global warming levels (high confidence)" (Masson-Delmotte et al., 2021, p. SPM-32).

1.3 Research Objectives and Questions

This research provides a stepping stone to design and implement AVSS that can build farming resilience in addition to addressing sustainability challenges by achieving the following objectives:

1) Derive an analytical framework to examine how AVSS are affecting farming resilience.
2) Apply the analytical framework to examine how AVSS are affecting farming resilience.
3) Provide insights for designing and implementing AVSS that can build farming resilience in addition to meeting their sustainability-related objectives.

Examining how farming resilience is affected by AVSS inspired the following central research question: ***How can AVSS enable the general resilience of farming systems?*** To answer this ambitious and open-ended question, focussing on how AVSS are currently affecting farming resilience is necessary to build on existing AVSS attributes that support farming resilience. For this reason, the central research question is disaggregated into the following sub-questions which focus on how AVSS ***are*** currently designed and implemented to build farming resilience:

- ***Sub-Question 1: How are AVSS designs affecting the general resilience of farming systems?***
- ***Sub-Question 2: How are AVSS implementation approaches affecting the general resilience of farming systems?***

The design and implementation distinctions are important since examining the design of AVSS conveys their aspirational goals and the processes by which they aim to achieve these goals while examining AVSS implementation conveys their tangible impacts on farming systems. Focusing on AVSS design provides a conceptual understanding of how they could potentially enable general resilience within farming systems. The implementation of AVSS production criteria by farming systems can affect their general resilience in different ways depending on a myriad of contextual specificities which cannot be fully understood and ascertained until they are implemented. Examining the design and implementation of AVSS provides a basis to provide insights on how they could enable the general resilience of farming systems.

1.4 Study Design

The approach adopted to address the research questions is guided by an analytical framework comprised of 3 resilience dimensions (intelligence, conditions and collaborations) and 18 resilience core indicators shown in Figure 1. Parts of the analytical framework are operationalized to address the research sub-questions by examining AVSS production criteria and undertaking a case study (see Figure 2).

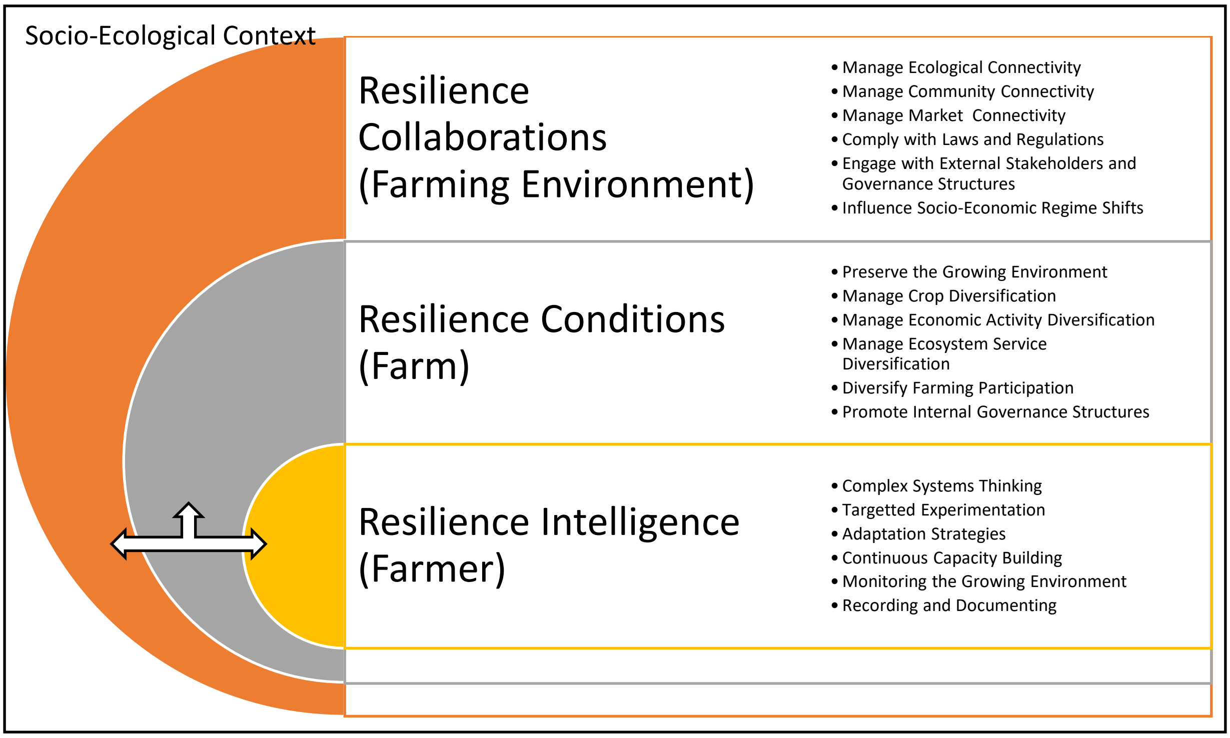

Figure 1 - The AVSS Resilience Analytical Framework oriented towards assessing the resilience of farming operations

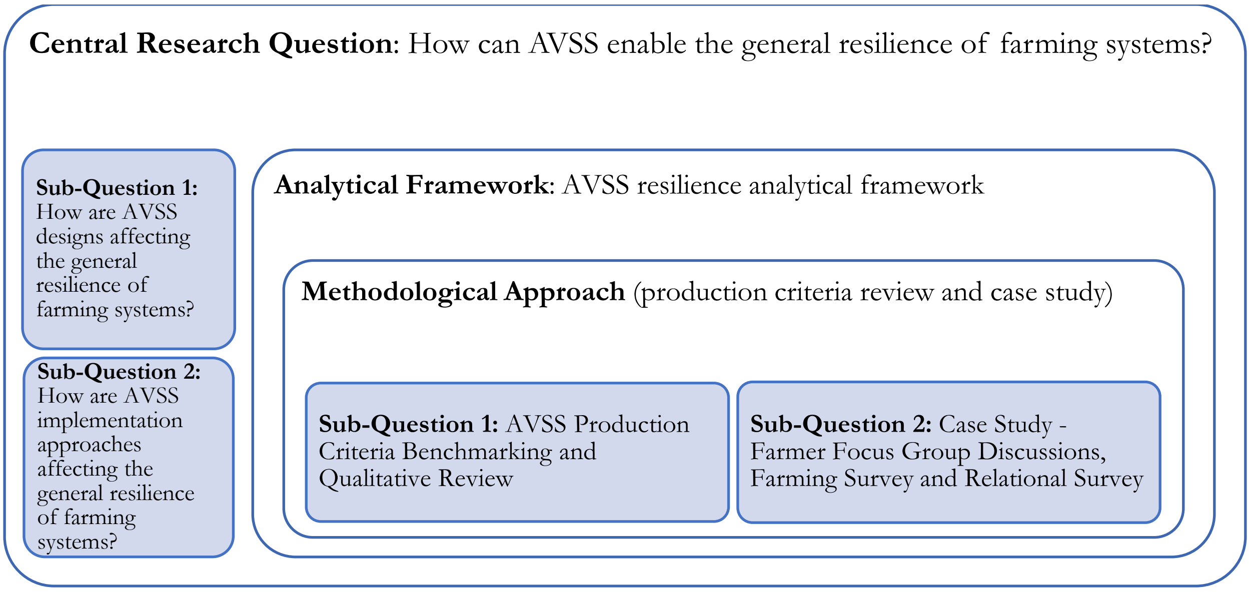

Figure 2 – Research roadmap

Addressing sub-question 1 centers on examining AVSS production criteria which must be adopted by farmers to be standard-compliant. The production criteria and indicators of 11 AVSS are benchmarked against the 18 resilience indicators of the AVSS resilience analytical framework to determine how AVSS could potentially affect farming resilience. The AVSS production criteria indicators were assigned a stringency score based on how fast they must be implemented to become and remain standard-compliant. A relative coverage of the 18 indicators was derived for each AVSS and then averaged to identify farming resilience gaps. This analysis provided a means to ascertain how AVSS designs could potentially affect farming resilience providing a basis to generate AVSS design recommendations to enable farming resilience in support of achieving their sustainability objectives.

As farming resilience is highly dependent on context, a single case study was undertaken to address sub-question 2. Limiting the study to a single case is justified since it provides a critical and revelatory case to examine the proposition that the AVSS resilience analytical framework can provide insights to better design and implement AVSS for farming resilience (Yin, 2018). The case study undertaken focused on the Better Cotton Initiative (BCI) program[6] in the Adoni Mandal[7] of India where farmer focus group discussions as well as farming and relational surveys were conducted. This particular case study was selected due to the demographics of the cotton farmers in the study area, which are primarily smallholder farmers with vulnerabilities to disturbances such as climate change. More importantly, a random control trial on the sustainability impacts of the BCI program in the Adoni Mandal was conducted in parallel with the data collection effort undertaken for this dissertation, providing additional information to compare and contrast the research findings from this case study. The farmer focus group discussions provided qualitative contextual information for the farming and relational surveys as well as additional evidence to support or challenge quantitative findings. The farming survey aimed to identify resilience threat, coping strategy and farming practice differences between farmers that are (treatment group) and are not (control group) participating in the BCI program. The farming survey results were examined using propensity score matching (or more specifically kernel matching) to minimize confounding factors that could affect the comparisons between the treatment and control groups. The relational survey focused on examining the water and food security organizational networks of the Adoni Mandal by compiling network metrics. Undertaking a multi-scale analysis of the selected case study, allowed for addressing how the implementation of the BCI program is affecting farming resilience in the study area to derive recommendations for implementing farming resilience enabling AVSS.

Although the study design provided valuable insights to answer the research questions, it had a number of limitations. Benchmarking is a subjective process as personal interpretations are used to determine if AVSS production criteria indicators can fulfill a farming resilience aspect or

[6] Approximately 2.3 million farmers produced BCI-verified in 2019, representing more than 20% of global cotton production (Better Cotton Initiative, 2020).
[7] Mandal refers to local government in India. More specifically the State of Andhra Pradesh is subdivided into Districts which are further subdivided into Mandals responsible for governing strictly rural areas comprised of villages. Urban areas fall outside of Mandal's jurisdictions are they are governed by municipalities.

indicator. To address this limitation benchmarking results deemed more open to interpretation were tracked and a replicability test was undertaken. Furthermore, the major farming resilience gaps identified in the AVSS examined were focused on to generate insights for designing AVSS that can enable farming resilience. The farming survey used propensity score matching to compare farming practices between farmers that are and are not participating in the BCI program based on a surveying effort conducted once. The results obtained from this analysis would have been strengthened if baseline (before the implementation of the BCI program in the study area) and endline surveys (after the implementation of the BCI program in the study area) could have been conducted. Nevertheless, the control group did provide a counterfactual which was used to derive insights on the training effectiveness of the BCI program. The relational survey and network analysis undertaken was based on an incomplete network of organizations working on water and food security in the Adoni Mandal. Since there was one organization of interest within the networks examined, the insights gained from the analysis were still insightful to determine how the BCI program may be affecting connectivity for farming resilience.

1.5 Intended Audiences

The primary audience for this research are standard setting bodies that develop and implement sustainability standards in the agricultural sector (or AVSS). The AVSS resilience analytical framework developed for this study as well as its application provides standard setting bodies with direction to re-imagine and revise their standards towards enabling both sustainable **and** resilient farming. Most voluntary sustainability standards regularly review the production criteria they require farmers to implement for them to achieve and maintain standard-compliance, offering opportunities for the insights generated in this PhD dissertation to stimulate reflection and steps for orienting AVSS towards farming resilience. For instance, standard setting bodies that are ISEAL members must provide clear and publically available documentation that describes their standards review processes which requires public consultations and must be undertaken every five years to remain compliant with the ISEAL code of good practice (ISEAL Alliance, 2014). By virtue of incorporating a case study on the effects of the Better Cotton Initiative (BCI) on the general resilience of cotton farming systems in the Adoni Mandal India, this dissertation also provides insights for the BCI to better structure the implementation of their programs to enable farming resilience. Lastly, this dissertation provides academics and development practitioners with an additional tool, the spatially bound AVSS resilience analytical framework, to interact with farmers and farming communities on farming resilience.

1.6 Document Structure

This doctoral thesis dissertation consists of 7 chapters. The introduction (Chapter 1) is followed by a literature review (Chapter 2) on resilience and its linkages to sustainability, AVSS and frameworks for assessing farming resilience. The literature review provides a basis for deriving an analytical framework to address the central research question, presented in the methodology chapter (Chapter 3) followed by details on how parts of the framework are operationalized. The study design and its limitations to address the research questions focus on two analytical tracts, how AVSS 1) designs and 2) implementation approaches affects the general resilience of farming systems. The results derived from the study design (Chapter 4 and 5) are presented in two separate chapters focusing on the research sub-questions. These results are then critically discussed and situated within the existing literature on resilience and AVSS (Chapter 6). Recommendations for designing and implementing AVSS that can enable farming resilience were formulated and presented for those interested in achieving the objectives of AVSS such as standards bodies, regulators, industry groups, companies and producer groups. The final chapter (Chapter 7) summarizes the overall findings of the research, research contributions of this dissertation and recommendations for future research. Overall the thesis provides insights for designing and implementing AVSS oriented towards building the general resilience of farming systems.

2 Literature Review

The analytical framework adopted to examine the central research question of this dissertation, "how can AVSS enable the general resilience of farming systems?", was derived from the literature reviewed on the conceptual evolution of resilience and its application in agriculture (section 2.1), AVSS and their evolution towards resilience (section 2.2) and existing frameworks for assessing the resilience of farming systems (section 2.3). The literature reviewed is discussing and analyzed revealing that there is a need for developed an analytical framework to assess how AVSS affect the general resilience of farming systems (section 2.4). The analytical frameworks reviewed provide a basis upon which to develop an analytical framework oriented specifically towards examining AVSS and their effects on the general resilience of farming systems which can be used by standard setting bodies to better design and implement AVSS for farming resilience.

2.1 Resilience and its Application in Agriculture

The resilience scholarship and its application in agriculture provides the basis for the conceptual framing of this thesis. The resilience concept, which can be traced as far back as the sixteenth century, has evolved significantly from the notion of bouncing back to incorporating complex interactions between society and nature and aspects of social justice (Arora-Jonsson, 2016; Bourbeau, 2018; Carr, 2019; Cote & Nightingale, 2012; J. Ensor et al., 2018; Fazey, 2010). The genesis of the term 'resilience' comes from the Latin verb 'resilire', which means to jump back or recoil (Bourbeau, 2018). It was subsequently used in English in the sixteenth and seventeenth centuries as the verb 'resile', which led to coining the term 'resilience' (Bourbeau, 2013, 2018). Francis Bacon used it to describe the reflection of sound in *Sylva Sylvarum*, a philosophical treatise on the nature of sound published in 1626. Samuel Johnson made references to the "resiliency of the mind" in the mid eighteenth-century, which was adopted and coupled with coping mechanisms by psychology scholars in the mid-twentieth century (Bourbeau, 2018).

Resilience has since been explored in multiple academic disciplines most notably in the fields of psychology and social work, engineering and material sciences and ecology. In psychology and social work resilience initially focused on individual capacities to overcome trauma but evolved to include individual resilience enabling conditions (Bourbeau, 2018; Center on the Developing Child at Harvard University, 2015; Cyrulnik, 2009).[8] Resilience was first used in engineering and material sciences in 1807 to describe the capacity of a material to regain its original shape after absorbing energy and material resilience remains an important area of research (Bourbeau, 2018; Helfgott, 2018). Ecologists started using the resilience concept in the nineteen seventies to describe the capacity of an ecosystem to withstand perturbations, offering a contrast to ecology's focus on states of equilibrium (Holling, 1973). The original focus on ecosystem resilience evolved to include socio-ecological system renewal, regeneration, reorganization and adaptation following change (Folke, 2016; Helfgott, 2018). Reflections on resilience by ecologists led to the development of the adaptive cycle model, which is now applied in various disciplines to better understand the socio-ecological system dynamics of resilience around states of conservation, release, reorganization and exploitation (Gotts, 2007; Sundstrom & Allen, 2019).[9]

The adaptive cycle model inspired other useful ways of thinking about resilience. For example, Walker et al. (2004) describe basins of attraction as an operating space where systems

[8] Individuals who have faced disasters consistently go through overlapping periods of impact, recoil and post-trauma which can be described and understood through the lens of the resilience concept (Tyhurst, 1957). Resilience related concepts explored in psychology and social work include ego-resilience, coping capacities, invulnerability, invincibility, protective factors, successful adaptation and resilience pathways.

[9] The adaptive cycle model consists of four phases describing a system's behavior over time (Sundstrom & Allen, 2019). The conservation phase describes a stable state where the system works to maintain its existing configuration. The release phase describes system failure and inability to maintain its configuration. The reorganization phase describes a process of renewal where the system is being reconfigured anew. The exploitation phase describes the process by which a reorganized system is expending energy to reach a conservation phase.

tend to remain and stability landscapes as regions comprised of basins of attraction and their boundaries where systems can move. These concepts can be illustrated by a small ball (representing a system) in a bowl (basin of attraction). As the system is disturbed the ball shifts positions within the bowl (basin of attraction) but is attracted back to the centre of the bowl (state of equilibrium). If the system undergoes a significant disturbance the ball can move completely out of the bowl and into another within the stability landscape which are larger systems that can also change leading to varying numbers and configurations of basins of attraction at any given time (Walker et al., 2004). The cross-scale effects of dynamic systems constantly acting on one another is referred to as panarchy and invariably affects the resilience of the system of interest (Walker et al., 2004). The reconfiguration of stability landscapes can also be thought of as a regime shift where it undergoes difficult to reverse changes as it is reconfigured or transformed (E. M. Bennett et al., 2014; Biggs et al., 2018; Lade et al., 2013). Based on these concepts and analogies, resilience is the ability of a system to remain in a basin of attraction, adaptability is a system's ability to remain resilient by purposefully modifying its basin of attraction and stability landscape and transformability reflects the ability to reconfigure stability landscapes to ones more advantageous to the system and its resilience (Walker et al., 2004).

One trend that can be observed in the resilience scholarship is a cross-fertilization and convergence between disciplines and shift towards a more holistic understanding of resilience. Whole communities are being studied to better understand enabling conditions for individual children to become resilient (Center on the Developing Child at Harvard University, 2015; Cyrulnik, 2009). The study of resilience in ecology evolved to include socio-ecological system dynamics. The subjective and normative nature of resilience and its connection to 'desirable and undesirable states' inspired a whole social and political sciences scholarship on the subject matter (Carr, 2019; Cote & Nightingale, 2012; Helfgott, 2018; Pelling & Manuel-Navarrete, 2011). For instance, the climate resilience scholarship has moved towards multi-disciplinary approaches that acknowledge the interconnected and multi-dimensional processes that make socio-environmental systems vulnerable to climate change and other stressors (Arora-Jonsson, 2016; Biggs et al., 2015; Carr, 2019). Starting from the simple notion of bouncing back, resilience has evolved into a holistic concept used to describe a system's behavior to change where system defines 'the what', behavior describes 'the how' and change describes 'to what' of resilience (Helfgott, 2018; Meuwissen et al., 2019). The most recent understanding of resilience includes "bouncing back and towards" in which "towards" describes academic discussions on transformation (Fazey, 2010; Feola, 2015). Today, resilience is applied to examine all manners of systems from the smallest object to planetary scale ecosystems, describes the ability to bounce back and towards desirable states (i.e. persistence, adaptation and transformation processes) and is used to examine a broad range of changes from small perturbations to large-scale disasters (Roostaie et al., 2019; Shi et al., 2018).

The evolution of the resilience concept follows a similar trend in the agricultural sector where a broader conceptualization of resilience is leading to more holistic resilience measurement and assessment approaches. For example, the Food and Agriculture Organization (2016) recently published its work on improving its resilience index measurement and assessment (RIMA-II) tool to include indirect factors, or determinants of resilience, to measure household food security (Food and Agriculture Organization of the United Nations, 2016). Meuwissen et al. (2019) present a framework for assessing the resilience of farming systems where they include attributes that can enhance resilience to disturbances and threats, including unknown ones. The current COVID-19 pandemic further highlights the need for enabling resilience in farming systems to known (i.e. climate change, market prices fluctuations) as well as unknown and unforeseen threats (i.e. novel viruses, natural disasters) by focusing on building the resilience enabling conditions or resilience attributes of farming systems (Stephens et al., 2020). Consequently, focussing on the resilience attributes of farming systems, such as managing the diversification of agricultural production and ecological connectivity, is both necessary and practical to ensure that they can deal with a broad range of disturbances and threats (E. M. Bennett et al., 2014; Meuwissen et al., 2019).

These examples illustrate that academia and practitioners alike are increasingly focussed on the enabling conditions of resilience as an imperative in agriculture. In fact, Cabell and Oelofse (2012) argue that measuring the 'resilience' of socio-ecological systems per se is futile as it is highly context dependent and influenced by spatial, temporal and subjective specificities. Socio-ecological systems are embedded in larger systems which are dynamic, constantly changing and influencing each other. What may be perceived by some as resilient at a given moment in time may not be at another. For instance, maintaining the status quo may be deemed resilient for people who benefit from the current configurations of a socio-ecological system, while its transformation towards more social justice may be a resilience prerequisite for people being exploited by the same system (Córdoba et al., 2020). Resilient and persistent dictatorships further illustrates this point and conveys the value-laden dimension of resilience (Cote & Nightingale, 2012; Helfgott, 2018). For these reasons, measuring the resilience of socio-ecological systems in definitive ways remains elusive.

Despite this challenge, a series of guidance questions have been devised to frame resilience assessments (S. Carpenter et al., 2001; Helfgott, 2018; Meuwissen et al., 2019). 'Resilience of what to what?' brings into focus what needs to remain resilient to specific disturbances (S. Carpenter et al., 2001). Establishing 'resilience for whom and from whose perspective?' brings in the subjective dimension of resilience calling for a reflection on resilience from what perspective and for whose benefit (Helfgott, 2018). Addressing the purpose of resilience is linked to the aforementioned questions as it highlights the functions of interest that need to remain resilient, which is, in and of itself, is a subjective process (Walker et al., 2004). To assess the resilience of farming systems, Meuwissen et al. (2019) ask the question 'resilience for what purpose?' to identify the farming system functions required for the continued production of public and private goods. Further to identifying resilience system functions, establishing resilience capacities (i.e. robustness, adaptability, transformability)[10] and attributes (enabling conditions) can also be insightful as it respectively establishes the current range of possibilities to remain resilient and the characteristics of a system which may enable and impede resilience. Meuwissen et al. (2019) define the three resilience capacities of farming systems, robustness, adaptability and transformability, as follows:

> Robustness is the farming system's capacity to withstand stresses and (un)anticipated shocks. Adaptability is the capacity to change the composition of inputs, production, marketing and risk management in response to shocks and stresses but without changing the structures and feedback mechanisms of the farming system. Transformability is the capacity to significantly change the internal structure and feedback mechanisms of the farming system in response to either severe shocks or enduring stress that make business as usual impossible. Such transformations may also entail changes in the functions of the farming system. (pp. 4-5)

Examining "resilience over what timeframe?" allows for exploring how specific actions can lead to more or less resilience over time (Helfgott, 2018). Lastly, asking 'why resilience' allows for a deeper understanding of its meaning and application. These resilience assessment framing questions are valuable when trying to ascertain the resilience of socio-ecological systems in specific contexts.

In addition to resilience assessment questions, frameworks have been devised to assess the resilience of farming systems. The capital and capacities approach to resilience focuses on access to resources and abilities to harness these resources to remain resilient when facing changes and disturbances (Serfilippi & Ramnath, 2018). Cabell and Oelofse (2012) table a set of 13 behavior-

[10] Another way to look at resilience processes is as follows: "1) Robustness/Resistance - ability to resist change, 2) Stability/Recovery - return to an original and desirable state with features of interest and 3) Adapting/Benefiting - moving to a new state that is at least as desirable as the original (Helfgott, 2018, p. 853)."

based indicators to assess resilience in agroecosystems, shifting the focus from assessing resilience as a particular state to examining its enabling conditions (or resilience attributes). Serfilippi and Ramnath (2018) propose the use of 76 benchmarked resilience indicators that can be aggregated in different ways to examine the static (human, socio-political, financial, physical and natural capitals) and dynamic (adaptive, adsorptive and transformative) dimensions of resilience within agriculture. Meuwissen et al. (2019) present a framework for assessing the resilience of farming systems primarily based on the resilience assessment guiding question described above where farming system resilience attributes are assessed based on the following five principles from the Resilience Alliance (2010): diversity, openness, tightness of feedbacks, system reserves and modularity.[11] They argue that these broad principles are appropriate due to their comprehensive nature and convergence with other frameworks. A related set of seven principles for building resilience (7PBR), derived by Biggs et al. (2015) to sustain ecosystem services in social-ecological systems, can also be oriented towards examining farming systems, since highly managed agricultural landscapes also provide ecosystem services (TEEB, 2015). The development of these resilience principles are oriented towards establishing general resilience patterns that aspire to be independent of context and value positions. These frameworks provide a starting point for assessing the resilience of farming systems and consequently how AVSS are building and impeding farming resilience.

2.2 Agricultural Voluntary Sustainability Standards and Resilience

Voluntary Sustainability Standards (VSS) are market-oriented programmes that aim to promote sustainable consumption and production. They typically consist of providing recognition to producers who adopt production practices deemed more sustainable than

[11] The five generic principles of resilience are comprised of: 1) Functional and response diversity which refers to ensuring that there is variety in system functions and responses to disturbances, 2) Modularity describes the system composition which are comprised of independent but connected subsystems, 3) Openness refers to the connectivity between systems, 4) Tightness of feedbacks refer to flows and responsiveness to change between subsystems and 5) System reserves which are stockpiles of resources that can be accessed to withstand shocks and stresses (Meuwissen et al., 2019).

conventional production practices in exchange for formal recognition and product differentiation in the marketplace (i.e. labels, seals or preferential sourcing) (Committee on Sustainability Assessments, 2013; Komives & Jackson, 2014). The same holds true for VSS operating in the agricultural sector (AVSS) which can be viewed as catalysts for enabling sustainable agriculture. AVSS can be traced back to the organic farming movement of the early nineteen seventies with the establishment of the International Federation of Organic Agriculture Movements (Arbenz et al., 2016). They started growing significantly in number and market presence after the 1992 Rio Earth Summit (Potts et al., 2014). As demand for more sustainable products increased, AVSS evolved from serving niche to meeting mainstream market needs. Standard-compliant products now represent more than 10% of production in a number of agricultural commodity sectors (i.e. coffee, cocoa, cotton, palm oil and tea) (Willer et al., 2019).

Although they have their own specific and unique intricacies, AVSS share similar design characteristics such as production criteria, chain of custody or traceability systems, standard conformity assurance measures, governance structures and labeling specifications (Komives & Jackson, 2014). The design characteristic most likely to directly impact the resilience of farming systems are AVSS production criteria as they must be implemented for farmers to be considered standard-compliant. Each agricultural sector faces different sustainability challenges which range broadly from high incidences of child and slave labour to deforestation and biodiversity losses. For this reason, AVSS have their own sustainability objectives targeted towards addressing the challenges facing the agricultural sectors they work in. Although AVSS-compliant agriculture may be deemed more sustainable compared to other forms of agriculture eroding the social and biophysical environments that underpin agriculture, they are primarily focused on optimizing production while lowering economic, social and environmental costs. Bennett et al. (2014) argue that focusing on optimizing agriculture for sustainability is insufficient since systemic changes, such as climate change, globalization and biodiversity loss, which are having profound effects, can, are and will continue to impact global agricultural production systems. Within this context, agricultural production systems deemed sustainable under specific conditions may not be when facing disturbances. Consequently, agricultural production systems need to be sustainable as well as resilient to address known and unknown challenges. This would require shifting the characterization of successful agriculture from profitable farming systems with lower socio-ecological impacts, viewed by some as sustainable agriculture, to farming systems that can also remain resilient in the face of systemic change (sustainable as well as resilient agriculture) (E. M. Bennett et al., 2014).

AVSS are well-positioned to enable both sustainable and resilient agriculture since the literature on sustainability and resilience indicates that they significantly intersect and can be complementary (E. M. Bennett et al., 2014; Folke, 2016; Roostaie et al., 2019). They are both normative, subjective and value-laden concepts, which have evolved into ideals that we should strive towards. "Determining when resilience is on a desirable or undesirable path, and for whom, is an inherently value-laden, subjective and political question, a question that, if sustainability is in focus, needs to be connected to human wellbeing as part of the biosphere" (Folke, 2016, Resilience of people or planet in development? sub-section, para. 1). In practice there are no sustainability and resilience definitions that can be uniformly applied independent of context and local interpretation which are subject to change. Nonetheless, both concepts are bounded by parameters which provide a starting point for their implementation. Furthermore, sustaining anything embedded in dynamic, interconnected and changing environments requires persistence, adaptation and even transformation which leads sustainability back to resilience. This thought is supported by Folke (2016) who states "…resilience thinking emphasizes that humanity is embedded within the biosphere and that any attempt that takes sustainability seriously will require sustainability transformations with stewardship that operates in synergy with the biosphere foundation" (Folke, 2016, Current definition of resilience thinking: integrating resilience, adaptability, transformability sub-section, para. 8). Despite their lack of specificity, the sustainability and resilience concepts have gained importance in guiding public and private sector decision-making across the world (Roostaie et al., 2019). Furthermore, their conceptual ambiguity has been helpful to build a shared understanding which is often a precondition for most sustainability and resilience initiatives.

Notwithstanding their rapid growth in the marketplace and potential for enabling resilient agriculture, the evidence base on the sustainability impacts of AVSS remains mixed at best (DeFries et al., 2017; Komives et al., 2018; Oya et al., 2018). Oya et al. (2018) find that there is inconclusive evidence that AVSS are having socio-economic benefits for farmers in low and middle income countries and that the contexts in which they are implemented have significant effects on their sustainability impacts. DeFries et al. (2017) examine the environmental, social and economic impacts of studies of AVSS reported in the literature and conclude that the majority of the response variables they examined indicating no significant differences. Komives et al. (2018) examine the conservation impacts of AVSS and find that there is some evidence that they are slowing deforestation and biodiversity loss in some contexts but not in others. A recent meta-analysis study finds more definitive evidence that AVSS are having positive effects on the profitability of smallholder farmers, although they point to significant heterogeneity across the studies examined (Meemken, 2020). The context in which AVSS are implemented matters with respect to their sustainability impacts (Ibanez & Blackman, 2016; Meemken, 2020; Oya et al., 2018; Tuck et al., 2014). For instance, the implementation of the Fairtrade standard, devised to provide farmers with fairer incomes, has in some cases resulted in lower returns than conventional farming (Bassett, 2010; Beuchelt & Zeller, 2011). The absence of consistent positive outcomes associated with the uptake and implementation of AVSS is concerning and questions their effectiveness to enable more sustainable forms of agriculture (Potts, 2017; Widengård et al., 2018). Furthermore, there are very few studies on AVSS and farming resilience and currently no published scientifically peer-reviewed journal articles on AVSS and their impacts on the general resilience of farming systems (Goncalves et al., n.d.; Stanbury, 2020).

Due to their continued proliferation and urgent need for more sustainable and resilient global farming systems, a more rigorous and consistent evidence base on the sustainability and resilience impacts of AVSS is needed. To this end, DeFries et al. (2017) recommends rigorous analysis, standardized criteria and independent evaluations to further assess the sustainability effects of AVSS. Nevertheless, sustainability assessments remain challenging and an evolving field of study (Bond et al., 2012; Pope et al., 2013; Zeleňáková & Zvijáková, 2017). Despite decades of experience conducting various types of impact assessments (i.e. environmental, social, health and strategic environmental and sustainability assessments) there remains theoretical, methodological and practical shortcomings. For this reason, Zeleňáková and Zvijáková (2017) explore the possibility of integrating environmental impact assessments with risk analysis and Bond et al. (2012) identify the resilience of socio-ecological systems as a potential means to further frame sustainability assessments by integrating systems-based methods and resilience thinking. One of the most challenging aspects of sustainability impact assessments is the need to account for plurality which necessitates establishing and framing sustainable development for a given context via proper public consultations (Pope et al., 2013). Thus, conducting proper and rigorous sustainability impact assessments can be time-consuming and costly. For this reason, many AVSS-compliance monitoring efforts have focused on ensuring that farmers are implementing farming and business practices as opposed to assessing the tangible sustainability outcomes associated with their implementation of specific farming and business practices required to remain standard-compliant (Smith et al., 2019).

Shifting from practice-based to performance-based standards would require measuring and monitoring the sustainability outcomes associated with the implementation of AVSS as opposed to monitoring the adoption of practices (Smith et al., 2019). Most of the studies conducted on the sustainability impacts of AVSS consist of surveying farmers to track productivity and profitability changes associated with modifying their farming practices (Committee on Sustainability Assessments, 2013; Kumar et al., 2019a). A rigorous sustainability impact assessment would have to measure the interlinked outcomes of an intervention, such as changes in profitability, incidences of child labour, energy consumption and biodiversity levels, compared to a counterfactual to ensure that causality can be linked to the implementation of the AVSS (Biesbroek et al., 2017; Willemen et al., 2019). Nevertheless, the literature indicates that basic tenets of scientific rigour are often not being met when evaluating the sustainability impacts of AVSS. According to Meemken (2020) most of the impact studies she reviewed on the sustainability impacts of AVSS on smallholder farmers, do not account for possible selection bias and there are no impact studies based on experimental data. Although some AVSS sustainability impact studies are more rigorous than others (i.e. accounting for selection bias, incorporating counterfactuals), more research is required to provide conclusive evidence that AVSS are having positive sustainability impacts (DeFries et al., 2017; Komives et al., 2018; Meemken, 2020; Oya et al., 2018).

The need to build more resilient farming systems coupled with the expansion of AVSS in the marketplace, mixed evidence on their sustainability impacts and no evidence on their resilience impacts provides a strong rationale to rethink their design and implementation for enabling farming resilience. Nevertheless, enabling resilience via the adoption of AVSS can be a contradiction of sorts. On the one hand, building resilient farming systems calls for flexible, adaptable and transformable production systems to face a broad range of disturbances while implementing standards can lead to more rigid production systems by imposing farming practices that must be followed to remain standard-compliant. This contradiction is being addressed to some degree by regular AVSS production criteria revision processes and by more flexible measures for farmers to become and remain standard compliant. For instance, the Rainforest Alliance standard is based on a continuous learning model trying to meet farmers at their capacity levels and encouraging their evolution towards more sustainable forms of agricultural production (Rainforest Alliance, 2019b, 2019a). The Rainforest Alliance standard also has exceptions related to pesticide use which can be useful for farmers to deal with unforeseen pest and disease outbreaks such as the coffee leaf rust disease which devastated yields in South America in the 2012/2013 growing season (Rainforest Alliance, 2019b, 2019a; Reuters Staff, 2014).

Most resilience considerations integrated into AVSS focus on addressing climate change impacts as opposed to a broad range of disturbances, or what Meuwissen et al. (2019) refers to as specific resilience versus general resilience. For example, the Better Cotton Initiative (BCI) standard requires medium and large farms to establish a water stewardship plan to conserve water resources and identify climate change adaptation opportunities, while the Fairtrade Standard for Small-scale Producer Organization (FSPO) standard recommends the adoption of climate adaptation measures suitable for the region and within the organization's capacities (i.e. crop diversification, rainwater harvesting, mulching) (Fairtrade International, 2019). Some scholars advocate for developing more holistic AVSS that incorporate resilience design considerations that address a broad range of disturbances in addition to climate change. "A major weakness of most existing eco-labeling systems involves their explicit focus on environmental issues associated with discrete aspects of production (i.e., prohibitions on the use of synthetic fertilizer and pesticides) and consequent failure to address the overall resilience of the agricultural system" (Angelo & Reilly-Brown, 2014, p. 696). Despite having in place some climate resilience measures, AVSS need to be redesigned to enable general farming resilience to known and unknown disturbances which requires a thorough understanding of how they are and are not enabling farming resilience.

2.3 Existing Farming Resilience Assessment Frameworks

The normative, subjective and value-laden underpinnings of resilience has made it elusive to measurement and operationalization. Despite this challenge, framing questions and frameworks have been developed providing guidance on assessing farming resilience. The Five Principles for Building Resilience (5PBR) (Meuwissen et al., 2019; Resilience Alliance, 2010), the

Seven Principles for Building Resilience (7PBR) (Biggs et al., 2015), the thirteen behavior-based indicators of resilience within agroecosystems (Cabell & Oelofse, 2012), the twenty-seven core resilience indicators for agriculture (Serfilippi & Ramnath, 2018) and three spheres for regenerative agriculture (Gosnell et al., 2019) are critically examined to provide a basis upon which to propose an analytical framework for examining how AVSS are affecting farming resilience.

The 5PBR and the 7PBR, developed by the Resilience Alliance (2010) and Biggs (2015) respectively can be applied to examine the general resilience of socio-ecological systems. The 5PBR are comprised of: 1) Functional and response diversity which refers to ensuring that there is variety in system functions and responses to disturbances, 2) Modularity describes the system composition which are comprised of independent but connected subsystems, 3) Openness refers to connectivity between systems, 4) Tightness of feedbacks refer to flows and responsiveness to change between subsystems and 5) System reserves are accessible resource stockpiles to deal with shocks and stresses. The 5PBR are used by Meuwissen et al. (2019) to examine the resilience attributes of farming systems. Although the 5PBR cover farming system structures that need to be in place to remain resilient, they do not directly address the farmer which must play an integral role in enabling farming resilience. Oriented towards sustaining ecosystem services in socio-ecological systems, the following 7PBR complement the 5PBR by directly addressing resilience implementers: 1) Maintaining diversity and redundancy refers to ensuring that there is variety, balance and disparity to face disturbances, 2) Managing connectivity means enabling and impeding connectivity to better cope with or prevent the propagation of disturbances, 3) Managing slow variables and feedbacks consists of managing key elements and their interactions to prevent or enable socio-ecological system transformations, 4) Fostering complex adaptive systems thinking recognizes the interconnected and unpredictable nature of socio-ecological systems, 5) Encouraging learning consists of building knowledge and capacities to evolve with changing socio-economic systems, 6) Broadening participation aims to build trust and consensus for collective action and 7) Promoting polycentric governance systems allows for entities to jointly govern for collective resilience (Biggs et al., 2015). Principles 4 to 7 are squarely focussed on resilience implementers as individuals and communities. Despite this focus, the 7PBR lacks sufficient specificity to examine farming resilience in depth. For instance, managing diversity and functional redundancy can refer to a broad range of measures within farming systems, typically limited to crop diversification (Goncalves et al., n.d.). For this reason, fleshing out the 7PBR within the context of farming systems could make them more useful for examining farming resilience.

Cabell and Oelofse (2012) propose thirteen behavior-based indicators to examine the resilience of agroecosystems. These indicators are more specific to farming systems and convey more insight. For instance, the profitability of the farming system indicator focusses on its ability to support livelihoods independent of government subsidies and secondary employment (Cabell & Oelofse, 2012). The authors characterize their indicators as 'behavior based' since they were devised to provide high level insights on the behavior of a broad range of agroecosystems and their implications on resilience. They justify their orientation to behavior-based indicators by stating "by its nature and because of our own limitations of comprehension resilience defies measurement" (Cabell & Oelofse, 2012, Introduction section, para. 3). Nevertheless, within the context of AVSS, behavior-based indicators may not be sufficient as verification and certification measures are used to ensure that farmers are adhering to the standard. Addressing this shortcoming would require more detailed behavior-based indicators allowing for a more thorough assessment of farming system behaviors and their implications for resilience while remaining applicable to a broad range of farming systems. For instance, the 'Functional and response diversity' indicator proposed by the authors could be further disaggregated into specific farming diversification measures that would allow for a more detailed assessment of how farming systems are fulfilling this indicator.

Serfilippi and Ramnath (2018) propose twenty-seven core indicators and seventy-six associated indicators to measure agricultural resilience which can be aggregated in different ways to examine the static (human, socio-political, financial, physical and natural capitals) and dynamic (adaptive, adsorptive and transformative) dimensions of resilience. To develop these indicators, the authors drew from the development literature which primarily uses a capitals and capacities approach to assess resilience focussing on abilities (capacities) to harness resources (capitals) when facing disturbances (Serfilippi & Ramnath, 2018). The twenty-seven core indicators are organized across the social, environment and economic sustainability dimensions (see Table 1).

Table 1 - Twenty-seven core indicators for measuring agricultural resilience.

Context
Risk context information - The array of risks that people are exposed to
Occurrence and severity of shocks - Shocks that reduced household wellbeing
Social
Recovery ability - Perceived speediness and ability to recover from shock
Coping strategy - Household coping strategies applied to face shocks
Individual preparedness strategies - Strategies implemented by household to face shocks
Dissemination of critical information - Access to information about adverse events
Access to safety nets - Access to formal and informal safety nets
Participation in decision-making structures – Household involves in decision-making
Perceptions about political environment - Accountable and transparent political processes
Poverty status - Poverty according to PPI and according to National poverty lines
Household adult education level - Members with primary school or higher level of education.
Days without sufficient food - Days household members cut consumption due to lack of food
Adoption of new technologies - Adoption of new cropping/livestock practices and equipment
Access to information - Access to cropping/livestock, market, weather and health information
Access to school - Availability of school within reasonable travel distance
Access to medical services - Availability of medical care
Access to safe water - Household access to water they consider safe to drink
Access to electricity - Availability of electricity at home
Environmental
Soil and water conservation measures - Measures taken to conserve soil and conserve water
Local nutrient cycle - Soil fertility practices and organic matter recycling
Land use change - Conversion of natural to productive land or vice-versa
Fertilizer use - Synthetic fertilizers used and compared to focus crop yields
Pesticide use - Amount of natural or synthetic pesticides used on focus crop
Integrated pest management - Integrated pest management practices employed on farm
Economic
Diversification of Livelihood - Portion of total net income from business activities
Access to credit - Access to production loan within a reasonable time
Productive assets - Number of agricultural productive assets

Although this framework provides detailed indicators to assess aspects of farming resilience, the core indicators are organized across the three main dimensions of sustainability, social, environmental and economic and lack spatial framing that conveys the multi-scalar aspect of farming resilience which includes the farmer, the farm and the farming environment. Furthermore, they are more heavily focused on accessing resources (capital assets) as opposed to abilities (capacities) which needs to be of primary focus when examining resilience building to known and unknown disturbances (Meuwissen et al., 2019). Approximately 13 core indicators focus on access to one resource or another while 7 core indicators focus on abilities and 7 core indicators focus on resource access and abilities. The focus of these indicators is oriented towards measuring resilience to specific or known disturbances as opposed to general resilience which include unknown disturbances.

Lastly, Gosnell et al. (2019) propose a framework focused on regenerative agriculture, which concerns itself with enabling resilient systems, comprised of the personal, practical and political spheres. The authors describe how the personal and political spheres act on the practical sphere resulting in ecological, economic and social outcomes. The framework is presented under the friction (impeding) and traction (enabling) components of transformation towards regenerative agriculture that focuses on "enhancing and restoring holistic, regenerative, resilient systems supported by functional ecosystem processes and healthy, organic soils capable of producing a full suite of ecosystem services, among them soil carbon sequestration and improved soil water retention" (Gosnell et al., 2019, p. 4). The framework addresses values, emotions, mental models, worldviews and cultural norms involved in enabling farming resilience across all three spheres. Using their framework, Gosnell et al. (2019) demonstrate how it can be used to map transitions towards regenerative agriculture for specific contexts. For example, using qualitative interviews with grazers in Australia, the authors mapped 24, 29 and 12 components of friction and traction respectively within the personal, practical and political spheres for their adoption of regenerative agriculture (Gosnell et al., 2019). In this way, the framework does address general as opposed to specific resilience as it allows for identifying the underpinnings of resilience for specific contexts.

Although the framework provides some spatial framing to assess for resilience via the personal, practical and political spheres, it is heavily focused on values and emotions, which are important drivers of farming resilience, but difficult to audit for assessing AVSS-compliance as they are more means as opposed to outcomes. Nevertheless, factoring in values, worldviews and cultural norms are important to better understand the contexts in which AVSS are implemented and assess their potential for enabling farming resilience. Furthermore, the framework is narrowly focused on the effects that the personal (farmer) and political (farming environment) spheres have on the practical sphere (the farming operations) but does not require the examination of the effects that farming operations have on farmers and farming environments. A better representation of these interconnections is required to accurately depict the interactive multi-scalar aspects of resilience within farming systems.

2.4 The Problematique

Scholars argue that there is a need for adopting agricultural production systems that are both sustainable and resilient for agriculture to remain viable in the face of shocks and stresses which are expected to become more frequent (E. M. Bennett et al., 2014; Biggs et al., 2015; Cabell & Oelofse, 2012; Meuwissen et al., 2019). AVSS, developed to enable more sustainable forms of agriculture, have potential for building more resilient farming systems as they have been growing in the marketplace. Despite this growth, they have had mixed sustainability impacts, questioning their effectiveness for enabling more sustainable and resilient forms of agriculture. This is partly due to impact measurement methodological shortcomings that need to be surmounted to strengthen the body of evidence on AVSS sustainability impacts. AVSS have started integrating resilience measures by designing more flexible standards and including climate resilience considerations. These efforts need to be strengthened by integrating general resilience measures so that farming systems can better face known and unknown disturbances which can be achieved by focussing on building farming resilience enabling conditions or attributes.

Despite remaining elusive to measurement, a number of farming resilience frameworks have been developed to operationalize the resilience concept within agriculture. Five farming resilience frameworks were examined offering spheres of focus, principles and indicators to assess the resilience of farming systems. All of the frameworks reviewed had some shortcomings such as a lack of focus on farmers, general resilience and the multi-scalar aspect of farming resilience. There is clearly a need to build on ongoing efforts to understand how resilience can be better implemented in the agricultural sector. This thesis aims to make a contribution in this regard by integrating features of the reviewed farming resilience frameworks together to address how the design and implementation of AVSS affect the general resilience of farming systems.

3 Methodological Approach

The methodological approach undertaken to address the central research question is devised and organized by focusing on two related sub-questions which focus on the design and implementation of Agricultural Voluntary Sustainability Standards (AVSS) and how they may affect the general resilience of farming systems. Making this distinction is important since the design of AVSS represents their aspirational objectives, while the implementation of AVSS reflects their actual effects on farming systems manifested in the field. For this reason, examining the design and implementation of AVSS provides a more holistic picture of how they can potentially affect the general resilience of farming systems.

To examine the research sub-questions, an AVSS resilience analytical framework was first devised by reviewing existing resilience assessment frameworks developed for the agricultural sector (see section 2.3). The proposed framework, comprised of three dimensions (resilience intelligence, conditions and collaborations) and eighteen related indicators, provides an overarching analytical lens to examine the design and implementation of AVSS and farming resilience. The analytical framework proposed contributes to understanding what it would take to move the agricultural sector towards more sustainable and resilient forms of production by providing a multi-scalar approach to examine how AVSS, as a management instrument, affect the general resilience of farming systems.

Parts of the framework were then operationalized to examine the design and implementation of AVSS and farming resilience. The design of AVSS and its potential effects on the general resilience of farming systems is examined by benchmarking the production criteria of 7 standard setting bodies adhering to the ISEAL Alliance Code of Good Practice against the eighteen indicators of the AVSS resilience analytical framework. A case study of the BCI program (one of the AVSS benchmarked) being implemented in the Adoni Mandal[12], India, was then undertaken by conducting focus group discussions with farmers, training effectiveness and organizational network analysis. The farmer focus groups provided contextual information and qualitative data on the main challenges facing cotton farmers in the study area and related coping strategies to support the case study findings. The training effectiveness focussed on ascertaining in what ways training provided by the BCI program affected the resilience of cotton farmers by conducting a farming survey and matching farmers that are and are not participating in the BCI training programme to compare their resilience threat, coping strategy and cultivation practice differences. The organizational network analysis consisted of examining relationships between organizations working on water and food security to determine how the BCI program may be enabling engagement with external stakeholders and governance structures, which is assumed to improve farming resilience. The benchmarking effort and case study, which used mixed methods to triangulate on research findings, provided valuable insights to answer the research questions (see Figure 3).

[12] Mandal refers to local government in India. More specifically the State of Andhra Pradesh is subdivided into Districts which are further subdivided into Mandals responsible for governing strictly rural areas comprised of villages. Urban areas fall outside of Mandal's jurisdictions are they are governed by municipalities.

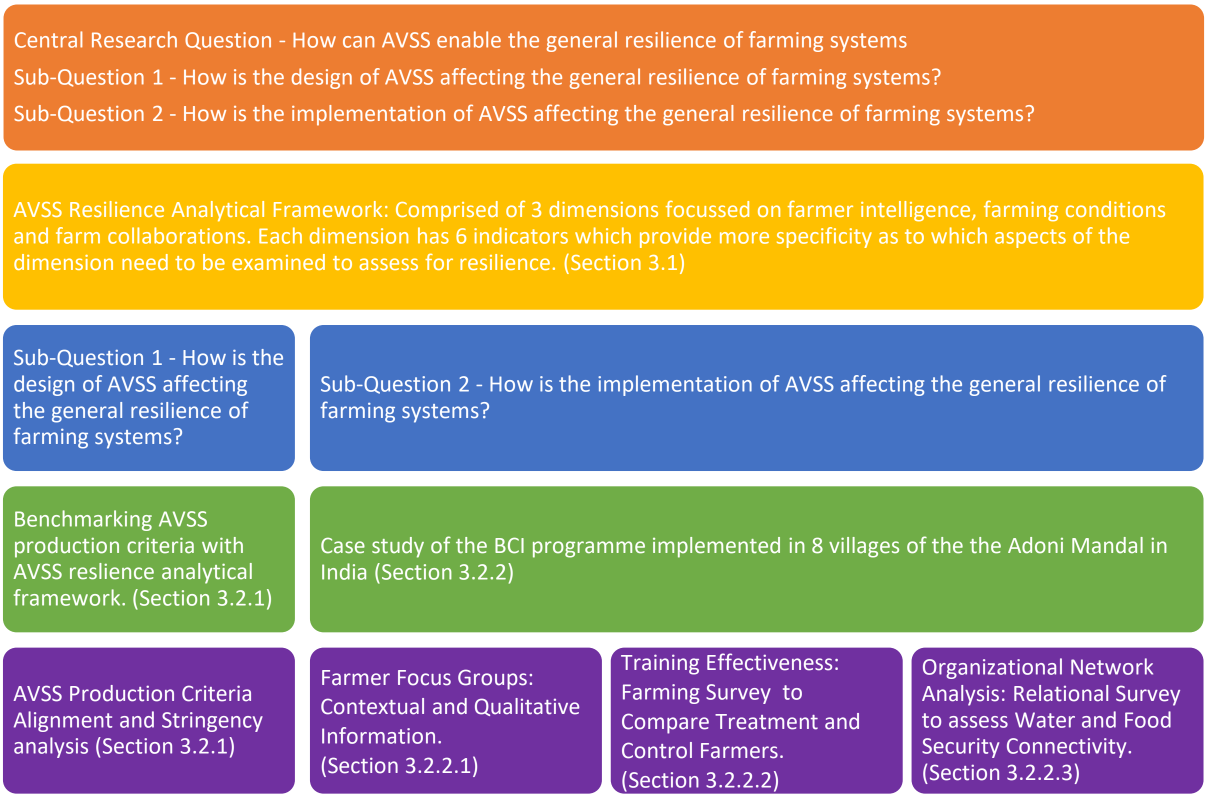

Figure 3 – Methodological approach

As described, the methodological approach adopted to address the research questions consisted of developing and operationalizing parts of an analytical framework presented in section 3.1 and section 3.2 respectively. Mixed methods were used to examine how the design and implementation of AVSS affect the general resilience of farming operations (Documentation review and benchmarking analysis - section 3.2.1, Case Study – section 3.2.2 consisting of 1) Qualitative examination of farmer focus group discussion - section 3.2.2.1, 2) Farming survey and statistical matching method - section 3.2.2.2, 3) Relational survey and network analysis method - section 3.2.2.3) (see Figure 3). The following sub-sections describe and justify the analytical framework developed and its operationalization to address the central research question of this PhD dissertation.

3.1 Proposed Resilience Analytical Framework

The existing literature and limitations in the frameworks reviewed in Sections 2.1 to 2.3 provided the inspiration for developing a farming resilience analytical framework oriented towards assessing how AVSS are affecting the general resilience of farming systems. More specifically, the spheres, principles and indicators from the resilience frameworks reviewed were used to develop an analytical framework comprised of three resilience dimensions and eighteen core indicators, to address the research question of this dissertation and provide a stepping stone towards rethinking the design and implementation of AVSS for farming resilience (see Figure 4 and Table 2) (Biggs et al., 2015; Cabell & Oelofse, 2012; Meuwissen et al., 2019).

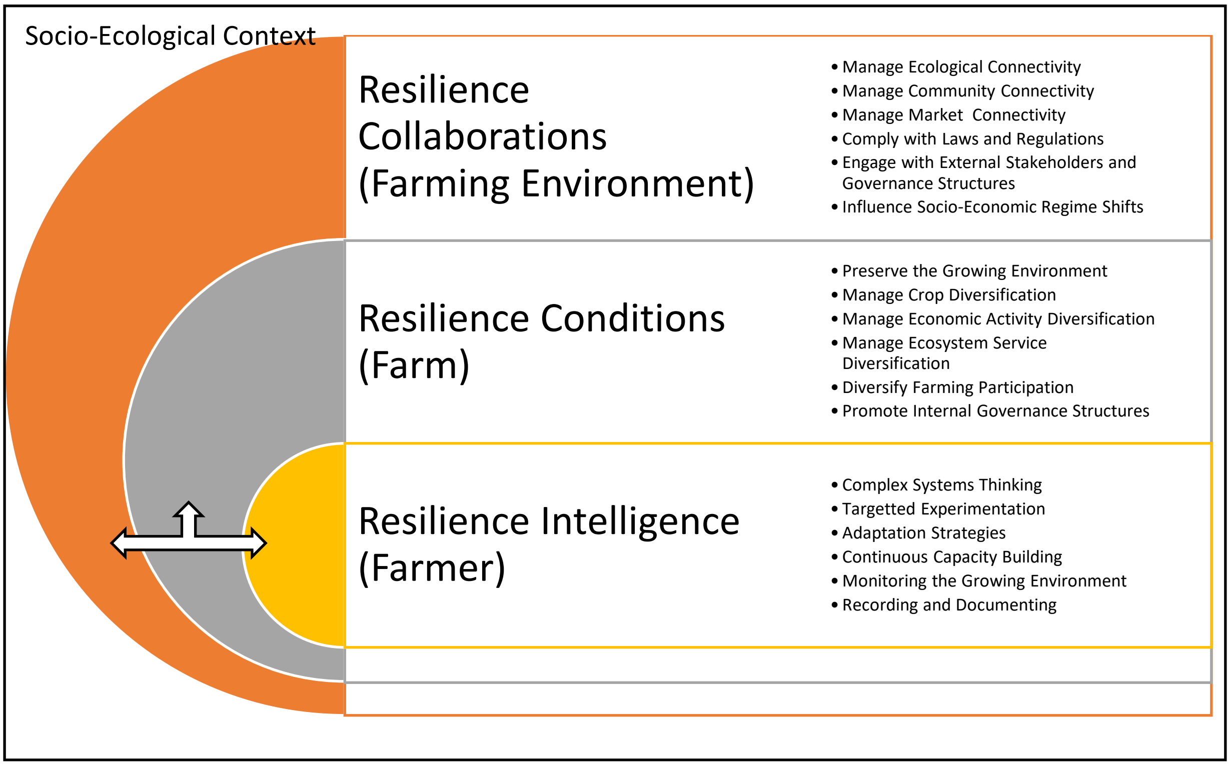

Figure 4 – The AVSS Resilience Analytical Framework

The three resilience dimensions proposed in this dissertation are comprised of resilience intelligence manifested by the farmer, resilience conditions conveyed by the farming operation and resilience collaborations defined by the farm's interactions with its surroundings. Resilience intelligence, conditions and collaborations simultaneously convey the multi-scalar and interconnected aspects of farming systems and resilience. Embedded in a socio-ecological context, the dimensions aim to provide insights on the farming system structure that can influence resilience at the level of the decision-makers managing the farm who ultimately decide (resilience intelligence) under what condition the farm operates (resilience conditions) and how the farming operation is enabling the collective resilience of the socio-ecological system in which it is embedded (resilience collaborations). These resilience dimensions, which align with Gosnell et al.'s (2019) regenerative agriculture spheres, allowed for having clear levels of focus when examining how AVSS are affecting the general resilience of farming systems and were derived by aggregating various aspects of the frameworks reviewed in section 2.3 into a simplified and multi-scalar farming resilience analytical framework. Table 2 summarizes how the components of the farming resilience frameworks examined were used to derive the analytical framework. For instance, the complex adaptive systems thinking and encouraging learning principles from the 7PBR were aggregated into the resilience intelligence dimension as both principles focus on developing knowledge needed for farming resilience in dynamic environments.

From these three resilience dimensions, eighteen indicators were derived for the proposed analytical framework to allow for a more detailed analysis of the farming system and its potential resilience. The proposed indicators are oriented towards examining the general resilience to known and unknown disturbances as opposed to specific resilience to specific disturbances. In this way, the proposed indicators provide more specificity than the 7PBR (Biggs et al., 2015) and the behavior-based indicators for agroecosystems (Cabell & Oelofse, 2012), but less detail than the core indicators for measuring agricultural resilience (Serfilippi & Ramnath, 2018) (see Table 2). The indicators also aim to strike a balance between remaining applicable to a broad range of farming systems and useful to identify farming resilience building characteristics. For example, the Functional and response diversity and Optimally redundant behavior-based indicators from Cabell and Oelofse (2012) are disaggregated into three core indicators focussed on managing the diversification of agricultural products, economic activities and ecosystem services which allow for a more detailed look at how the farming system is managing the diversification of its operations which can have consequences on farming resilience (see Table 2). These three indicators focused on the diversification of the farming operation can also be matched with the Diversification of livelihoods, Productive assets and Adoption of new technologies core indicators for measuring agricultural resilience proposed by Serfilippi and Ramnath (2018) which are more strongly oriented towards assessing capital assets instead of capacities for resilience (see Table 2). Similarly to Cabell and Oelofse (2012), farming systems that do not exhibit one or another of the core indicators conveys an opportunity for improving farming resilience. The proposed resilience dimensions and indicators are used to address the main research question of this PhD Thesis Dissertation, “How can AVSS enable the general resilience of farming systems?”, are further described in the following sub-sections.

Table 2 – Resilience dimensions and indicators for farming systems

AVSS Resilience Analytical Framework		**Existing Farming Resilience Assessment Frameworks**			
Resilience Dimensions	**Farming Resilience Attribute Assessment Indicators**	**The Five and Seven Principles for Building Resilience** (Biggs et al., 2015; Resilience Alliance, 2010)	**Agroecosystem Indicators** (Cabell & Oelofse, 2012)	**Agricultural Resilience Core Indicators** (Serfilippi & Ramnath, 2018)	**Regenerative Agriculture Spheres with friction (F) and traction (T) aspects** (Gosnell et al., 2019)
Resilience Intelligence	1. Complex Systems Thinking 2. Targeted Experimentation 3. Adaptation Strategies 4. Continuous Capacity Building 5. Monitoring the Agricultural Operation 6. Recording and Documenting	-Fostering complex adaptive systems thinking (7PBR) -Encourage learning (7PBR)	-Reflective and shared learning -Exposed to disturbance -Honors legacy	-Recovery ability -Coping strategy -Individual preparedness strategies -Poverty status -Household adult education -Days without sufficient food	Personal Sphere: -Fear of change (F) -Ego and pride (F) -Habit, tradition (F) -Newfound humility (T) -Holistic goals (T) -Sense of integrity (T)
Resilience Conditions	7. Manage agricultural product diversification 8. Manage economic activity diversification 9. Manage ecosystem service diversification 10. Preserve the growing environment 11. Broaden participation in farming activities 12. Promote internal governance structures	-Functional and Response Diversity (5PBR) -Openness (5PBR) -Modularity (5PBR) -Tightness of feedbacks (5PBR) -System Reserves (5PBR) -Diversity and Redundancy (7PBR) -Managing Slow Variables and Feedbacks (7PBR)	-Functional and response diversity -Optimally redundant -Spatial and temporal heterogeneity -Ecologically self-regulated -Coupled with local natural capital -Reasonably profitable	-Soil and water conservation measures -Local nutrient cycle -Land use change -Fertilizer use -Pesticide use -Integrated pest management -Diversification of livelihood -Productive assets -Adoption of new technologies	Practical Sphere: -Steep learning curve (F) -Initial investments (F) -Peer pressure (F) -More biodiversity (T) -Less financial risks (T) -Sense of community (T)
Resilience Collaborations	13. Manage ecological connectivity 14. Manage community connectivity 15. Manage market connectivity 16. Comply with laws & regulations 17. Engage with external stakeholders & governance structures 18. Influence socio-economic regime shifts	-Openness (5PBR) -Tightness of feedbacks (5PBR) -System Reserves (5PBR) -Managing Connectivity (7PBR) -Broaden Participation (7PBR) -Polycentric Governance (7PBR)	-Appropriately connected -Socially self-organizing -Globally autonomous and locally interdependent	-Dissemination of critical information (early warning) -Access to safety nets -Access to information -Access to school -Access to medical services -Access to safe water -Access to electricity -Access to credit	Political Sphere: -Conventional agri-business (F) -Research community skepticism (F) -Local politics (F) -Niche markets (T) -Training programmes (T) -Supportive networks (T)

3.1.1 Resilience Intelligence

Core Indicators:
1. Complex Systems Thinking
2. Targeted Experimentation
3. Adaptation Strategies
4. Continuous Capacity Building
5. Monitoring the Farming Operation
6. Recording and Documenting

Resilience is first and foremost a mindset. This means cultivating a sense of self that can overcome adversities, adapt to change and even have the confidence to transform (Berkes & Ross, 2016; Cyrulnik, 2009). It is also characterized by an awareness that everything is interconnected, which lends itself to complex adaptive systems thinking (Biggs et al., 2015). Resilience intelligence needs to be constantly sharpened by encouraging continuous learning to ensure that broad and varied knowledges can be mobilized to respond to disturbances. Knowledge can be acquired from first-hand lived experiences or from other sources (Berkes & Ross, 2016). Resilience intelligence is manifested by individuals who have built up resilience-related knowledge. In the case of farming systems, resilience intelligence is primarily manifested by the main decision-makers of the farm or the farmers who own and operate the farm. Resilience intelligence forms the heart of building resilient farming systems and the center of the proposed analytical framework since it is the main factor that dictates resilience emergence (see Figure 4).

To frame the resilience intelligence dimension, indicators related to mindsets and capacity building efforts were developed. Complex adaptive systems thinking is a way of seeing the world as an interconnected system where uncertainties are integral. Farmers who understand the interconnected nature of their farming system establish adaptation strategies to deal with known and unknown disturbances and experiment to foster complex adaptive systems thinking (Biggs et al., 2015; Caves et al., 2020). Continuous capacity building efforts are also needed to ensure that farmers have a broad and varied pool of knowledge to draw from to deal with potential disturbances to their farming systems. To do so, they must monitor and document ongoing activities within their farming operations.

Farmers that implement complex adaptive systems thinking work towards understanding and managing the interconnectedness of their farming systems. This could take the form of cultivation and business management practices that leverage more holistic farming and business approaches. For instance, integrated pest management (IPM) utilizes complex pest predator relationships to protect crops as opposed to using chemical pesticides which can also affect predators and lead to pesticide resistances over time (Peshin et al., 2014). Planting cover crops can help maintain soil fertility and moisture for cash crops and contribute to household food security. Farmers who have adaptation strategies to deal with uncertainties will remain more resilient than farmers who do not. For instance, adaptable farming systems to climate change are more likely to withstand erratic weather patterns (Anderson et al., 2020). Furthermore, resilient farming systems can also be more flexible and predisposed to shift to alternative states to remain resilient (Ashkenazy et al., 2018). For example farming systems that can easily shift or adopt other economic activities are better equipped to remain resilient in the face of disturbances. Targeted experimentation is a good way to learn from successes and failures with the objective of building resilience (Biggs et al., 2015; Cabell & Oelofse, 2012; Caves et al., 2020). This can be achieved by experimenting with new crops, technologies and farming approaches such as agroforestry (Amadu et al., 2020; Serfilippi & Ramnath, 2018).

Constantly changing growing and business environments, often influenced by disturbances such as climate extremes and disruptive technologies, requires farmers to continuously learn to maintain resilient farming systems. Expanding knowledge via capacity building efforts raises the probability that farmers will have the mental acuity and imagination required to face disturbances.

This can be achieved via first-hand experiences and knowledge transferred from others (Šūmane et al., 2018). Farmers that monitor their farms can enhance their knowledge and build farming resilience through observation which can result in identifying and maintaining critical factors, such as soil fertility and water availability, that support agricultural production (Gosnell et al., 2019). For example, farmers who monitor pests and pest predators can take timely measures to prevent pest outbreaks. Along with monitoring, farmers who keep records of and document their operations are better equipped to learn from their experiences and make timely adjustments so they can make better decisions for maintaining the resilience of their agricultural operations. For example, farmers who track farming inputs over time can avoid excessive application which can be costly and damaging to the environment (Wang & Fok, 2017). Documenting can also mean sharing experiences to improve the potential for preserving the experiential knowledge acquired (Berkes et al., 2007). Taken together, capacity building, monitoring the growing environment and recording their operations, provides a basis for farmers to develop an ability to foresight (referred to by UNESCO as futures literacy[13]) which can support the development of adaptation strategies to remain resilient.

3.1.2 Resilience Conditions

Core Indicators:
1. Manage agricultural product diversification
2. Manage economic activity diversification
3. Manage ecosystem service diversification
4. Preserve the growing environment
5. Broaden participation in farming activities
6. Promote internal governance structures

Resilience conditions focus on ensuring that options are in place within the farm to respond to disturbances. For instance, diversifying the economic activities of a farming operation provides farmers with options to remain viable if the agricultural production component of their operation is

[13] "Futures literacy is a capability. It is the skill that allows people to better understand the role that the future plays in what they see and do (UNESCO, 2020)."

affected or fails due to disturbances. Furthermore, adopting farming practices that maintain the agricultural growing environment which underpins farming production also builds resilience by ensuring that it remains a livelihood option that can be pursued. Resilience conditions refers to various resilience building measures established within the confines of the farm so that it can persist, adapt and even transform to face a broad range of known and unknown disturbances.

To frame the resilience conditions dimension, core indicators on maintaining the agricultural growing environment, managing diversity, broadening farming activity participation and enabling internal governance structures are proposed. Ensuring that the agricultural growing environment is maintained in perpetuity provides farmers with the option to continue farming. This can also include transforming the growing environment in a way that continues to support farming opportunities. For instance, modifying an agricultural field to a pasture, orchard or a forest would be acceptable as it would allow farmers to continue harvesting grass, fruits or trees if they chose to. Managing the diversification of the activities occurring on the farm provides farmers with options to face known and unknown disturbances. For this dissertation, diversification refers to ensuring that there is a variety of measures in place that can respond differently to disturbances and that this variety provides similar functions to achieve similar objectives (Biggs et al., 2015). Enabling a broad and diverse participation in farming activities, including decision-making, allows for drawing from a greater and more diverse pool of knowledge to face potential threats. Establishing internal equitable governance structures within the farm provides a formal structure to question and improve farm management for all involved in the farming operation.

Preserving the agricultural growing environment implies maintaining the natural resources required for agricultural production in perpetuity. More specifically, this consists of managing critical resources and feedbacks to prevent or enable regime shifts, defined by Biggs et al. (2015) as: "large, persistent and often abrupt change in the structure and dynamics of a socio-ecological system that occurs when there is a reorganization of the dominant feedbacks in a system" (2015, p. 22). Critical resources are referred to by Biggs et al. (2015) as slow variables which underpin socio-ecological systems since they can change incrementally until they reach a threshold resulting in regime shifts or rapid transformations of socio-ecological systems. Global climate change, a striking example of slow variables and feedbacks at work, is being altered by the changing composition of the atmosphere leading to unpredictable and erratic weather patterns which can affect agricultural productivity. Managing feedbacks associated with the critical resources of the farm can prevent or enable potential regime shifts. For instance, lowering greenhouse gas emissions contributes to regulating the climate and limiting irrigation can prevent soil salinization, both of which are difficult to reverse regime shifts (E. M. Bennett et al., 2014). Preventing biodiversity losses, such as pollinators, can also have a devastating effect on ecosystems as well as agricultural production (Hoffmann et al., 2019).

Diversity and functional redundancy are important characteristics of resilience (Biggs et al., 2015; Cabell & Oelofse, 2012; Meuwissen et al., 2019). Diversifying farming operations must be carefully managed as it requires trade-offs in time and resource investments (Ashkenazy et al., 2018; Cabell & Oelofse, 2012). Biggs et al. (2015) describe this challenge within the context of ecosystem services: "In managing social-ecological systems for production of ecosystem services, the resilience value of diversity and redundancy should be explicitly recognized so that it can be weighed against the gains in efficiency derived from streamlining towards optimal exploitation types" (2015, p. 65). Although various aspects of farming systems can be diversified, focusing on managing agricultural product, economic activity and ecosystem service diversification, is appropriate as it provides farming systems a range of responses to persist, adapt and transform to remain resilient (Goncalves et al., n.d.; TEEB, 2015). For instance, diversifying the farm's agricultural products allows for withstanding fluctuating market prices, while diversifying the farm's economic activities allows for withstanding catastrophic weather events that can wipe out weather sensitive agricultural production and diversifying ecosystem services supports agricultural production and economic activities by providing suitable conditions for pursuing a diversity of livelihood strategies (Biggs et al., 2015; Goncalves et al., n.d.; TEEB, 2015). For farming systems, managing diversity can be considered a first line of defense or resilience against known and unknown disturbances.

Along with managing the diversification farming systems, managing people's involvement in farming activities can also build resilience. This can be achieved by allowing a diversity of people to equally participate in the farming activities and decision-making. For instance, eliminating all forms of discrimination can support the establishment of a diverse workforce, which can be a valuable asset for building farming resilience in the form of a diverse knowledge base which can be drawn from when confronting known and unknown disturbances (Biggs et al., 2015). Establishing internal governance structures within farming operations also diversifies and challenges existing governance and management structures so that farming systems can be managed for the benefit of everyone involved (Morrison et al., 2019). Promoting internal equitable governance structures provides ways of diversifying people involved in the management of the farming system (Biggs et al., 2015).

3.1.3 Resilience Collaborations

Core Indicators:
1. Manage ecological connectivity
2. Manage community connectivity
3. Manage market connectivity
4. Comply to laws & regulations
5. Engage with external governance structures
6. Influence socio-economic regime shifts

Resilience collaborations focus on building the collective resilience of the socio-ecological system surrounding the farm, which can be a source of disturbance and resilience for the farming operation. For instance, managing the connectivity of the farming operation to its surrounding ecosystems, community and markets offers opportunities to build farming resilience by protecting against potential external disturbances and leveraging external resilience building opportunities (Berkes & Ross, 2016). Furthermore, external collaborations can result in more coordinated and effective responses when faced with disturbances compared to isolated efforts (Berkes & Ross, 2016). For instance, participation in external governance efforts can ensure that farming activities are incorporated in and contribute to collective resilience building efforts (Verburg et al., 2019a). As importantly, the social-ecological processes affecting the viability of farming systems over the long-term need to be understood to effectively build farming resilience, which can only be achieved by engaging with the farm's surrounding socio-ecological environment (Morrison et al., 2019).

To frame the resilience collaborations dimension, indicators focused on the connectivity of the farm to it surrounding environment, compliance with laws and regulations, participation in external governance structures and influencing socio-economic regime shifts are proposed. Farmers that manage the connectivity of their farm with their socio-ecological farming environment can build collective resilience. With some exceptions, farming operations compliant with relevant treaties, laws and regulations are better placed to facilitate constructive engagements with their communities. Furthermore, engaging with governance entities outside of the farming operation also provides important opportunities to build collective and farming resilience (Verburg et al., 2019a). Lastly, enabling beneficial socio-economic regime shifts can only be achieved by engaging with and better understanding its socio-ecological environment (Lade et al., 2013).

The connectivity of farming systems to their surrounding socio-ecological environment must be managed as it can affect farming resilience (E. M. Bennett et al., 2014; Biggs et al., 2015; Cabell & Oelofse, 2012; S. R. Carpenter et al., 2012; Meuwissen et al., 2019). Managing connectivity can result in collective responses to or the prevention of disturbances. It is also fundamental for the sustainable management of common resources which underpin agricultural production (Bodin et al., 2011). For instance, enhancing the connectivity of the farm to its natural habitats can lead to improved biodiversity while lowering it can prevent the spread of natural fires or invasive species both of which can improve farming resilience (Biggs et al., 2015; TEEB, 2015). Focusing on managing the connectivity of the farming system to its surrounding ecosystems, community and markets provide a means to examine resilience collaborations between farming operations and their socio-ecological surroundings. Managing the farm's ecosystem consists of ensuring that the farm's natural habitats are connected to its surrounding ecosystems, while managing community connectivity means developing mutually supportive relationships with the community and managing market connectivity refers to developing product distribution channels and access to markets (Biggs et al., 2015; TEEB, 2015). For example, understanding the upstream and downstream connections of the farm's water resource can result in more sustainable water management approaches which take into consideration community and ecosystem water requirements (Patterson et al., 2013). Farms that are actively engaging with their surrounding community may find it easier to source skilled labor and access local markets (Biggs et al., 2015).

Establishing community relations starts with fitting into its collective fabric, which implies operating by the same rules, norms and conventions. Therefore ensuring that the farming operation is complying with all relevant laws and regulations is important to build community relationships. There are exceptions when power imbalances exist, which may require contravening laws and regulations to enable collective resilience (Córdoba Vargas et al., 2020). Engaging with external governance structures relevant to the farming operation could enable better alignment with community objectives and priorities as well as ensure that the farm is represented in decision-making processes, all of which can build collective resilience. In this way, the farming operation can contribute to collectively addressing disturbances faced by their socio-ecological environment. These efforts can be beneficial even when faced with uneven power dynamics which can be favorably shifted via engagement (Córdoba Vargas et al., 2020). For instance, direct information exchanges between Northern Ethiopian farmers working with impoverished soils and national experts led to the establishment of diverse production systems better able of withstanding droughts and rainfall uncertainties (Goncalves et al., n.d.). Furthermore, enabling socio-economic regime shifts requires engagement with the farm's surrounding community. For instance, enabling women's empowerment is best achieved by shifting societal norms as opposed to implementing measures limited to the farm (Ravera et al., 2019). Gender equality measures at the farm level could address uneven power relations in the workplace but may be limited in addressing uneven gender power relations embedded in society (Ravera et al., 2019).

3.1.4 Interrelated Resilience Dimensions

The AVSS resilience analytical framework, depicted in Figure 4, consists of the three interrelated resilience dimensions presented in the previous sub-sections, with resilience intelligence being manifested by farmers, resilience conditions reflecting the farming operation and resilience collaborations focused on interactions with the farm's surroundings. These resilience dimensions are embedded in a socio-ecological context underpinned by cultural norms and values orienting beliefs and behaviors. The dimensions interact with each other enabling farming resilience to emerge when facing disturbances. For instance, resilience collaborations with the socio-ecological surroundings of the farm can influence the resilience conditions of the farm and the resilience intelligence of farmers. Six indicators are associated with each resilience dimension focused on the resilience attributes of farming systems provide more detailed analytical lenses. By focusing on the resilience building aspects that foster the general resilience of farming systems to known and unknown disturbances, these interrelated resilience dimensions and indicators allow for addressing the main research question of this dissertation: "How can AVSS enable the general resilience of farming systems?"

The AVSS resilience analytical framework is novel as it is oriented towards assessing how AVSS can enable the general resilience of farming systems, a research endeavor yet to be addressed in the literature. Along with our understanding of resilience, analytical frameworks for its operationalization have evolved towards being more holistic (E. M. Bennett et al., 2014; Cabell & Oelofse, 2012; Helfgott, 2018; Meuwissen et al., 2019). From examining the restorative and adaptive capacities of individuals, communities and ecosystems after disturbances to establishing resilience enabling conditions in different contexts, analytical frameworks have given researchers and practitioners tools to assess resilience in more of its aspects. The AVSS resilience analytical framework builds on existing frameworks for operationalizing farming resilience to provide a multi-scalar approach to reflect on how AVSS are building and impeding farming resilience. Consequently, the AVSS resilience analytical framework fills a gap in the literature and provides a stepping stone for AVSS to be better designed and implemented to enable more sustainable and resilient forms of agriculture.

3.2 Operationalizing the Resilience Analytical Framework

The AVSS resilience analytical framework is operationalized to analyze the relationship between the design and implementation of AVSS and the general resilience of farming systems. It is first used to assess how the production criteria of select AVSS fulfill the three dimensions and eighteen indicators of the framework. Doing so allowed for examining how the general resilience of farming systems, which implement the production criteria of AVSS could potentially be strengthened or weakened. This analysis is followed by a case study which focuses on examining how the implementation of one AVSS is affecting the general resilience of farming systems in a specific context (see Figure 5). A single case focused on a specific commodity and context is justified to answer the sub-question 2 for the following two main reasons: first, determining how implementing an AVSS can affect the general resilience of farming systems is best observed in context since the phenomenon of interest (the effect of implementing the AVSS on general farming resilience) is tightly entangled with its context (the farming system and the socio-ecological system it is embedded in); second, focusing on a single case allowed for going into more depth to make analytic generalizations as opposed to statistical generalizations as the case is used to test parts of the AVSS analytical framework presented in Section 2.1 (Yin, 2018).

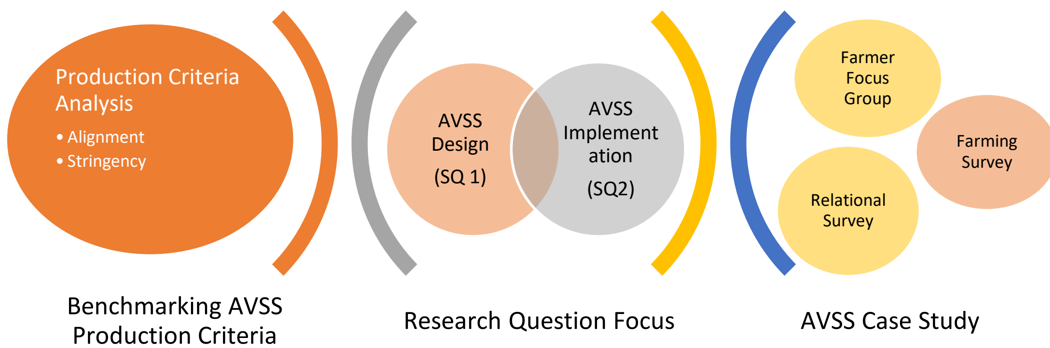

Figure 5 – Operationalizing the AVSS resilience analytical framework

The following sub-sections further justify and describe how the AVSS resilience analytical framework was operationalized by detailing the data collection and analysis approaches used to shed light on how the design and implementation of AVSS affect the general resilience of farming systems. The main methodological limitations of the analysis undertaken are also discussed to provide some additional context to better interpret and understand the research findings. Section 3.2.1 provides detail on how the production criteria of 11 AVSS from seven standard setting organizations were benchmarked against the AVSS resilience analytical framework, while section 3.2.2 describes how the case study was selected and designed to provide an in-depth examination of an implemented AVSS and farming resilience for a specific commodity and context.

3.2.1 Agricultural Voluntary Sustainability Design Assessment

To address Sub-Question 1: ***How is the design of AVSS affecting the general resilience of farming systems?***, the production criteria of eleven AVSS were examined qualitatively against the AVSS resilience analytical framework to determine how they could potentially affect the general resilience of farming systems. The analysis focussed on AVSS production criteria since they must be implemented by farmers to be standard-compliant and for this reason have the greatest potential to directly affect farming resilience. Other AVSS characteristics such as theories of change, governance, assurance, chain of custody and claim and labelling systems were not examined since they do not have a more direct impact compared to AVSS production criteria on farming practices (ISEAL Alliance, 2019).[14] More specifically, theories of change expresses the sustainability goals and objectives of standard setting bodies while the governance system reflects its management and decision making structure. Assurance systems refer to monitoring that standard-compliant farmers are adhering to the standard. Chain of custody systems refer to processes for tracing standard compliant products as they move through supply chains. Claims and labelling specifies rules concerning what and how information concerning a standard-compliant product can be conveyed to market a final product. Perhaps with some rare exceptions, these AVSS characteristics do not have a more direct impact on farming resilience relative to AVSS production criteria.

The analysis undertaken can also be characterized as benchmarking, which is commonly used to examine how AVSS address sustainability frameworks (ISEAL Alliance, 2019; Potts et al., 2010, 2014). Benchmarking, which consists of examining alignment with a reference point (or benchmark), has been identified as having great potential for initiating transformational change within the private sector to achieve the Sustainable Development Goals[15] by the World Benchmarking Association which was established in 2018 to incentivise a business sector that is working towards enabling a

[14] The ISEAL Alliance Sustainability Benchmarking Good Practice Guide dissociates elements of a standard along performance (production criteria) and operational requirements (governance, assurance, chain of custody, claims and labbeling) (ISEAL Alliance, 2019).
[15] "The Sustainable Development Goals are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. The 17 Goals were adopted by all UN Member States in 2015, as part of the 2030 Agenda for Sustainable Development which set out a 15-year plan to achieve the Goals." (United Nations, n.d.).

sustainable future (World Benchmarking Association, n.d.). They claim that benchmarks are effective at communicating to the private sector societal expectations, how they can make sustainability contributions, enable competition for more sustainable business practices, track progress towards achieving goals and is an effective tool for dialogue and engagement (World Benchmarking Association, 2018). Benchmarking is the process of systematically evaluating an entity's (AVSS production criteria) alignment with a benchmark (ISEAL Alliance, 2019). For this dissertation, entity refers to AVSS production criteria while benchmark refers to the AVSS resilience analytical framework. The increasing use of benchmarking to examine and compare Voluntary Sustainability Standards (VSS) motivated the International Social and Environmental Accreditation and Labelling Alliance (ISEAL)[16] to publish the Sustainability Benchmarking Good Practice Guide in 2019 (ISEAL Alliance, 2019). Drawing primarily from best practices from the World Benchmarking Association and the ISEAL Alliance Sustainability Benchmarking Good Practice Guide, the AVSS production criteria were assessed relative to the AVSS resilience analytical framework indicators presented in Section 3.1.

The benchmarking effort undertaken aims to provide insights to develop, design and incorporate AVSS production criteria that can build the general resilience of farming systems. Since AVSS production criteria have been primarily designed to address sustainability issues in agriculture as opposed to resilience, misalignment between production criteria and the AVSS resilience analytical framework is to be expected (see Section 3.2). Nevertheless, the normative concepts of sustainability and resilience closely intersect and this holds true for farming systems which also need to remain resilient if they are to be sustainable (E. M. Bennett et al., 2014; Roostaie et al., 2019).

[16] The ISEAL is an umbrella organization of AVSS who work towards enabling coordination and coherence amongst their membership so that they can fulfill their visions, missions and theories of change for sustainable development in their respective sectors (ISEAL Alliance, Undateda).

Consequently, undertaking this benchmarking effort is worthwhile to support the design of AVSS that aim to build the general resilience of farming systems. This is especially true in light of global disturbances, such as the COVID-19 pandemic, which can disrupt agricultural systems and are expected to become more frequent and common in the future (Stephens et al., 2020).

The AVSS examined had to be a full member of ISEAL which requires adherence to ten credibility principles on setting, assuring compliance with and assessing the impacts of sustainability standards (ISEAL Alliance, 2013). Focusing on ISEAL members allowed for examining AVSS considered best in class as they must commit to incorporating stakeholder interests, establishing more accurate assurance systems and enabling measurement approaches to monitor and learn for more positive impacts, and regularly revise their standards. Focusing on AVSS that are ISEAL members also provides opportunity for influencing their revision towards enabling farming resilience, which must be undertaken at least every five years (see Appendix 1 – AVSS Revision Process).

As of 2021, there were thirteen ISEAL Alliance members working in agriculture. From these organizations, the Textile Exchange, Union for Ethical Biotrade (UEBT), Sustainable Agriculture Network (SAN), Fairtrade USA and UTZ Certified were excluded as they either seldom work directly with farmers (UEBT), are closely aligned with an AVSS already examined (SAN and Fairtrade USA)[17] or have merged with another organization (UTZ Certified). The remaining 7 ISEAL members kept for the analysis are shown in Table 3. Bonsucro, Fairtrade International, Roundtable for Sustainable Biomaterials and Roundtable for Sustainable Palm Oil, have developed

[17] The RA took full ownership of the shared RA/SAN certification systems in 2017 and Fairtrade USA splintered off Fairtrade International in 2011 but producers can still interchangeably be cer
tified Fairtrade USA or Fairtrade International (Fair Trade USA, 2021a, 2021b; Sustainable Agriculture Network, 2017).

smallholder focused standards which were also reviewed (see Appendix 1 – AVSS Description for more detail on each AVSS).

Table 3 – Standard documents reviewed for the AVSS production criteria benchmarking

AVSS	**Standard Document**	**Focus Crops**	**Producer Focus**
Better Cotton Initiative (BCI)	Better Cotton Principles and Criteria Version 2.0 – 2018	Cotton	Smallholders, Medium and Large Farms
Bonsucro	• Bonsucro Production Standard version 4.2 – 2016 (BSC) • Bonsucro Production Standard for Smallholder Farmers – Version 1.0 – 2018 (BSC Small)	Sugarcane	• Sugar Mills • Smallholders sugarcane producers
Fairtrade International	• Fairtrade Standard for Small-scale Producer Organizations Version 2.2 – 2019 (FSPO) • Fairtrade Standard for Hired Labor Version 1.5 – 2014 (FHL)	All Crops	• Smallholder Cooperatives • Hired Workers
Linking Environment and Farming (LEAF)	LEAF Marque Standard Version 15.0 – 2019	All Crops	All Farms
Rainforest Alliance (RA)	Rainforest Alliance Sustainable Agriculture Standard: Farm Requirements Version 1 – 2020	Tree Crops, Fruits, Nuts and Cut Flowers	Group and Individual Certification for Small and Large Farms
Roundtable for Sustainable Biomaterials	• RSB Principles and Criteria – 2016 (RSB) • RSB Principles and Criteria for Smallholder Groups Version 2.0 – 2014 (RSB Small)	Biomass	• Biomass Producers • Smallholder Groups of Feedstock Producers
Roundtable for Sustainable Palm Oil	• Principles and Criteria for the Production of Sustainable Palm Oil – 2018 (RSPO) • Independent Smallholder Standard – 2019 (RSPO ISP)	Palm Oil	• Oil Palm Plantations • Smallholders defined by producing country

Benchmarking the AVSS production criteria against the AVSS resilience analytical framework consisted of ascertaining if a given production criteria is fulfilling one or more of the 18 indicators from the AVSS resilience analytical framework by asking the questions formulated in Table 4. For instance, a link is made between complex systems thinking (indicator related to the Resilience Intelligence Dimension) and understanding the interconnected nature of farming systems thus providing more specificity to examine AVSS production criteria (see Table 4). More specifically, AVSS that require their farmers to implement integrated pest management practices also requires complex systems thinking due to the interconnected nature of using biological and synthetic approaches to crop protection. The benchmarking exercise allowed for identifying where there is and is not alignment between the AVSS production criteria and the AVSS resilience analytical framework indicators. Similarly to the behavior-based indicators for agroecosystem resilience developed by Cabell & Oelofse (2012), a lack of coverage indicates an opportunity to develop production criteria that can support farming resilience.

Table 4 – Key questions for assessing the AVSS production criteria farming resilience potential

AVSS Resilience Analytical Framework	**Probing Questions**
Resilience Intelligence Indicators	
Complex Systems Thinking	Does the criterion require complex systems thinking to better understand the interconnected farming system?
Targeted Experimentation	Does the criterion require experimentation to learn and adapt?
Adaptation Strategies	Does the criterion require developing adaptation strategies to deal with known and unknown disturbances?
Continuous Capacity Building	Does the criterion require capacity building and knowledge of the farming operation?
Monitoring the Farming Operation	Does the criterion require monitoring the farming operation?
Recording and Documenting	Does the criterion require documenting and recording the activities of the farming operation?
Resilience Conditions Indicators	
Manage agricultural product diversification	Does the criterion require managing the diversification of agricultural production?
Manage economic activity diversification	Does the criterion require managing the diversification of the farming system economic activities?
Manage ecosystem service diversification	Does the criterion require managing the diversification of the ecosystem services provided by the farm?
Preserve the growing environment	Does the criterion demand the farmer to manage the resources required for maintaining farming production in perpetuity?

AVSS Resilience Analytical Framework	**Probing Questions**
Broaden participation in farming activities	Does the criterion require the diversification of people participating in the activities of the farming operation?
Promote internal governance structures	Does the criterion require governance structures to be established within the farming system?
Resilience Collaboration Indicators	
Manage ecological connectivity	Does the criterion require managing the ecological connectivity of the farm with its surrounding natural environments?
Manage community connectivity	Does the criterion require managing the connectivity of their farm with their surrounding community?
Manage market connectivity	Does the criterion require managing the connectivity of their farm with markets to sell their products and services?
Comply with laws and regulations	Does the criterion require compliance with all relevant national and local laws and regulations?
Engage with external stakeholders and governance structures	Does the criterion require collaborating with external stakeholders and governance entities?
Influence socio-economic regime shifts	Does the criterion require influencing local socio-economic conditions to improve collective resilience?

The benchmarking effort was further informed by examining the stringency of the production criteria reviewed, which conveys how quickly they must be implemented to become and remain standard-compliant. A weighting system was obtained and modified from the State of Sustainability Initiatives to convey the stringency of the AVSS production criteria based on how expediently they must be implemented for farmers to become and remain standard-compliant (see Table 5) (Potts et al., 2014). This process allowed for a more accurate assessment of how the design of AVSS is potentially affecting farming resilience since some production criteria are critical – standard compliance cannot be achieved without immediate adherence - while others need to be implemented over time – standard compliance can be achieved without adherence. A weight of 0 was assigned to production criterion that are only recommended or do not cover or contribute to fulfilling any of the indicators from the AVSS resilience analytical framework. The stringency analysis allowed for examining AVSS coverage scores by farm size (1) Medium and Large Farms and 2) Small Farms) to determine how they are enabling the general resilience of farming systems.

Table 5 – AVSS production criteria stringency weighting approach

Requirement Categorization and Weight	Mandatory & immediate Weight=5	Mandatory & within 1 year Weight=4	Mandatory & within 2 years Weight=3	Mandatory within 3 years Weight=2	Mandatory more than 3 years Weight=1
Better Cotton Initiative (BCI)	Core	-	-	-	Improvement
Bonsucro General (BSC) & Smallholder (BSC Small) Standards	Core Non-Core[a]	-	-	-	-
Fairtrade International Smallholder Producer Organizations (FSPO) and Hired Labor (FHL) Standards	Core – Year 0	Core – Year 1		Core – Year 3 Dev – Year 3	Dev – Year 6
Linking Environment and Farming (LEAF)	Essential	-	-	-	-
Rainforest Alliance (RA)	Core	Mandatory – Smart Meter	Mandatory – Year 3		Mandatory – Year 6
Roundtable for Sustainable Biomaterials General (RSB) and Smallholder (RSB Small) Standards	Minimum Year 0	- Year 1	Progress Year 2	- Year 3	- -
Roundtable for Sustainable Palm Oil General (RSPO) and Independent Smallholder (RSPO ISP) Standards	Critical Eligibility[b] Milestone A Milestone B	Non-Critical -	- -	- -	- -

[a] The BSC and BSC Small standards require farmers to fulfill its core and 80% of all its non-core requirements. Therefore it was assumed that core and non-core requirements need to be fulfilled immediately for standard-compliance.
[b] The RSPO ISP standard is based on a stepwise process from meeting Eligibility to Milestone A to Milestone B requirements. For this reason, Milestone B was the only requirement assumed to be required for standard compliance.

All the AVSS examined have their own way of conveying how fast their production criteria must be implemented to become and remain standard compliant (see Table 5). The BCI is comprised of core and improvement indicators which must be met to respectively become BCI verified and meet continuous improvement expectation over time (Better Cotton Initiative, 2018). The Bonsucro general and smallholders standards are comprised of core and non-core requirements with all core requirements and 80% of all requirements (core and non-core) to be met to obtain certification (Bonsucro, 2016, 2018). An action plan must be prepared for all non-core requirements that are not met to identify areas for continuous improvement. The Fairtrade International Smallholder Producer Organization and Hired Labour standards are comprised of core and development requirements (Fairtrade International, 2014a, 2019). All core requirements must be met and a minimum score on the development requirements must be achieved to become Fairtrade certified. The LEAF standard is comprised Essential control point which must be met to become certified and Recommended control points (Linking Farming and Environment, 2019). The Rainforest Alliance is comprised of core, mandatory and self-selected improvement requirements (Rainforest Alliance, 2020). Core requirements must be met to become certified while mandatory requirements need to be met either within 3 or 6 year to remain certified (Rainforest Alliance, 2020). In addition to these, mandatory requirements based on smart meters are monitored annually for continuous improvement (Rainforest Alliance, 2020). Lastly, self-selected improvements are optional and are measured either as pass or fail or monitored for improvement over time (Rainforest Alliance, 2020). The RSB general standard is comprised of minimum and progress requirement which must be respectively met immediately and over time while the RSB smallholder standard is comprised of production criteria that must be met immediately, within 1, 2, and 3 years to become and remain standard compliant (Roundtable for Sustainable Biomaterials, 2016a, 2016a). The RSPO general standards is comprised of critical which must be met immediately and non-critical indicators which must be met within one year of being certified (Roundtable on Sustainable Palm Oil, 2018). Certificate holders must fulfill all critical indicators to remain compliant while non-critical indicators must be addressed before subsequent annual surveillance audits to avoid losing certification (Roundtable on Sustainable Palm Oil, 2020). The RSPO independent smallholder standard is comprised of Eligibility (to be met right away), Milestone A (to be met within 2 years of becoming eligible) and Milestone B (to be met within 3 years of becoming eligible) indicators which must be met to become certified (Roundtable on Sustainable Palm Oil, 2019).

The ISEAL Alliance encourages AVSS benchmarking efforts to examine more than AVSS production criteria to get a more holistic perspective on the characteristics of AVSS. Examining other AVSS characteristics such as assurance and chain of custody systems could have revealed other ways in which AVSS affect farming resilience offering opportunities for further research. Nevertheless, focusing on production criteria was appropriate to examine how AVSS are most likely to directly affect farming resilience. Furthermore, the benchmarking exercise undertaken focussed on operationalizing the AVSS resilience analytical framework as opposed to comparing AVSS, where establishing a more holistic understanding of their similarities and differences becomes more important. Furthermore, AVSS interact with various parts of agricultural supply chains which could indirectly affect farming resilience. For instance, providing a platform for supply chain actors to address sustainability challenges can improve farming resilience. Nevertheless, examining the potential for AVSS to indirectly enable farming resilience was beyond the scope of this dissertation which focused on better understanding how AVSS are directly affecting farming resilience.

Benchmarking is invariably a subjective process which can be more rigorous by incorporating multiple perspectives. For this analysis, the AVSS production criteria was examined primarily from the perspective of the author of this dissertation. To address the subjective limitation of the analysis, the results found to be questionable were tracked and a subset of the results obtained were assessing for replicability. A randomly selected sample of the AVSS indicators were also benchmarked by a qualified individual with expertise in VSS. The limited number of perspectives used to conduct the assessment can be seen as problematic since both the AVSS criteria and resilience indicators examined can be broadly interpreted. For example, banning pesticides can be viewed by some as limiting farmer options to deal with pests, while it may be viewed by others as important to prevent negative ecological impacts. Nevertheless, mapping the AVSS production criteria to the resilience indicators was a valuable exercise to test the AVSS resilience analytical framework and provide a basis to identify AVSS design strengths and weaknesses for enabling farming resilience. Future benchmarking efforts could be further refined and improved by integrating additional perspectives to strengthen the analysis.

Overall the benchmarking effort aimed to identify opportunities for designing AVSS production criteria to build farming resilience. Although AVSS have been benchmarked in many different ways by numerous organizations, benchmarking AVSS production criteria to farming system resilience indicators studies have yet to be published (International Trade Centre, 2019). For this reason, the analysis contributes to building knowledge by providing AVSS design insights and considerations for building the general resilience of farming systems which could assist standard setting bodies achieve their sustainability objectives.

3.2.2 Case Study – The Better Cotton Initiative in the Adoni Mandal

To address Sub-Question 2: *How is the implementation of AVSS affecting the general resilience of farming systems?*, a single exploratory case study was undertaken since the implementation of AVSS and its effects on farming resilience is best observed within a specific context. A case study is a suitable research method for generating insights related to contemporary events where understanding processes unfolding over time (typically in the present and recent past) is of primary importance (Yin, 2018). In other words, case studies allow for investigating specific events in context, which is especially useful when a phenomenon of interest (the effects of an implemented AVSS on farming resilience) is entangled with its context (the farming system). For this research dissertation, a single case was undertaken to explore in detail the operationalization of the AVSS resilience analytical framework. Thus, the case study undertaken can be considered a critical case as it consists of testing the AVSS resilience analytical framework in a specific context. Critical cases are used to test theoretical propositions (AVSS resilience analytical framework) with a clear set of circumstances (implementation of AVSS in farming systems) (Yin, 2018). The case study undertaken is also revelatory as exploring how an implemented AVSS affects the general resilience of farming systems in a specific context has yet to be published (Yin, 2018). Although multiple case designs can provide more defensible findings compared to single case designs, going into more depth within a single case as opposed to generating replicable findings better served the research objectives - to develop and test an analytical framework for examining the farming resilience effects of AVSS.

The case study selection was limited to the AVSS benchmarked so that its research findings could inform the case study. The implementation of the BCI program among cotton farmers in the Adoni Mandal in the State of Andhra Pradesh, India was selected as the case study since it is a context where resilience building interventions could have significant effects. Cotton grown in the Adoni Mandal is primarily rain fed and cultivated by smallholder farmers which are typically vulnerable to shocks and stresses. The Adoni Mandal is located in an arid to semi-arid part of India which is regularly affected by a lack of precipitation and droughts (ETV Andhra Pradesh, 2015; Hans India, 2015; Special Correspondent, 2017; Sudhakar, 2019, 2021). The BCI standard has production criteria focused on water conservation and its implementation should in theory affect the resilience of cotton farmers in the study area (Better Cotton Initiative, 2018). The case study was also selected to leverage the published findings of a random control trial (RCT) conducted between 2015 and 2018 to measure the sustainability impacts of the BCI program in the Adoni Mandal.[18] RCTs are one of the most rigorous approaches to determine the effects of an intervention on an outcome (Hariton & Locascio, 2018). The RCT was conducted during the same time period and in some of the same villages examined as part of this research, thus providing information to compare, contrast and discuss the findings generated to answer the research questions of this dissertation.

Located in the Southwest part of the State of Andhra Pradesh in India, the Adoni Mandal is a subdivision of the Kurnool District spanning 53,219 hectares. It is comprised of the Town of Adoni, 41 villages and 36,026 households, where approximately 250,000 people reside (Directorate of Census Operations Andhra Pradesh, 2011; Kumar et al., 2019a) (see Figure 6). Literacy levels are approximately 60% among men and 43% among women (Kumar et al., 2019a). Agricultural production is the main form of livelihood supported by suitable soils (mostly black soils – 21 villages, mostly red soils – 12 villages and mostly mixed soils - 9 villages) and temperatures ranging from 31 to 45 ºC in the summer and 21 to 29 ºC in the winter (Kumar et al., 2019a). In recent years, agriculture has been plagued by a lack rainfall with only 2% of households having reliable irrigation (Kumar et al., 2019a). The main cash crops grown in the Mandal include cotton, chilli and groundnuts (Tirupati Central Excise, Undated). Approximately 18,000 farmers grow cotton, out of which 39% are smallholders cultivating less than 2 hectares (Kumar et al., 2019a). The majority of cotton farmers in the Adoni Mandal grow genetically modified cotton (soil bacterium Bacillus thuringiensis - Bt cotton) which they report has increased yields and production costs leading to indebtedness during poor harvest seasons (Farmer Focus Groups, personal communication, March

[18] The RCT consisted of a baseline, midline and endline farming household survey designed and implemented by a consortium of research institutions led by the Natural Resource Institute at the University of Greenwich and administered by ISEAL funded by the Ford Foundation (Kumar et al., 2019a).

2016; Kumar et al., 2019a). The cotton grown in the Mandal is primarily destined to ginning facilities in the City of Adoni that supply spinning mills in the State of Tamil Nadu (Kumar et al., 2019a). The main challenges faced by cotton farmers in the Adoni Mandal includes unfavourable weather, access to land and irrigation, pest outbreaks, access to finance and high input costs (Kumar et al., 2019a).

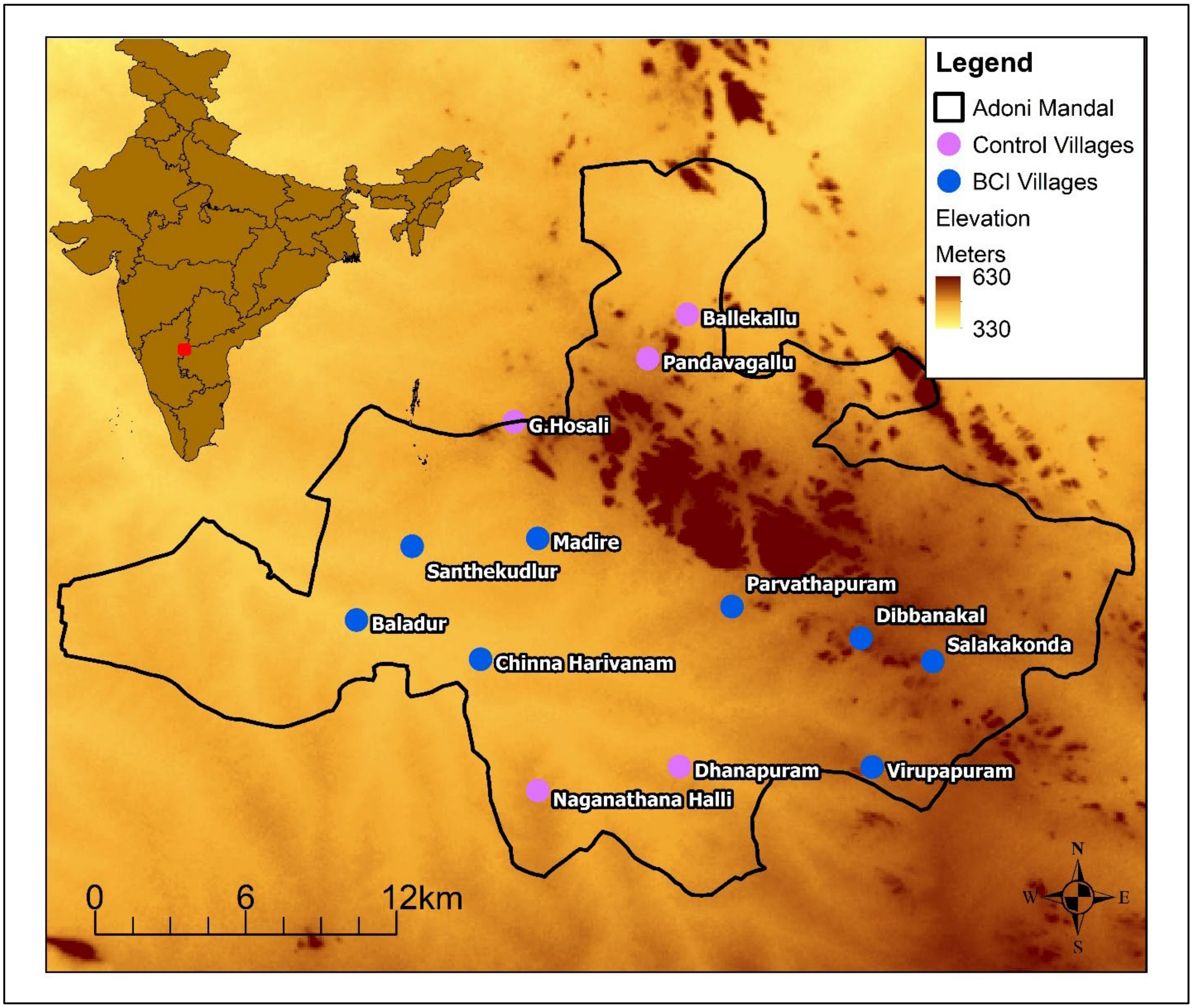

Figure 6 – The Adoni Mandal in the District of Kurnool of the State of Andhra Pradesh, India

The Better Cotton Initiative, established in 2005, has become the largest voluntary sustainability standard operating in the cotton sector (Better Cotton Initiative, n.d.-b; Willer et al., 2019). The BCI program is present in 21 countries and approximately 2.3 million farmers produced

5.6 million tonnes of BCI-verified cotton in the 2018-2019 production season (Better Cotton Initiative, n.d.-a). The latest version of the standard, implemented March 1st of 2019, is comprised of 7 Principles primarily oriented towards addressing environmental and social sustainability challenges in the cotton sector (Better Cotton Initiative, 2018).[19] The standard is based on a continuous improvement model where core indicators need to be fulfilled to become BCI-verified while improvement indicators need to be met over time to extend licence periods (Better Cotton Initiative, 2018). Varying measures are required for smallholder, medium and large cotton farms to produce BCI-verified better cotton. The BCI standard has had a significant footprint in the cotton sector as a little over 20% of all global cotton was BCI-verified in 2019, produced by approximately 2.3 million farmers (Better Cotton Initiative, 2020). The BCI program has been active in India since 2010 and started actively working to expand its programme in the State of Andhra Pradesh in 2013 (Better Cotton Initiative, n.d.-b; Participatory Rural Development Initiatives Society, 2014a). To do so, it partnered with the Participatory Rural Development Initiatives Society (PRDIS) in 2013 which started working to build the capacity of farmers in the District of Guntur in 2014 (Participatory Rural Development Initiatives Society, 2014a). The PRDIS has since expanded its capacity building efforts for adopting the BCI standard within the District of Kurnool in 2015 where it has been working to train approximately 3000 farmers to become BCI-verified by 2018 (Participatory Rural Development Initiatives Society, 2014a).

A mixed methods approach was selected to undertake the case study which is compatible with a single case study design since it requires the integration of varied methods to address complex research questions (Yin, 2018). It also follows Meuwissen et al. (2019) who applied their farming system resilience assessment framework by using quantitative (statistics, econometrics and modeling)

[19] The 7 principles of the BCI standard include production requirements related to crop protection, water stewardship, soil health, biodiversity enhancement and responsible land use, fibre quality, decent work and effective management (Better Cotton Initiative, 2018).

and qualitative methods (interviews, participatory approaches and workshops) to assess for resilience in eleven farming systems in Europe. More specifically, the case study first consisted of collecting qualitative information from farmer focus group discussions which provided guidance for undertaking a farming survey and a relational survey to examine how the implementation of the BCI program is affecting the general resilience of cotton farming in the study area. The farming survey allowed for ascertaining the resilience threat, coping strategy and farming practice differences between farmers that are and are not participating in the BCI program, while the relational survey provided information to examine how the BCI program is potentially affecting resilience collaborations among organizational networks working on water and food security in the Adoni Mandal.

3.2.2.1 Farmer Focus Groups

A total of 10 farmer focus group discussions were undertaken to better understand the context in which the BCI program was being implemented. The farmers interviewed within each village were consistently asked to share information on farming contexts, challenges and coping strategies. For example, the farmers were asked what crops they cultivate, if they have access to the lower level canal for irrigation, if they face water shortages and how they cope with them. The qualitative information collected provided context to better understand the case study and orient the farming and organizational relational surveying efforts. It also provided additional information to support or contradict research findings.

The villages where the farmer focus group discussions were held aligned with the ones being sampled as part of an RCT oriented to measure the sustainability impacts of the BCI program implemented by a consortium of research institutions led by the Natural Resource Institute at the University of Greenwich (Kumar et al., 2019a). At the time of the farmer group discussions the BCI program was being implemented in five of the ten villages that were visited. Farmers were randomly approached and tracking the exact number of farmers who participated in the discussion groups was challenging as people joined and left organically during the discussions. Nonetheless 2 to 8 farmers participated per discussion group and consent forms were collected from farmers that stayed till the end of the conversations.

The qualitative data collected was then transcribed and reviewed to identify information that can be compared and contrasted with the research findings generated from the other methods used in the case study. The qualitative information collected was primarily examined to identify the main threats to and coping strategies of cotton farmers to better understand the farming resilience dynamics in the Adoni Mandal. The information shared provided insights to better understand the socio-cultural context of cotton farming in the study area to frame the application of the AVSS resilience analytical framework.

3.2.2.2 Better Cotton Initiative Training Effectiveness

One of the main pathways by which the BCI program can build farming resilience is via its training efforts which focuses on building the capacity of cotton farmers to adopt more sustainable cultivation and business practices to become BCI verified cotton farmers. For this reason, a farming survey was conducted to examine the training effectiveness of the BCI program by determining training attendance and willingness to implement the lessons learned and comparing farming practices of farmers that are and are not participating in the BCI program. This allowed for ascertaining to what extent the BCI program is affecting the resilience of their participating farmers (treatment group) compared to a counterfactual (control group).

It is worth noting that the analysis undertaken provided two distinct means to ascertain how the implementation of the BCI program is affecting the resilience of cotton farmers in the Adoni

Mandal. The first is associated with the implementation of the BCI program, via their training efforts, for the adoption of the standard and the second is the implementation of the BCI standard by cotton farmers, reflected by farming practices adopted to cultivate cotton. The analysis also required ascertaining how the various farming practices that were surveyed could support the farming resilience indicators of the AVSS resilience analytical framework. In this way, the farming survey and analysis provided a means to examine the effectiveness of the BCI training, which is clearly linked to the continuous capacity building indicator of the framework, as well as various other aspects of the AVSS resilience analytical framework such as preserving the growing environment and recording the farming operation.

Farming surveys are commonly used to assess the sustainability impacts of AVSS by NGOs and academia (Committee on Sustainability Assessments, 2013; DeFries et al., 2017; Iddrisu et al., 2020; Kumar et al., 2019a). Furthermore, survey methods and surveying have a long history of being used in agriculture to report various national statistics which are collected and housed on online global databases such as FAOSTAT. Surveying farmers directly allowed for collecting current quantitative and qualitative information on the various aspects of their farming operations. Collecting perspectives from various farmers allowed for a collective picture to emerge to address the dissertation research questions.

The farming survey was conducted by 23 surveyors, from June 5th to 16th 2017, 2 years into the 3-year BCI program which commenced the summer of 2015. The surveyors used a random and snowball sampling approach to survey 970 cotton farmers in 8 Adoni Mandal villages.[20] Farmers who did <u>not</u> participate in a BCI learning group or training sessions made up the control group (765 surveys) and the balance made up the treatment group (205 surveys). The survey tool, designed to be

[20] An opportunistic surveying approach was used by the surveyors who randomly approached prospective respondents who recommended other prospective farmers to survey.

completed in 45 minutes, was comprised of questions on household and farm profiles, information accessed, training received, cultivation practices, resilience threats and coping strategies (see Appendix 2 – Farming Survey Tool). The survey tool was adapted from surveys compiled by the University of Greenwich – Natural Resources Institute (NRI) and the Committee for Sustainability Assessment (COSA) since they were respectively designed to examine the sustainability impacts of the BCI program in the study area and provide a standardized way to assess farming sustainability and ascertain adaptation to resilience threats (Committee on Sustainability Assessments, 2013; Kumar et al., 2019a; Serfilippi & Ramnath, 2018).[21] The responses were collected on paper and entered into a database via an online Qualtrics questionnaire.[22] Consent forms were obtained from the respondents allowing for the anonymous use of the information shared.

The survey data collected was then cleaned and formatted for conducting descriptive statistics and a propensity score matching (PSM)[23] analysis on the training, cultivation practices and resilience sections of the survey. The data cleaning and formatting step consisted of eliminating surveys with insufficient data, correcting for data inconsistencies between questions and coding the responses so they can be processed with the STATA psmatch2 statistical software package.[24] The data analysis steps consisted of examining training effectiveness and differences in resilience threats, coping strategies and cultivation practices between the treatment and control groups using descriptive statistics and kernel matching to assess the effectiveness of the BCI program in building farming

[21] Questions from the COSA survey were modified to be relevant for cotton cultivation in the Adoni Mandal while questions from the NRI survey were simplified and incorporated, yielding a significantly different survey tool oriented towards assessing the sustainability and resilience of cotton farming in the study area.
[22] Qualtrics is an online platform used to design survey tools, collect, store and analyze information (Qualtrics, 2021).
[23] PSM is a statistical approach which consists of matching control and treatment group subjects based on covariates, variables forming the basis for the matching process, and then comparing the pairs established to identify distinctions (Austin, 2011). In the case of the household survey, PSM allowed for comparing farming practices, resilience threats and coping strategies of similar farmers in the control and treatment group based on a set of household and farm characteristics (covariates).
[24] "Stata is a statistical package for managing, analyzing, and graphing data" (Stata, n.d.). The psmatch2 routine runs on STATA and implements propensity score matching methods to account for differences between treatment and control groups (Leuven & Sianesi, 2003).

resilience. The resilience threats and coping strategies adopted by matched control and treatment farmers were first examined to provide additional context on the resilience challenges of cotton farming in the study area. Descriptive statistics were then used to ascertain training effectiveness by examining attendance and willingness to implement lessons learned across 11 training topics. Differences in farming practices associated with specific training topics were then examined between matched treatment and control farmers (see Figure 7). For instance, the pest management practices of farmers who attended BCI pest management training were compared to farmers who did not to determine if the BCI program is building farming resilience.

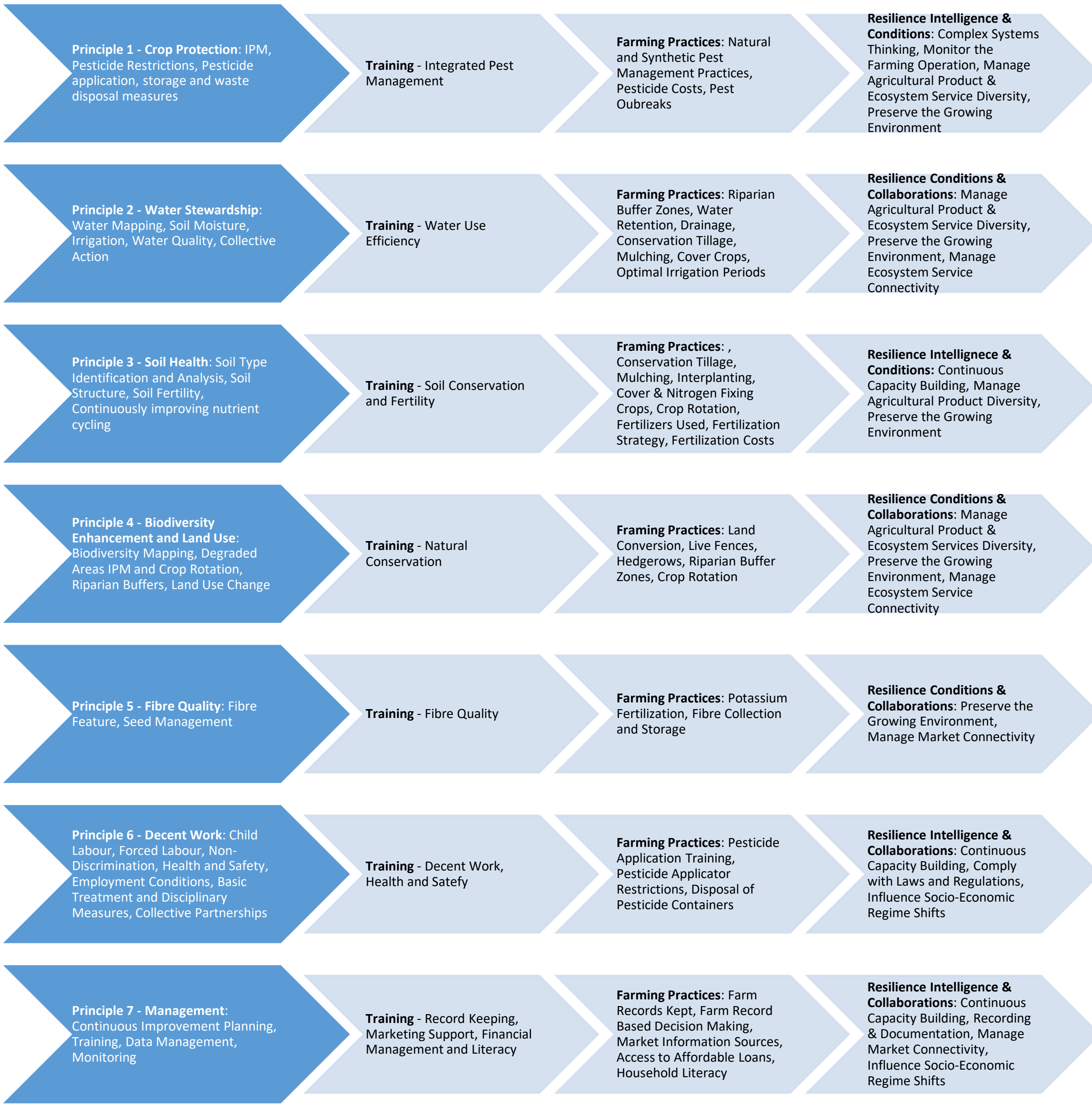

Figure 7 – The BCI program impact pathways in the Adoni Mandal

As the household survey information was collected in a non-randomized fashion, it is considered non-experimental observational data which can be assessed using stratification, regression models and matching methods. PSM was selected as a suitable matching method for the analysis since stratification would have limited the sample number within each strata and regression models with many covariates would have likely violated model assumptions such as linearity

(Chiuzan, 2018). Furthermore, PSM was used instead of other matching methods, such as Mahalanobis distance matching or coarsened exact matching, as it approximates complete randomization enabling closer comparisons with the RCT conducted by the University of Greenwich Natural Resource Institute (Jann, 2017; King & Nielsen, 2019; Kuss et al., 2016).

The steps in conducting the PSM analysis can be described as selecting a distance calculation algorithm and covariates to generate the propensity scores, selecting a matching algorithm to compare similar treatment and control samples, assessing the matching quality and examining the outcome variables of the post-matched treatment and control groups (Austin, 2011; Caliendo & Kopeinig, 2008; Chiuzan, 2018; Stuart, 2010). A logit model was selected to calculate the propensity scores of the covariates as it is suitable for examining the relationship between covariates (predictor variables) and binary outcomes (participating in the BCI program) (Ranganathan et al., 2017). The covariate selection was primarily based on field experience and observations in the study area. Out of a possible 28 covariates 14 were selected for the PSM (see Appendix 2 – Covariate Selection and Propensity Score Matching). Kernel matching was used as the matching algorithm which allowed for taking into account King and Nielsen's (2019) warnings about using PSM and Jann's (2017) rebuttal specifying under what conditions PSM can be used to provide acceptable results. Good balancing statistics were obtained using kernel matching which uses all the control cases to generate an aggregate control unit for each treatment unit (see Appendix 2 – Covariate Selection and Propensity Score Matching). A total of 10 treatment farmers were eliminated from the dataset due to a lack of information related to the data collected of interest and to ensure that male farmers were not compared to female farmers. Difference in means between matched treatment and control farmers implementing specific farming practices were then examined and assessed for statistical significance. Difference in the top three most important resilience threats and coping strategies between the matched treatment and control groups were also examined. The differences examined allowed for understanding to what extent the BCI program is affecting the general resilience of cotton farming operations in the Adoni Mandal and generate insights on how they could be implemented to build farming resilience.

The farming survey was conducted in eight villages of the Adoni Mandal where the BCI program is being implemented. The sampling strategy focused on surveying treatment and control farmers in each village to derive statistically significant differences between sample groups. The treatment and control farmers were determined by their participation in BCI learning groups or training sessions.[25] Nevertheless, the matching process ultimately focused on matching treatment farmers that attended specific training sessions with control farmers. Focusing the sampling strategy on surveying a sufficient number of farmers attending specific training sessions could have yielded more robust results especially for training sessions that seemed poorly attended. Despite this sampling and analysis misalignment, the method adopted was robust as it provided a means to compare matched sample groups along specific household and farm characteristics. A more rigorous and ambitious approach to the farming survey would have required sampling a greater number of treatment and control farmers within each village to enable a stratified assessment per village and training session which could have improved the matching process and overall assessment of the farmers compared. Nevertheless, the matching effort focused on testing the AVSS resilience analytical framework as opposed to deriving a statistical model that could be applied to other contexts. Some level of causality was examined by comparing differences in farming practice linked to specific training topics between farmers that are and are not participating in the BCI program.

3.2.2.3 Organizational Network Analysis

[25] A total of 970 farmers were surveyed – 765 farmers (control group) that did not participate in a BCI learning group or training session (control group) and 205 farmers (treatment group) that did.

A network analysis of the organizations working on water and food security in the Adoni Mandal was undertaken to examine how the BCI program is affecting farming resilience by enabling connectivity and engagement with governance structures. Water security was identified as the main resilience threat to cotton farming in the Adoni Mandal (Farmer Focus Groups, personal communication, March 2016). Food security in the study area goes hand in hand with water security as crop losses directly affect the ability of farming households to meet their nutritional requirements (Farmer Focus Groups, personal communication, March 2016). Furthermore, the BCI standard requires engagement in collective action for sustainable water use.[26] Consequently, focusing on organizational networks involved in enabling water and food security in the Adoni Mandal is relevant and appropriate to test the resilience collaborations dimension of the AVSS resilience analytical framework as it focuses on organizational collaborations associated with the main resilience threats facing cotton farmers in the study area and is relevant for meeting the BCI standard requirements. More specifically, the network analysis allowed for ascertaining the extent to which the BCI is indirectly enabling cotton farmers to engage with external stakeholders and governance structures working on water and food security in the Adoni Mandal.

Social network analysis was chosen as a suitable approach to examine the role that the BCI program is having in enabling engagement with organizations working on water and food security in the study area as it can provide a more holistic picture of how organizations are positioned in a network to enable resilience (Bodin & Crona, 2009; Janssen et al., 2006). Furthermore, social network analysis goes beyond examining direct relationships between organizations providing a means to assess the structural characteristics in which these relationships take place, which can also

[26] The Better Cotton Initiative requires smallholder, medium and large cotton farms to adhere to develop a Water Stewardship Plan which requires "Engaging in collaboration and collective action to promote sustainable water use" (Better Cotton Initiative, 2018, p. 35).

provide valuable insights on the effectiveness of organizational networks to enable resilience (Bodin & Crona, 2009; Janssen et al., 2006). Social network analysis is still a nascent field in resilience research and this analysis makes a contribution by leveraging relational information to build networks and provide insights on organizational network structures and nodal network positioning to assess farming resilience (Biggs et al., 2015; Rocha, 2020; Rockenbauch & Sakdapolrak, 2017; Wilkin et al., 2019).

A relational survey was first conducted and the sampling approach was limited to surveying state level organizations as national organizations were deemed too far removed from village level interventions.[27] This sampling approach was deemed reasonable as only one national government agency involved in water and food security in the Adoni Mandal was identified by the respondents surveyed. State and District government agencies involved in water and food security were determined by visiting websites, while Mandal government agencies and Village leadership were identified by speaking with local officials. The NGOs surveyed were selected based on whether they have worked on water and food security in the Adoni Mandal. A total of 44 relational surveys were conducted with individuals representing government agencies and NGOs targeted as part of the sampling strategy. All relational surveys were conducted with a native Telugu speaker to interact, as required, with the interviewees in the local language. The surveys were conducted one on one and via a group session in five primary locations, Hyderabad, Vijayawada, City of Kurnool and City of Adoni. The respondents were requested to list the organizations that their organization interacts with on specific aspects of water and food security and provide relevant qualitative information (see Appendix 3 – Relational Survey Tool).[28] Using the recall (respondents generate a list of

[27] Indian government jurisdictions consisted of National, State, District, Mandal and Village levels when the relational survey was conducted in 2017.
[28] The survey tool was inspired by a relational survey designed by the Fisheries Centre of the University of British Columbia and the Stockholm Resilience Centre at the University of Stockholm to examine interconnections between

organizational connections) as opposed to the recognition method (respondents select organizational connections from an existing list) allowed for identifying stronger and more influential organizational connections since this method typically elicits the most frequent, intense and recent interactions (Crona & Bodin, 2011). Although all targeted entities could not be surveyed, the relational information collected was sufficient to provide insights on how the BCI program may be affecting the connectivity of cotton farmers with organizations working on water and food security in the study area.

The information collected was then analyzed to determine how the Participatory Rural Development Initiatives Society (PRDIS), the BCI program implementing partner in the Adoni Mandal, is positioned in the water and food security organizational networks relative to the other organizations surveyed and if there are connectivity differences between farming villages surveyed that are and are not participating in the BCI program.[29] The relational data was first cleaned and used to construct two organizational weighted and unweighted networks. The number of water and food security aspects that organizations collaborate on provided a means to compile weighted organizational networks to examine potential for enabling multi-jurisdictional collaborations. Unweighted and undirected networks were then compiled to examine the network structure, communities and node characteristics of organizations working on water and food security in the Adoni Mandal.

organizations involved in the governance of fisheries, how important these organizations are to one another and what they cooperate on.

[29] The PRDIS is a Non-Government Organization that has been working in various parts of the State of Andhra Pradesh since 1999. For this reason, the PRDIS likely had connections with various relevant state and district government agencies before implementing the BCI program in the Adoni Mandal. Nevertheless, a review of 51 projects they completed published on their website revealed that they never worked in the Adoni Mandal prior to offering their services for the BCI program in the study area (only 10 projects were explicitly conducted in the State of Andhra Pradesh) (Participatory Rural Development Initiatives Society, 2014b). Furthermore, the PRDIS representatives surveyed as part of the relational survey indicated that the PRDIS has never operated in the area prior to their work with the BCI (P. Singh, personal communication, October 23, 2017)

The data cleaning step consisted of aggregating information, merging duplicative surveys, eliminating self-referential and vague entries and adding data where needed. Inconsistent references to the same organizations arose from asking respondents to generate their own list of organizations. Information collected from the Mandal Agriculture Office, Mandal Agriculture Extension Office, the PRDIS and 5 villages from different individuals were merged.[30] Eliminating self-referential and vague information was necessary to remove self-ties and non-identifiable organizations. Where organizational relationships were identified in broad terms (i.e., all villages or state level departments), they were disaggregated into individual organizations. For organizations that were entered using general terms such as "agricultural department" or "animal husbandry", relational information entered in other parts of the survey (see Question 1 in Appendix 3 – Relational Survey Tool) was examined to identify the jurisdictional level that these entries were most likely referring to. Relations were added where it logically made sense to do so. For instance, it was assumed that all villages that have access to the lower level canal, the main source of irrigation water in the Mandal, were connected to the District Irrigation Department responsible for managing the lower the level canal.

The water and food security weighted and unweighted networks were constructed.[31] The weighted networks were compiled to examine the tie composition of each node, which was categorized into 14 network actor categories, to determine how the BCI program is enabling connectivity across different jurisdictional levels compared to the other organizations in the network. Unweighted and undirected networks were then compiled to examine the network

[30] A relational survey was conducted at the village level, where possible, with the elected Sar Panch and an appointed Panchayat Secretary, who assume political and administrative roles respectively, to ensure that a more comprehensive assessment of the village leadership was obtained. The Sar Panch and Panchayat Secretary were surveyed for 5 out of 13 villages surveyed.

[31] The networks were constructed using Gephi which is "an open-source software for network visualization and analysis. It helps data analysts to intuitively reveal patterns and trends, highlight outliers and tells stories with their data" (Gephi, 2017).

structure which consisted of calculating network density and degree and identifying communities (degree and betweenness centrality) to examine the role of specific organizations within the networks for enabling water and food security (see Table 6). These steps allowed for examining how the potential network function and positioning of the PRDIS, the implementing partner of the BCI program in the study area, compares with the potential network function and positioning of the Krishi Vigyan Kendra (KVK) and the Resilience Foundation (RF), two NGOs with similar mandates operating in the Adoni Mandal. It also allowed for comparing the potential network function and positioning of village leadership where the BCI program is and is not being implemented by comparing their average node level metrics. This comparison was undertaken by including and excluding the PRDIS from the water and food security networks to determine the influence of the BCI program on the network function and positioning of the village leadership that were surveyed. The analysis provides a means to examine how the BCI program is affecting the engagement with external stakeholders and governance entities indicator of the AVSS resilience analytical framework.

Table 6 – Network metrics used to examine the water and food security networks

Network Metric	Measurement	Significance for Resilience
Network Density	Reflects how connected the nodes of a network are to each other. A network density of 1 indicates that the network is completely connected or that all nodes are connected to each other.	A poorly connected network may result in inefficiencies for dealing with disturbances while a highly connected network may reflect homogeneity both of which can impede resilience.
Network Degree	Reflects the extent to which networks connections are distributed or concentrated across the nodes. A network degree of 1 indicates that the connections are concentrated while 0 indicates that the connections are more evenly distributed (Prell, 2011).	A high network degree indicates that a few nodes in the network as connected while the others are not while a low network degree that the connections are more evenly distributed across the nodes.
Network Communities	Refers to a group of nodes in a network that are more densely connected to each other internally.	Allows for identifying how nodes are likely to coalesce during disturbances and which connections are key to

Network Metric	Measurement	Significance for Resilience
		maintaining connectivity between communities.
Degree Centrality	Measure of a node's direct connections (Rodrigues, 2019). If these connections are directed, the in-degree and out-degree describes the number of incoming and outgoing connections for a given node, respectively.	Nodes with high in-degrees may be sought after for their knowledge and resources to cope with disturbances while nodes with high out-degrees tend to reach out to other actors in the networks (Abid et al., 2017).
Betweenness Centrality	Measure of the shortest paths between two nodes that flow or pass through a given node (Rodrigues, 2019). Nodes with high betweenness centralities can considered gatekeepers as they enable efficient propagation across networks.	Nodes with high betweenness centrality are well positioned for allowing information and resources to propagate across networks and prevent the spread of disturbances across networks (Abid et al., 2017; Biggs et al., 2015).

The methodological limitations of social network analysis span broadly from challenges in establishing appropriate boundaries to losing relational qualitative aspects (Matin et al., 2015; Prell et al., 2011). For example, water and food security touches everyone in the Adoni Mandal and a more complete network of organizations working on these security imperatives could have yielded more insights on how the BCI program is enabling connectivity for water and food security in the study area. Furthermore, individuals were surveyed to identify inter-organizational relationships which reflected one perspective on the connectivity of their organizations. Surveys of individuals representing the same organizations were merged together providing more detailed connectivity information. Data collection challenges in the field also required one on one and a group surveying effort resulting in varying relational data quality. The data collected during the group survey was less detailed than the data collected during the one on one surveys due to language barriers. This required an important data cleaning step and a careful selection of network metrics to keep the assessment insightful and manageable. This analysis consisted of examining 3 network and 2 node level metrics which aligns with published social network analysis resilience assessments which typically focus on a few metrics such as network density, degree centrality and betweenness centrality (Abid et al., 2017; Cadger et al., 2016; Quiédeville et al., 2018; Rockenbauch & Sakdapolrak, 2017; Stein et al., 2011; Wood et al., 2014).

More importantly, the assessment undertaken provides a snapshot at a specific point in time of the organizational water and food security networks in the study area. For this reason, connectivity changes cannot be directly attributed to the implementation of the BCI program in the Adoni Mandal due to potential confounding factors. A longitudinal social network analysis would have yielded more robust insights to examine for causality between the implementation of the BCI program and the connectivity of its participating farmers with organizations working on water and food security (Prell et al., 2011). Nevertheless, the social network analysis allowed for testing the resilience collaborations dimension of the AVSS resilience analytical framework by providing useful quantitative and qualitative information to answer the research questions of this dissertation. Furthermore, some causality may be attributed to the BCI program by comparing the connectivity of villages participating in the BCI program with similar villages that are not as a counterfactual.

4 Designing Agricultural Voluntary Sustainability Standards for Building Resilience

To address Sub-Question 1, *How are AVSS designs affecting the general resilience of farming systems?*, the production criteria of 11 standards from 7 standard setting bodies, that are ISEAL members, were benchmarked against the AVSS resilience analytical framework indicators. This analytical chapter focusses on the average coverage of the resilience indicators across the AVSS examined to identify overall emergent trends (see Section 4.1). To provide a more nuanced understanding of the benchmarking results obtained, the AVSS coverage of farming resilience is also examined qualitatively. The results are then summarized and briefly discussed within the context of rethinking AVSS designs for farming resilience (see Section 4.2).

4.1 Benchmarking Farming Resilience

A total of 350 production criteria and their 1,386 supporting indicators from the following 11 AVSS were examined to determine if they fulfill the 18 indicators of the AVSS resilience analytical framework, yielding 24,948 pieces of analysis (or categorizations): the Better Cotton Initiative (BCI), Bonsucro (BSC for processing, milling and agriculture and BSC Small for smallholders farms), Fairtrade Standard for Small-scale Producer Organizations (FSPO), Fairtrade Standard for Hired Labour (FHL), Linking Environment and Farming (LEAF), Rainforest Alliance (RA), Roundtable for Sustainable Biomaterials (RSB biomass producers and RSB Small for smallholder biomass producers) and Roundtable for Sustainable Palm Oil (RSPO for mill operators and oil palm growers and RSPO ISP for independent smallholders). A set of key questions guided the benchmarking effort which allowed for examining what farming resilience aspects, captured in the AVSS resilience analytical framework, the AVSS production criteria and associated indicators could potentially support if implemented. The benchmarking effort focused strictly on required AVSS production criteria and indicators and did not incorporate recommended measures.

The analysis first examines the stringency of the AVSS production criteria that align with the framework and then qualitatively discusses the adequacies and inadequacies of the AVSS production criteria and indicators in satisfying the elements of the framework. A stringency score was compiled by weighting the AVSS production criteria and indicators based on their expediency with which they need to be fulfilled to become and remain standard compliant (see Table 7). The weighted AVSS production criteria and indicators were used to calculate their relative percentages within each AVSS oriented towards fulfilling the indicators of the AVSS resilience analytical framework. The AVSS production criteria focused on larger farms (medium and large farms) and smallholder farms (small farms) were assessed separately to provide additional insight on how the design of AVSS may be affecting the farming resilience of farmers that are more vulnerable to disturbances (Dixon & Stringer, 2015).

Table 7 – AVSS production criteria indicators categorized by stringency weights

VSS	Mandatory & immediate Weight = 5		Mandatory & within 1 year Weight = 4		Mandatory & within 2 year Weight = 3		Mandatory & within 3 years Weight = 2		Mandatory & more than 3 years Weight = 1		Total	
	Count	Score	Count	Score	Count	Score	Count	Score	Count	Score	Count	Score
BCI	70	350							94	94	164	444
BSC	45	225									45	225
BSC Small	35	175									35	175
FSPO	70	350	24	96			37	74	15	15	146	535
FHL	119	595	30	120			22	44	5	5	176	764
LEAF	233	1165									270	1165
RA	144	720	12	48			28	56	5	5	204	829
RSB	140	700					8	16			149	716
RSB Small	23	115	23	92	6	18	3	6			55	231
RSPO	75	375	87	348							162	723
RSPO	33	165									33	165

VSS	Mandatory & immediate Weight = 5		Mandatory & within 1 year Weight = 4		Mandatory & within 2 year Weight = 3		Mandatory & within 3 years Weight = 2		Mandatory & more than 3 years Weight = 1		Total	
ISP												

To convey the limitations of the benchmarking effort undertaken, results found to be questionable were tracked and a subset of the results obtained were assessing for replicability. A total of 237 out of 1386 AVSS criteria and associated indicators (or 15%) were found to questionably fulfill the indicators of the AVSS resilience analytical framework. To examine the replicability of the results obtained, 155 AVSS criteria and indicators (approximately 11% of the total assessed) were randomly selected and benchmarked against the 18 indicators AVSS resilience analytical framework by a qualified individual with AVSS knowledge. The average replicability obtained across the farming resilience aspects of the framework was 78% ranging from 25% (managing community connectivity) to 99% (managing the diversification of agricultural products and economic activities of the farm), with 15 out of 18 having a replicability of 70% or higher (see Appendix 1). The questionable results tracked and benchmarking replicability assessment convey the limitations of the assessment which are primarily due to its subjective nature.

Nevertheless, the analysis addresses how the AVSS examined could be better designed to build resilience within farming operations by identifying important farming resilience gaps in the AVSS production criteria and indicators. Furthermore, the results from the analysis may be applicable to other AVSS as the ones examined adhere to the ISEAL code of best practices which requires a rigorous standards setting process and staying relevant to address the various dynamic sustainability challenges facing the agricultural sector (ISEAL Alliance, Undatedb).[32] Focusing on

[32] Nevertheless, there were other AVSS that have significant presence in the agricultural sector that could have also been examined to generate further insights. These other AVSS of note include the Organic standard administered by IFOAM, GlobalG.A.P. and Cotton made in Africa.

AVSS that are ISEAL members also provides an opportunity to influence the contents of the standard which must be revised every five years to maintain full member status (ISEAL Alliance, 2014). The analysis is presented in accordance with the resilience intelligence (section 4.1.1), resilience conditions (section 4.1.2), and resilience collaborations (section 4.1.3), dimensions of the AVSS resilience analytical framework.

4.1.1 Resilience Intelligence

The AVSS production criteria that can build resilience intelligence refers to production requirements that can expand an agricultural producer's knowledge base to better deal with disturbances when they are arise. To benchmark the AVSS production criteria against the indicators of the resilience intelligence dimension, key questions were examined to assess whether the production criteria require the development of complex systems thinking, adaptation strategies and targeted experimentation, continuous capacity building, monitoring the growing environment and record keeping, all of which can assist with expanding the breadth and depth of one's knowledge base for farming resilience. Doing so allowed for identifying where there are clear gaps within the production criteria to fulfill the resilience intelligence indicators.

As shown in Figure 8, most of the AVSS examined have almost 10% of their production criteria and indicators oriented towards monitoring the agricultural operation (9.1% of the production criteria reviewed), continuous capacity building (16.1% of the production criteria reviewed) and recording and documenting various aspects of the farming operation (21.0% of the production criteria reviewed). There are less production criteria focused on enabling and requiring complex systems thinking (7.0% of the production criteria reviewed) and even less requiring the development of adaptation strategies (3.9% of the production criteria reviewed). With the exception of the BSC standard, there are no requirements within the other AVSS examined to conduct targeted experiments (0.3% of the production criteria reviewed). The AVSS focused on smallholder farmers have a similar pattern in terms of their production criteria stringency coverage of the resilience intelligence indicators (see Figure 9). Interestingly, a greater percentage of AVSS production criteria and indicators for small farms was focused on developing adaptation strategies compared to the AVSS production criteria and indicators for medium and large farms (4.9% for small farms versus 3.9% for medium and large farms). Adaptation strategies can be especially important for small farming operations with less capacity and resources who may be more vulnerable to disturbances compared to medium and large farming operations.

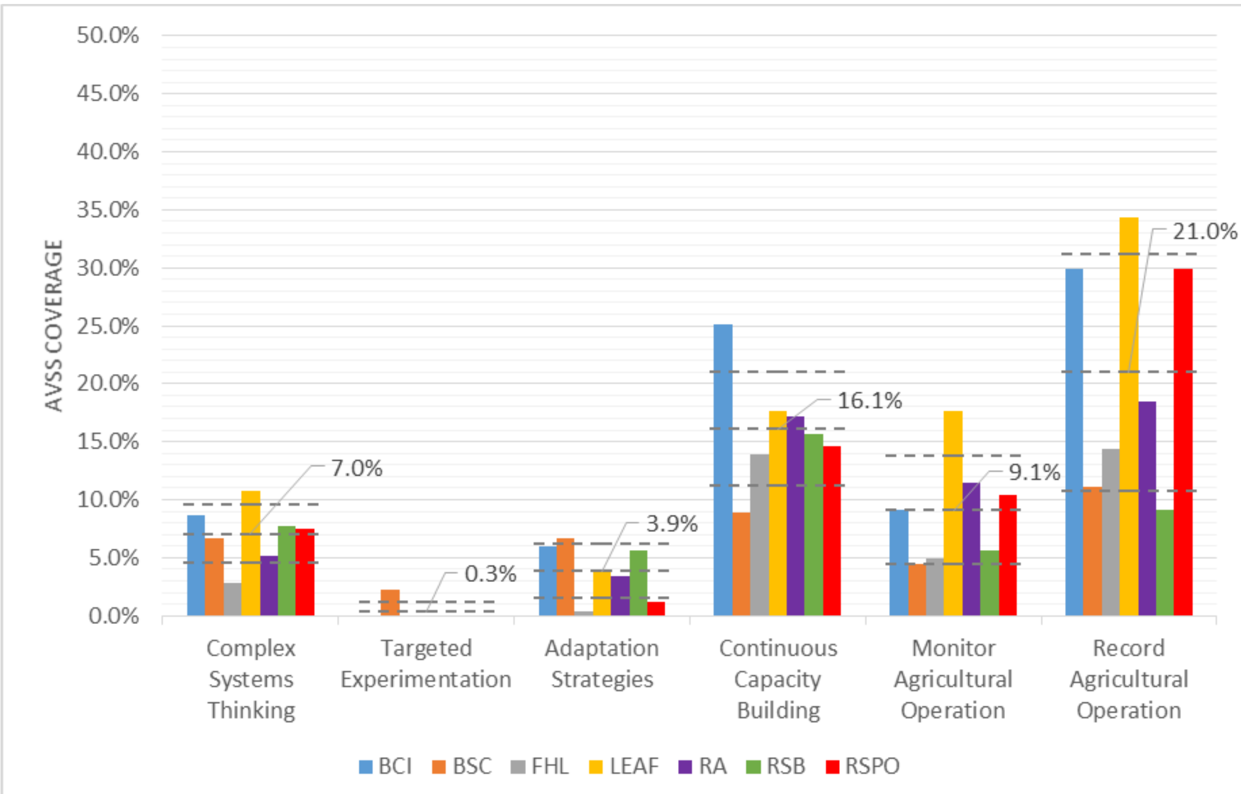

Figure 8 – AVSS production criteria benchmarked against resilience intelligence indicators for medium and large farming operations

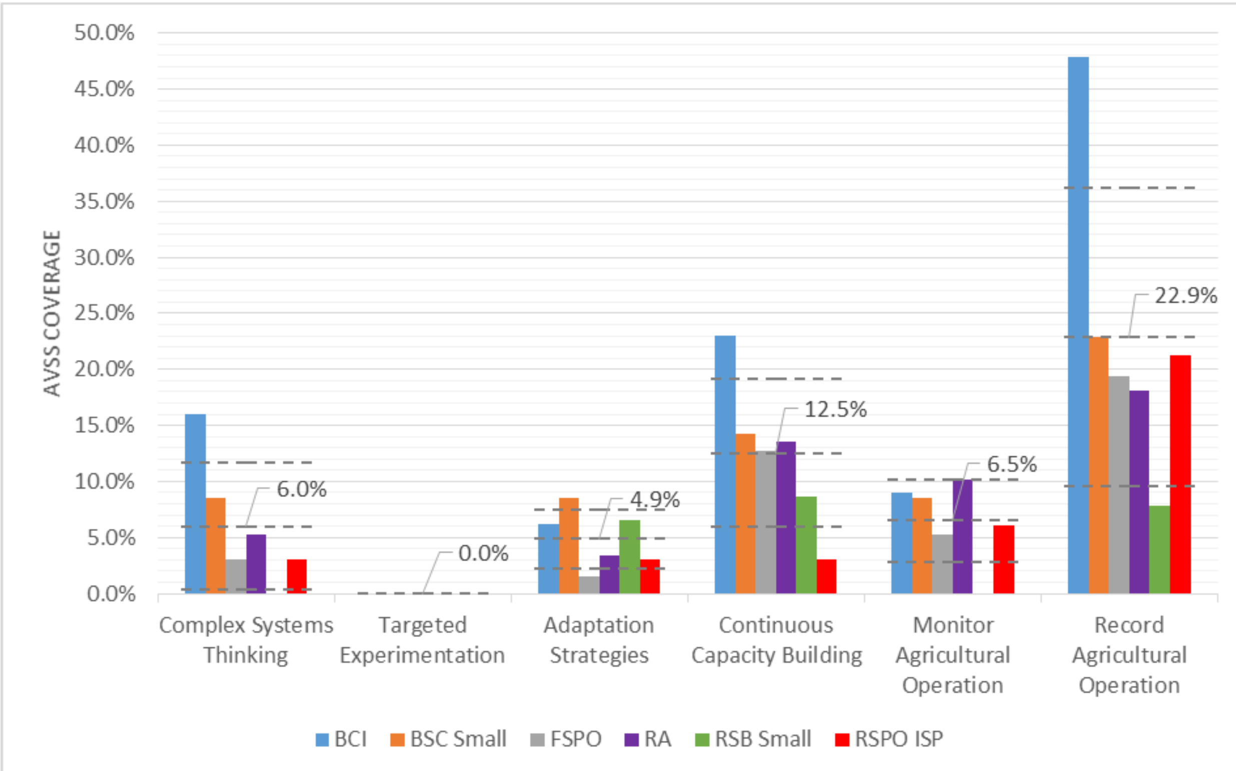

Figure 9 – AVSS production criteria benchmarked against resilience intelligence indicators for small farming operations

All the AVSS examined have production criteria that require developing complex systems thinking by adopting integrated farming practices and generating knowledge on interconnected farming systems. For instance, all the AVSS examined require the implementation of integrated pest management and the LEAF standard requires the adoption of an integrated farm management plan (Linking Farming and Environment, 2019). The BCI, BSC, RSB and RSPO all require socio-ecological management plans to better understand how farming operations are interconnected with their contexts to prevent or minimize negative impacts (Better Cotton Initiative, 2018; Bonsucro, 2016; Roundtable on Sustainable Palm Oil, 2018). More specifically, the RSB standard requires biomass producers to undertake an impact assessment of their activities: "Where specifically stated in a criterion the impact assessment process shall extend beyond the scope of the immediate operational area, for instance for food security, water management and use, ecosystem impacts, biodiversity and conservation" (Roundtable for Sustainable Biomaterials, 2016b, pp. 18–19). The

BSC Small requires that the major environmental issues of the farming operation are covered and addressed in an environmental impact and management plan (Bonsucro, 2018). These measures require farmers to reflect on how their operations are interconnected with their socio-ecological contexts so they can be maintained.

With the exception of the BSC standard, none of the AVSS examined have production criteria that require farming operations to experiment, which can be an important precursor to developing adaptation strategies. The BSC standard has a research and development indicator monitored by research and extension investments as a percent of sales which must be greater than 0.5% (Bonsucro, 2016). AVSS could include requirements for farmers to experiment and build place-based experiential knowledge to ensure that they are making the best decisions to build farming resilience to potential disturbances (Biggs et al., 2015; Chowdhooree, 2019; Ford et al., 2020; Gómez-Baggethun et al., 2012; Kandal et al., 2019; Ladio & Lozada, 2009; Uddin et al., 2020). Nevertheless, this requirement will have to be carefully designed to ensure that it is not too demanding in time and resources for farmers to implement. The adoption of AVSS production criteria can be considered for many farmers experimenting with new production methods.

The BCI and FSPO standards are the only two AVSS examined that address the development of adaptation strategies, which in both cases focus on climate change (Fairtrade International, 2019). The BCI standard requires the development of a water stewardship plan which needs to identify opportunities for climate change adaptation (Better Cotton Initiative, 2018). The FSPO standard has two recommendations that focus specifically on implementing climate change adaptation measures such as installing rainwater collection systems, using soil cover and mulching, planting drought resistant varieties and diversifying crops and improving sustainable production practices which can include climate change adaptation measures (Fairtrade International, 2019). Nevertheless, all the AVSS examined have various farming risk assessment requirements, providing a basis for developing adaptation strategies. For instance, the RA standard has a core requirement to achieve group certification for large farms and group management as well as independent certification for small and large farms to conduct a risk assessment at least every three years (Rainforest Alliance, 2020). With a few exceptions, the AVSS examined do not have explicit requirements for developing adaptation strategies, which are imperative for building resilience intelligence as they focus on being prepared to deal with shocks, disturbances and changes.

Continuous capacity building is manifested in AVSS production criteria by training, awareness raising, knowledge building and continuous improvement requirements. All the AVSS examined require training and awareness raising on various aspects of agricultural operations. For instance, all the AVSS examined require training for handling agro-chemicals and hazardous substances. The RSPO Independent Smallholder standard has the following requirement to raise awareness on various aspects of sustainable oil palm production: "All members attended training and can demonstrate understanding of the ISH Standard, group management and certification requirements including awareness on BMPs, HCV, environmental protection, social welfare of workers and business operations" (Roundtable for Sustainable Palm Oil, 2019, p. 50). The AVSS examined also require farmers to undertake knowledge building activities and continuous improvement efforts such as developing management plans, undertaking risk and impact assessments, resource mapping and measurements, regular reviews and assessments of plans. These training, capacity building and continuous improvement requirements establish an amenable culture to dealing with disturbances (S. Elder, 2021). For instance, VSS-compliant producers in Guatemala, Colombia and Rwanda were perceived as being better able to implement new COVID-19 health measures compared to their counterparts (S. Elder, 2021).

The AVSS examined all require monitoring various aspects of their farming operations. For example, monitoring soil and water resources via regular tests and assessments for timely interventions that can maintain agricultural productivity is required by all the AVSS examined. For instance, the BCI standard requires their farmers to monitor long-term soil nutrition trends, while the RSB standard requires monitoring the effectiveness of water management plans (Better Cotton Initiative, 2018; Roundtable for Sustainable Biomaterials, 2016b). All the AVSS examined require integrated pest management (IPM), which requires monitoring pest and pest predators to allow for timely interventions to prevent pest outbreaks. For instance, the RA has requires small farms seeking to achieve group or independent certification to monitor for pest and their predators as part of implementing IPM measures: "Producers regularly monitor pests and their principal natural enemies" (Rainforest Alliance, 2020, p. 46).

The AVSS reviewed require their participating farmers to document and record various aspects of their farming operations which can be used to support more effective decision-making and to substantiate AVSS compliance and continuous improvement towards more sustainable agriculture. All the AVSS reviewed require documenting various farming activities. For instance, the RA standard requires recording certified sales, employment conditions, wages paid, health and safety incidents, water consumption, soil condition, pesticides purchased and applied, pests, diseases and pest predators, all of which is used to ascertain compliance (Rainforest Alliance, 2020). The RSB smallholder standard requires its members to generate a list of areas within their farming operations that have conservation value (Roundtable for Sustainable Biomaterials, 2016a). Recording farming activities allows farmers to learn from their observations and course correct towards more sustainable outcomes which can assist in building resilience.

With a few exceptions, the AVSS examined do not have direct requirements for experimenting and developing adaptation strategies to build farming resilience. Despite having requirements that can provide building blocks for developing adaptation strategies, such as fostering complex adaptive systems thinking and understanding farming risks, the AVSS examined fall short in directly requiring the development of adaptation strategies which can be especially important for farmers with less capacities and resources to deal with disturbances. Furthermore, establishing AVSS requirements for farmers to experiment can also generate insights for developing adaptation strategies.

4.1.2 Resilience Conditions

The AVSS production criteria that can build resilience conditions of the farm refer to requirements that establish the tangible conditions needed for farming operations to remain resilient to disturbances. The AVSS production criteria against the indicators of the resilience conditions dimension were benchmarked by examining key questions focused on whether the production criteria requires managing the diversification of agricultural products, economic activities and ecosystem services[33] generated by the farm as well as preserving the growing environment, broadening participation in the farming operation and promoting internal governance structures within the farm. Doing so allowed for identifying gaps in the AVSS production criteria to fulfil the resilience conditions indicators.

Figure 10 conveys that most of the AVSS examined have more than 10% of their production criteria and indicators oriented towards managing the ecosystem service diversity supported by the farm (22.3% of the production criteria reviewed) and preserving the growing environment (20.1% of the production criteria reviewed) and broadening participation in the farming activities (13.0% of the production criteria reviewed). There are less AVSS production criteria indicators focused on promoting internal governance structures (6.0% of the production criteria reviewed). Very few AVSS production criteria indicators are oriented towards managing the diversification of agricultural

[33] "Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (Millennium Ecosystem Assessment, 2003, p. 49)."

products (0.5% of the production criteria reviewed) and economic activities (0.7% of the production criteria reviewed) of farming operations. The AVSS production criteria and indicators for small farms had a similar coverage of the resilience conditions indicators (see Figure 11). Despite its potential importance for farming resilience, managing the diversification of agricultural products and economic activities of the farming operation is barely covered by the AVSS examined regardless of farm size (less than 1% - see Figure 10 and Figure 11).

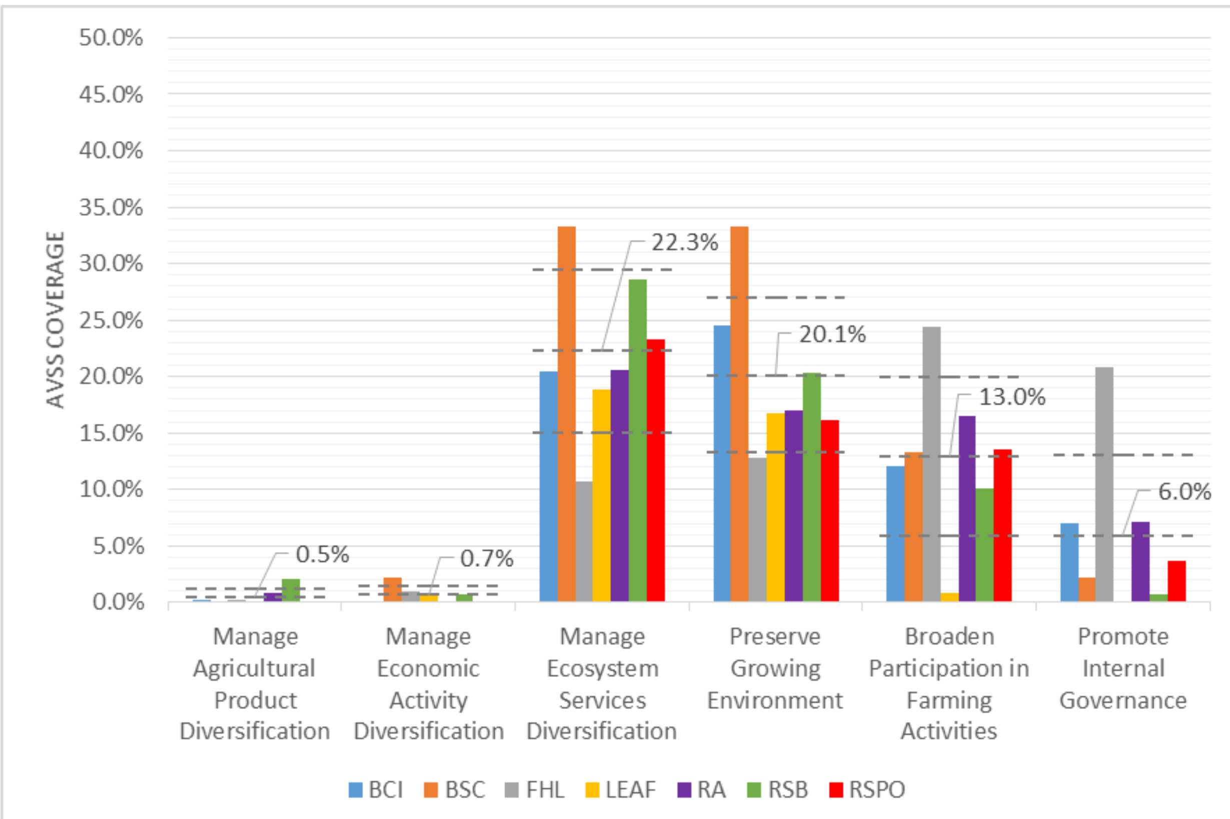

Figure 10 – AVSS production criteria benchmarked against resilience conditions indicators for medium and large farming operations

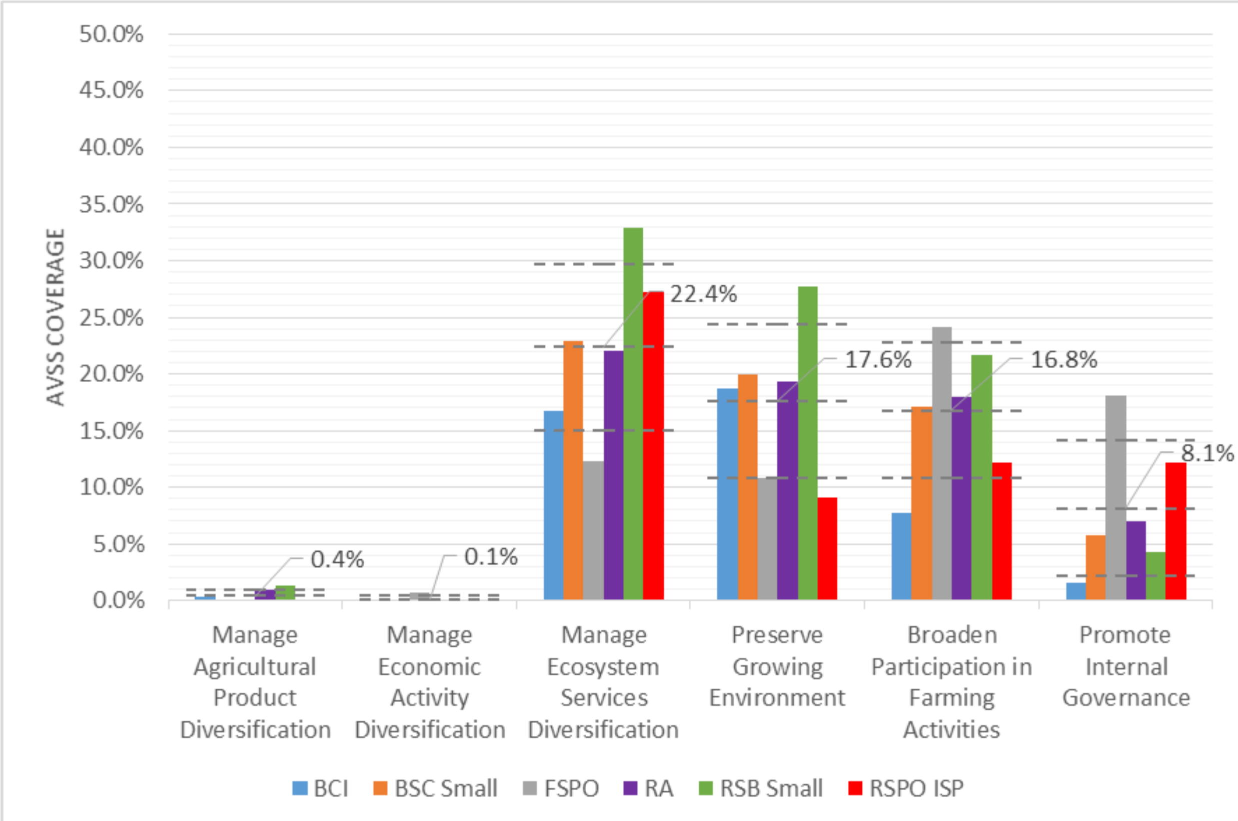

Figure 11 – AVSS production criteria benchmarked against resilience conditions indicators for small farming operations

Very few of the AVSS examined directly require their farming operations to manage the diversification of their agricultural products. This typically occurs as a result of other compatible requirements such as soil conservation measures.[34] The RA standard has the following core requirement to achieve group and independent certification for small and large farms for new plantings: "… have a well-established cropping system which takes into account, requirements of the variety used, geographical, ecological and agronomic conditions, diversification and intercropping crops with different rooting depths and soil uses to enhance soil quality and health and planting density" (Rainforest Alliance, 2020, p. 41). The BCI, FSPO, LEAF, RA, RSB and RSB Small standards require farming operations to adopt crop rotation, cover crops and intercropping to

[34] The three elements of diversity and redundancy consist of 1) variety – number of different crops being cultivated, 2) balance – total number of each different crop plant being cultivated and 3) disparity – how different the different crops being cultivated are (Biggs et al., 2015).

maintain soil health, all of which can diversify agricultural production. The RSB standard requires biomass producers to implement the following practices: "… maintenance of a permanent soil cover, by mulch or growing cover crops to protect the soil surface; Diversifying and fitting crop rotations and associations in the case of annual crops and plant associations in the case of perennial crops (Roundtable for Sustainable Biomaterials, 2016b, p. 66)." There are clear opportunities across the AVSS examined to include more direct requirements for managing agricultural product diversification.

The AVSS that require managing economic diversification are ones that require engaging in economic activities supported by the farm other than agricultural production. For example, agroforestry can provide farmers with economic activity beyond agricultural production in the form of timber and non-timber forest products such as mushrooms, nuts and ornamental products (de Mello et al., 2020). The RA standard recommends small and large farms as well as group management to adopt agroforestry for shade tolerant crops, while the FSPO recommends agroforestry to conserve soils (Fairtrade International, 2019; Rainforest Alliance, 2020). Beyond recommended agroforestry practices, the AVSS examined have very little measures that recommend economic diversification. RA recommends group management to support its members to implement income diversification strategies, while BSC recommends processing mills and farmers sugarcane value addition measures (Bonsucro, 2016; Rainforest Alliance, 2020). None of the AVSS examined require managing the diversification of economic activities within farming operations.

All the AVSS reviewed have requirements for managing the diversity of ecosystem services provided by the farm which range broadly from conserving high conservation values areas[35] to adopting integrated pest management. For instance, the LEAF standard requires the conservation of

[35] High conservation value areas are natural environments which are considered of critical importance as they are valued for their ecological, biological social and cultural attributes (Areendran et al., 2020).

hedges along farm boundaries, the RSPO prohibits the expansion of new oil palm plantations on peatlands and the RA standard requires maintaining buffer zones around water bodies to protect aquatic biodiversity (Linking Farming and Environment, 2019; Rainforest Alliance, 2020; Roundtable on Sustainable Palm Oil, 2018). The RSB standard explicitly requires biomass producers and industrial facilities to maintain ecosystem services: "…Participating Operators shall implement practices through the Environmental and Social Management Plan (ESMP) that maintain ecosystem functions and services, such as biodiversity both inside and outside the operational site, on land which is directly affected by the operations (Roundtable for Sustainable Biomaterials, 2016b, pp. 60–61)." Although AVSS have been established to protect ecosystems from the impacts of agricultural production, the RSB is the only AVSS examined that has specific measures focused on maintaining and enhancing ecosystems' functions and services.

Preserving the growing environment consists of ensuring that the resource base supporting agricultural production is maintained in perpetuity. All the AVSS examined have requirements aiming to preserve the growing environment such as soil and water conservation measures, avoiding or minimizing agro-chemical use and lowering agricultural pollution which includes greenhouse gas emissions. For instance, the RA standard has a core requirement for small and large farms that prohibits the use of toxic agrochemicals[36], the BSC standard requires sugarcane farming operations to recycle more than 50 % of its non-production waste (i.e. fiber, metal, plastic, oil and lubricants, batteries and chemical products) and the RSPO has critical requirement to assess the greenhouse gas emissions so they can be reduced and publicly reported (Bonsucro, 2016; Rainforest Alliance, 2020; Roundtable on Sustainable Palm Oil, 2018). Measures to preserve the growing environment to

[36] These include the ones listed in the Annex A of the Stockholm convention, Annex 3 of the Rotterdam convention, Annexes A, B, C and E of the Montreal protocol and the WHO list Ia and Ib.

reduce greenhouse gas emissions from the farming operation are especially important to mitigate against climatic changes which can lead to regime shifts[37] in the growing environment.

Broadening participation in farming activities refers to ensuring that a diversity of people are involved in the activities and decision-making of the farming operation. The AVSS examined do so by requiring non-discrimination measures, consultative processes and grievance mechanisms to improve decision-making. Except for the LEAF standard, all of the AVSS examined have production criteria requiring non-discrimination measures in the workplace. For instance, the RSPO requires: "A publicly available non-discrimination and equal opportunity policy is implemented in such a way to prevent discrimination based on ethnic origin, caste, national origin, religion, disability, gender, sexual orientation, gender identity, union membership, political affiliation or age" (Roundtable on Sustainable Palm Oil, 2018, p. 42). With the exception of the LEAF and the BSC standards, the AVSS examined have production criteria to prevent gender discrimination. For instance, the Rainforest Alliance standard has three production criteria dedicated to enabling gender equality and the RSB Small standard requires its smallholder biomass producers to ensure that there is no discrimination in the workplace based on gender (Rainforest Alliance, 2020; Roundtable for Sustainable Biomaterials, 2016b).

All the AVSS examined have production criteria that promote internal governance structures by requiring farming operations to allow freedom of association and collective bargaining. For instance, BSC Small standard requires smallholder sugarcane farms to: "Respect the right of all workers to form and join trade unions and/or to bargain collectively" (Bonsucro, 2018, p. 10). Some go further by requiring additional management and governance structures to be established. For instance, FSPO and FHL standards require the establishment of a Fairtrade Premium committee to

[37] Regime shifts are dramatic changes in the structure of ecosystems or socio-economic systems that are often hard to predict and difficult to reverse (Stockholm Resilience Centre, 2011). The collapse of a fishery or stock market crash are examples of regime shifts which can have important impacts and result in long-lasting systemic change.

administer the expenditure of premiums generated from Fairtrade production sales on projects that benefit their smallholder producer groups or hired labor communities (Fairtrade International, 2014b, 2019). The BCI standard recommends farmers to establish and participate in producer organizations by tracking their participation in these governance structures as an improvement indicator (Better Cotton Initiative, 2018).

The AVSS examined for the most part do not have requirements for managing the diversification of agricultural products and economic activities of the farming operation. This is problematic as diversification has been identified as fundamental for farming resilience (E. M. Bennett et al., 2014; Biggs et al., 2015). Although diversifying requires investment, AVSS need to incorporate production requirements focused on managing the diversification of agricultural products and economic activities to ensure that farming operations have the right resilience conditions in place to weather disturbances.

4.1.3 Resilience Collaborations

The AVSS production criteria that can build the resilience collaborations of farming operations consist of production requirements that connect farming operations to the socio-ecological systems in which they are embedded to build collective resilience to disturbances. Benchmarking the AVSS production criteria against the indicators of the resilience conditions dimension consisted of examining key questions to assess whether the production criteria require managing ecological, community and market connectivity, conformance with applicable laws and regulations, engagement with external stakeholders and governance systems and influencing socio-economic regime shifts. Doing so allowed for identifying gaps in the AVSS production criteria to fulfil the resilience collaborations indicators.

According to the stringency analysis, most of the AVSS examined have almost 10% of their production criteria and indicators oriented towards managing ecological (15.2% of the production criteria reviewed) and community (9.4% of the production criteria reviewed) connectivity as well as adhering to relevant laws and regulations (9.7% of the production criteria reviewed) (see Figure 12). There are significantly less AVSS production criteria indicators that are focused on managing market connectivity (6.2% of the production criteria reviewed), engaging with external stakeholders and governance structures (7.8% of the production criteria reviewed) and influencing socio-economic regime shifts within socio-economic systems (4.0% of the production criteria reviewed). The AVSS examined for small farms has a similar coverage pattern of the resilience collaborations indicators (see Figure 13). Interestingly, a greater percentage of AVSS production criteria and indicators for small farms focused on influencing socio-economic regime shifts compared to the AVSS production criteria and indicators for medium and large farms (6.7% for small farms versus 4.0% for medium and large farms) who likely have more capacity and resources to influence change.

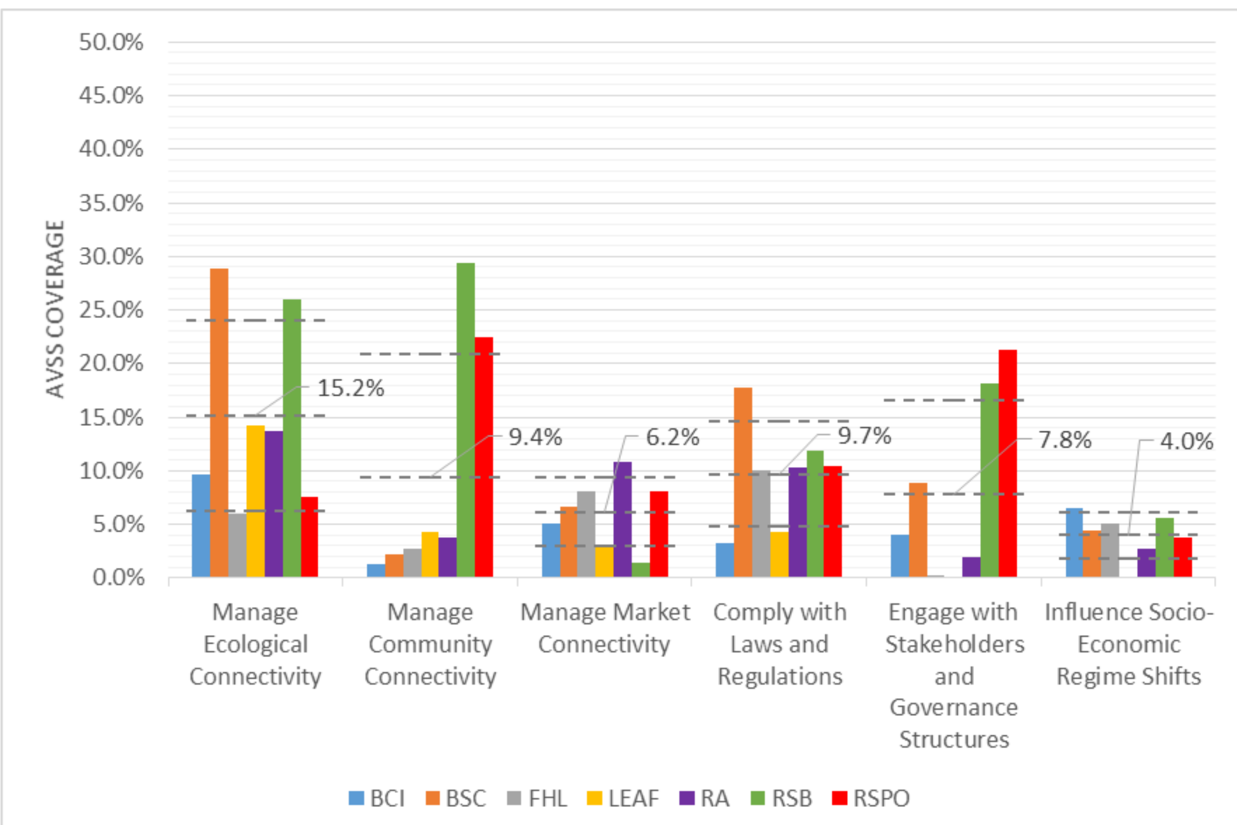

Figure 12 – AVSS production criteria benchmarked against resilience collaborations indicators for medium and large farming operations

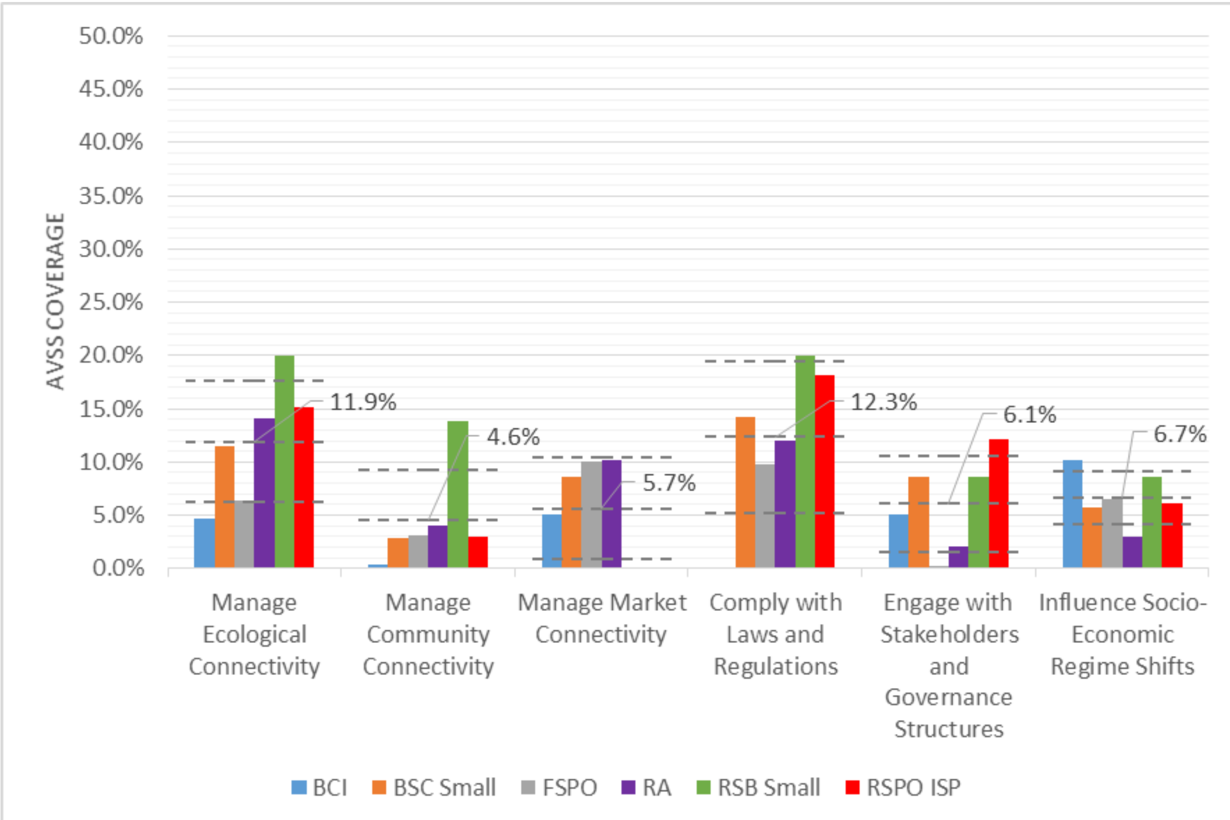

Figure 13 – AVSS production criteria benchmarked against resilience collaborations indicators for small farming operations

Managing the ecological connectivity of farming operations consist of protecting natural environments within and outside farming operations, which can increase connectivity between the farm and its natural surroundings. All the AVSS examined require managing the ecological connectivity of farming operations by having production criteria that require ecosystem conservation and restoration measures within and outside farming operations and pollution prevention measures. For instance, the FSPO standard requires farmers to "…maintain buffer zones around bodies of water and watershed recharge areas and between production areas and areas of high conservation value, either protected or not. You do not apply pesticides, other hazardous chemicals and fertilizers in buffer zones" (Fairtrade International, 2019, p. 29). Although all the AVSS examined require ecosystem preservation and agricultural pollution prevention, the RSB is the only standard examined with specific requirements for protecting and restoring ecological corridors (Roundtable for Sustainable Biomaterials, 2016b).

With the exception of the BSC standard, all the AVSS examined have production criteria that require managing connectivity with local communities. For example, the LEAF standard requires farmers to engage with their local communities by organizing at least one event per year (Linking Farming and Environment, 2019). All the AVSS examined have measures to prevent agricultural pollution from negatively affecting local communities. For instance, the BCI standard requires the implementation of a water stewardship plan that conserves water and prevents water quality impacts (Better Cotton Initiative, 2018). The FSPO standard requires farmers to "…not apply pesticides and other hazardous chemicals within 10 meters from ongoing human activity (housing, canteens, offices, warehouses or the like with people present)" (Fairtrade International, 2019, p. 21). The RSB require biomass producers to enhance local food security in food insecure regions (Roundtable for Sustainable Biomaterials, 2016b). All the AVSS examined have production criteria enabling community connectivity by requiring agricultural operations to engage with and prevent negative impacts on their surrounding communities.

Within the AVSS examined, managing market connectivity occurs in various ways. Fairtrade is the only AVSS examined that requires producer organizations to directly connect with prospective markets.[38] The FSPO and FHL standards both require their members to demonstrate that there is market potential for Fairtrade products to become certified (Fairtrade International, 2014b, 2019). Almost all the AVSS examined have provisions for enabling transparency by requiring product traceability systems and sale records which can link buyers and sellers along supply chains. The AVSS that do not have traceability measures in their production standards have a separate chain of

[38] "A market is a place where two parties can gather to facilitate the exchange of goods and services. The parties involved are usually buyers and sellers. The market may be physical like a retail outlet, where people meet face-to-face, or virtual like an online market, where there is no direct physical contact between buyers and sellers (Kenton, 2020)."

custody and supply chain certification standards (Bonsucro, 2016; Linking Farming and Environment, 2019; Roundtable for Sustainable Biomaterials, 2016b; Roundtable on Sustainable Palm Oil, 2018). The RA standard requires farming operations to establish a grievance mechanism which is also available to buyers (Rainforest Alliance, 2020). These various requirements (i.e. binding contracts, traceability, sale records and buyers grievance mechanisms) can contribute to managing connectivity between farming operations and prospective markets.

All the AVSS reviewed require farms to conduct lawful agricultural operations according in accordance with all applicable laws and regulations. For instance, the BSC and the RSPO standards require that land and water use rights must be obtained and that customary rights must be respected (Bonsucro, 2016; Roundtable on Sustainable Palm Oil, 2018).. The RA standard has a core requirement to achieve group certification for large farms as well as independent certification for small and large farms specifying that "activities diminishing the land or resource use rights or collective interests of indigenous peoples and local communities, including High Conservation Values (HCVs) 5 or 6, are conducted only after having received free, prior and informed consent[39] (FPIC)" (Rainforest Alliance, 2020, p. 72). AVSS also require working conditions and agreements aligned with the regulatory systems in which they operate. These can include paying minimum wages, respecting maximum working hours and providing suitable working conditions. For instance, the BSC Small standard requires smallholder sugarcane producers to comply with laws related to the following: "**Environmental**: waste, pollution & environmental protection, nature conservation, water extraction, energy, soil protection; **Social**: labor conditions, social wellbeing, health and safety;

[39] "Free, Prior and Informed Consent (FPIC) is a specific right that pertains to indigenous peoples and is recognised in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP). It allows them to give or withhold consent to a project that may affect them or their territories. Once they have given their consent, they can withdraw it at any stage. Furthermore, FPIC enables them to negotiate the conditions under which the project will be designed, implemented, monitored and evaluated. This is also embedded within the universal right to self-determination (Food and Agriculture Organization of the United Nations, 2020)."

Production: agricultural production practices, transportation, land conversion to cane (if legally required, environmental and social impact assessment)" (Bonsucro, 2018, p. 7).

AVSS require engagement with external stakeholders and governance structures in various ways which can include stakeholder consultations, establishing grievance mechanisms and formal participation in external governance structures. For instance, the BCI, BSC, RA, RSB and RSPO standards all require the FPIC of stakeholders for various farming activities. Except for the BCI and the FSPO standards, all the AVSS examined require establishing external stakeholder grievance mechanisms. For instance, the RSPO standard requires mill operators and oil palm growers to establish a grievance mechanism for smallholder farmers (Roundtable on Sustainable Palm Oil, 2018). Five of the AVSS examined have production criteria that specifically require farmers to consult, engage and collaborate with external governance structures. For instance, the RSB requires engagement with relevant government authorities to streamline legal requirement processes, while the FSPO requires developing sustainable water management solutions with local authorities and the BCI standard requires engaging with external governance structures for enabling sustainable water use and eliminating child and forced labor (Fairtrade International, 2019; Roundtable for Sustainable Biomaterials, 2016b). Engaging with external governance structures allows for building collective resilience and is an important opportunity for AVSS to build farming resilience (Carlisle & Gruby, 2017).

Influencing socio-economic regime shifts can take many different forms. Child and forced labor are persistent sustainability challenges in agriculture with lasting negative impacts (Food and Agriculture Organization of the United Nations, 2017; International Labour Organization et al., 2019; Phillips, 2015). Child labor can prevent children from getting educated which can help lift families out of poverty, while forced labor can lead to generational impacts for subjected individuals (International Labour Organization et al., 2019). For this reason, AVSS production criteria that aim to eliminate child and forced labor were considered to influence socio-economic regime shifts. Except for the LEAF standard, all the AVSS examined have production criteria that prohibit child and forced labor. For instance, the RSPO standard has a core requirement which specifies: “All work is voluntary and the following are prohibited: Retention of identity documents or passports, Payment of recruitment fees, Contract substitution, Involuntary overtime, Lack of freedom of workers to resign, Penalty for termination of employment, Debt bondage and Withholding of wages” (Roundtable on Sustainable Palm Oil, 2018, p. 50). The BSC Small standard for smallholder sugarcane producers requires that the minimum age for specific tasks must be respected: “18 for hazardous work, 15 for non-hazardous work, 13 for light family farm work on family and small-scale farms or minimum ages specified by law or country’s adoption of ILO C138” (Bonsucro, 2018, p. 8).

AVSS could incorporate more direct requirements for engaging with external stakeholders and influencing socio-economic regime shifts as they are especially important for improving the collective resilience of the socio-ecological systems in which farming operations are embedded (Biggs et al., 2015). Ensuring that farming systems are operating collaboratively within their socio-ecological contexts is paramount for building resilience.

4.2 Farming Resilience Design Considerations

The benchmarking effort allowed for identifying the extent to which the AVSS examined cover the resilience dimensions and indicators of the AVSS resilience framework developed for this research. In doing so, the analysis answers how AVSS designs affect the resilience of farming systems and provides insights to improve them for farming resilience. The resilience aspects inadequately covered by the AVSS examined are especially relevant to identify areas for improvement within AVSS designs to build farming resilience. The higher, medium and lower AVSS coverage of the farming resilience aspects from the AVSS resilience analysis framework are discussed in detail below (see Table 8).

Table 8 – Farming resilience indicators by descending AVSS average coverage level

Farming Resilience Indicators or Aspects	Medium and Large Farms Average (Standard Deviation)	Small Farms Average (Standard Deviation)	Overall Average
More than 10% coverage			
Manage Ecosystem Services Diversification	22.3% (+/-7.2%)	22.4% (+/-7.2%)	22.3%
Record Agricultural Operation	21.0% (+/-10.2%)	22.9% (+/-13.3%)	21.9%
Preserve Growing Environment	20.1% (+/-6.9%)	17.6% (+/-6.8%)	18.9%
Broaden Participation in Farming Activities	13.0% (+/-7.1%)	16.8% (+/-6.0%)	14.9%
Continuous Capacity Building	16.1% (+/-4.9%)	12.5% (+/-6.6%)	14.3%
Manage Ecological Connectivity	15.2% (+/-8.9%)	11.9% (+/-5.7%)	13.5%
Comply with Laws and Regulations	9.7% (+/-4.9%)	12.3% (+/-7.1%)	11.0%
Less than 10% and more than 5% coverage			
Monitor Agricultural Operation	9.1% (+/-4.7%)	6.5% (+/-3.7%)	7.8%
Promote Internal Governance	6.0% (+/-7.1%)	8.1% (+/-6.0%)	7.0%
Manage Community Connectivity	9.4% (+/-11.4%)	4.6% (+/-4.7%)	7.0%
Engage with Stakeholders and Governance Structures	7.8% (+/-8.7%)	6.1% (+/-4.5%)	6.9%
Complex Systems Thinking	7.0% (+/-2.5%)	6.0% (+/-5.7%)	6.5%
Manage Market Connectivity	6.2% (+/-3.2%)	5.7% (+/-4.8%)	5.9%
Influence Socio-Economic Regime Shifts	4.0% (+/-2.1%)	6.7% (+/-2.5%)	5.3%
Less than 5% coverage			
Adaptation Strategies	3.9% (+/-2.4%)	4.9% (+/-2.7%)	4.4%
Manage Agricultural Product Diversification	0.5% (+/-0.8%)	0.4% (+/-0.6%)	0.5%
Manage Economic Activity Diversification	0.7% (+/-0.8%)	0.1% (+/-0.3%)	0.4%
Targeted Experimentation	0.3% (+/-0.8%)	0.0% (+/-0.0%)	0.2%

The AVSS examined have production criteria and indicators that had a coverage of more than 10% include managing the diversification of ecosystem services, recording and documenting the agricultural operation, preserving the growing environment, broadening participation in farming operations, continuous capacity building, managing the ecological connectivity of the farm and complying with laws and regulations. These farming resilience aspects closely align with how AVSS are orientated and operate. For instance, recording and documenting the farming operation can provide valuable information for farmers to build resilience intelligence but it is also required to demonstrate AVSS-compliance and adopting AVSS-compliant business and farming practices often requires capacity building and training. AVSS were historically designed to enable more sustainable forms of agricultural production that are economically viable and lower negative socio-ecological impacts such as soil erosion, water pollution and child labour. Consequently, the AVSS that were examined have production criteria and indicators that satisfactorily cover farming resilience aspects related to preserving the agricultural growing environment, natural ecosystems and social fairness and equity within farming operations. Identifying the resilience aspects adequately covered by the AVSS examined, provides insights for maintaining design elements aligned with enabling farming resilience in future versions of the standard.

The following farming resilience aspects had a coverage of less than 10% but greater than 5% due primarily to the interpretation and scope of the AVSS production criteria reviewed: monitoring the agricultural operation, promote internal governance structures, managing community and market connectivity, engaging with external stakeholders and governance structures, complex systems thinking and influencing socio-economic regime shifts. For instance, the AVSS production criteria and indicators deemed to require complex systems thinking were limited to ones that clearly foster an understanding of the interconnected farming operation and monitoring the agricultural operation was examined separately from recording and documenting the agricultural operation even though they go hand in hand as monitoring is often a precursor to documenting. The low coverage of managing market connectivity is not representative as some AVSS have separate supply chain standards that can enhance market connectivity. Furthermore, the very existence of AVSS focusses in large part on connecting farms with the marketplace by distinguishing AVSS-compliant products with labels. Incorporating production requirements that can influence socio-economic regime shifts is less clear since these measures require context to have effect. Nevertheless, the majority of the AVSS examined consistently had child and forced labor prevention measures, which can have beneficial social ramifications. Engaging with external stakeholders and governance structures was also limited in its coverage as it is often included as a recommendation as opposed to a requirement. Collectively building the resilience of the socio-economic systems in which farming operations are embedded is imperative for enabling farming resilience (Verburg et al., 2019b). The limited AVSS coverage of these resilience aspects could be improved, with a particular emphasis on engaging with external stakeholders and governance structures.

The resilience aspects which had a coverage of less than 5% by the AVSS examined include, establishing adaptation strategies, managing the diversification of agricultural products and economic activities and targeted experimentation. Despite its compatibility with continuous capacity building measures and developed effective adaptation strategies, there were almost no requirements or recommendations for targeted experimentation. There were very few explicit requirements for developing adaptation strategies even though the AVSS examined require generating the knowledge needed for developing them. This indicates that requiring farming operations to develop adaptation strategies is reasonable as it would leverage existing requirements. The lack of AVSS requirements for managing crop and economic activity diversification is problematic as it is fundamental for farming resilience (Ashkenazy et al., 2018; E. M. Bennett et al., 2014; Biggs et al., 2015). This can be especially important for small farms with less resources. Bitzer and Steijn (2018) describe this dynamic by stating: "If VSS encourage increased specialization of agricultural production without considering producers' livelihood decisions, including engagement in off-farm activities, they restrict their potential for poverty alleviation" (Bitzer & Steijn, 2018, p. 3). A narrow focus on the sustainable production of particular crops can ensnare farmers into less resilient crop-specific dependent livelihoods (Bitzer & Steijn, 2018). The resilience aspects inadequately covered by the AVSS examined provide opportunities for re-designing AVSS for farming resilience.

The coverage of the AVSS resilience analytical framework differed between the AVSS examined as they were designed for different crops and geographies, by different stakeholders with different sustainability objectives in mind. To account for AVSS production criteria and indicators targeted on specific farms sizes, the analysis was conducted separately for small farms. Making this distinction seemed important as smaller farmers and farming operations may have less capacities and resources to face disturbances compared to medium and large farms. The benchmarking results obtained for AVSS production criteria and indicators targeted on small farms were very similar to the ones obtained for medium and large farms (see Table 8). Although the resilience aspect, manage community connectivity was better covered by the AVSS focused on medium and large farms compared to the ones focused on small farms.

The benchmarking effort undertaken was subjective as it required interpreting the potential for AVSS production criteria and indicators to fulfill various aspects of farming resilience within the AVSS resilience analytical framework void of context. Consequently, undertaking the benchmarking analysis with context could provide additional insight to rethink how they can be designed and implemented for farming resilience. Nevertheless, the analysis did provide insights to determine how AVSS designs are affecting the general resilience of farming systems and identify AVSS "blind spots" (i.e. farming resilience aspects with little to no AVSS coverage) to be addressed for them to build farming resilience.

5 Implementing Agricultural Voluntary Sustainability Standards for Building Resilience

To address Sub-Question 2*, How are AVSS implementation approaches affecting the general resilience of farming systems?*, a case study of the BCI program implemented in the Adoni Mandal of the State of Andhra Pradesh in India was conducted. Information was collected via farmer focus group discussions as well as farming and relational surveys to provide insights on how implementing the BCI program is affecting the general resilience of cotton farming systems in the study area. The insights obtained from the farmer focus group discussions and the resilience threats and coping strategies responses from the farming survey are first examined (Section 5.1) to provide context for the case study. The farming survey was then used to examine the training effectiveness of the BCI program by ascertaining attendance and willingness to implement lessons learned and comparing farming practices between farmers who attended training and farmers that are not participating in the BCI program (Section 5.2). The information collected as part of the relational survey allowed for examining the BCI program's function and positioning to affect resilience within organizational water and food security networks in the study area (Section 5.3). The analysis presented provides insights to address the central research question by first establishing the resilience context (is the BCI standard aligned to address the resilience threats facing farmers in the study area?), then examining the BCI training effectiveness for building the general resilience of cotton farmers (how effective is the implementation of the BCI program for enabling continuous capacity building towards farming resilience?) and lastly by examining the BCI program's role in enabling resilience of cotton farming in the study area at the organizational level (what is the BCI's role in enabling engagement with external stakeholders and governance structures and collective resilience?).

5.1 Cotton Farming in the Adoni Mandal

Farmer focus group discussions and responses to the resilience threats and coping strategies section of the farming survey were used to examine some general resilience questions pertaining to cotton cultivation in the Adoni Mandal (resilience for what to what, from whose perspective and capacities - see Section 1.1). The case study focuses on ascertaining the general resilience of cotton farming systems in the Adoni Mandal (resilience of what?), which consist of individual farmers and their families (households) who manage agricultural lands supporting cotton cultivation. The main resilience threats (resilience to what?) and coping strategies (resilience capacities) in the Adoni Mandal were obtained directly from farmer responses (resilience from whose perspective?) via farmer focus group discussions and the farming survey. This contextual information is used to better understand the case study and its application to answer the central research question. Distinctions between farmers that are participating in the BCI program and those that are not was only possible for the information collected during the farming survey as the farmer focus group discussions were conducted with random farmers who may or may not have been participating in the BCI program.[40]

Cotton farming in the Adoni Mandal is challenging primarily due to a lack of precipitation which has been changing over time. According to the recollection of some farmers in the study area, rainfall has become less frequent and has significantly dropped since 2012. Farmers from Santhekudlur stated "we have had 4 years of dry weather", while farmers from Chinna Harrivanam commented on rainfall frequency: "now we don't have that 3 month spread of rains. They are

[40] Villages where farmer focus group discussions were held include 5 villages where the BCI program was being implemented (Chinna Harrivanam, Santhekudlur, Madire, Baladur and Virupapuram) and five villages where the BCI program was not being implemented (Dhanapuram, Naganathana Halli, G. Hosali, Pandagavallu and Ballekalu).

untimely or there are none at all" (Farmer Focus Groups, personal communication, March 2016). As most of the cotton grown in the study area is rain fed, lower precipitation has resulted in dropping yields and revenues. Farmers from Dhanapuram shared that "people have spent, depending on their capacity from INR 30,000 to 100,000 per acre. All of it is lost due to lack of rain" (Farmer Focus Groups, personal communication, March 2016). Farmers from the villages of Madire, Dhanapuram, Pandagavallu and Ballekal reported a two to four fold drop in productivity over 3 years. More specifically, farmers from Pandagavallu stated: "This year and last year, we incurred losses due to low productivity ranging from 1- 4 quintals[41] per acre. Two years ago, it was good ranging from 8-15 quintals per acre" (Farmer Focus Groups, personal communication, March 2016). Those with access to the lower level canal, the main water infrastructure supplying the Adoni Mandal, also pointed out that without precipitation there is very little water for irrigation which is often appropriated by farmers further upstream. Farmers from Chinna Harrivanam describe the lower level canal and their access to irrigation water as follows:

> The lower level canal originates some 250 km upstream of this village. So, water has to come all this way, after abstractions by other farmers and practically no additions into the discharge, if the farms have to be irrigated, which is not happening. The canal will receive water from the dam in June last or July depending on rains. Normally, the canal should have discharges right up to the end of March. This year, due to the shortfall of water in the dam itself, the canal discharge stopped in December. After a break of about 20 days in January, they opened water for another few days. Now you have large dams, but what use are they if there is no rain to put water into them (Farmer Focus Groups, personal communication, March 2016).

[41] In India the quintal refers to 100 kg (Textile Exchange, 2011).

Farmers who do not have access to the lower level canal but have irrigation infrastructure on their farms also conveyed similar water security challenges. Farmers from Dhanapuram stated: "the tube wells as well as the open wells have dried up. None of them have any water. The water is 300 feet deep" (Farmer Focus Groups, personal communication, March 2016). The farmers from Chinna Harrivanam conveyed a sense of desperation by stating: "In the absence of rain, management is meaningless whether you install pumps, check dams or what not, this place is going to be a desert" (Farmer Focus Groups, personal communication, March 2016). This was further supported by farmers from Santhekudlur who shared: "If there is no water all is lost including getting seeds for the next crop. Canal water is accessible to very few. Rainwater is the main issue. This year farmers are under big loss and cotton has failed" (Farmer Focus Groups, personal communication, March 2016). Nevertheless, farmers from Nagathana Halli pointed out that the Adoni Mandal is situated in the Deccan Plateau, a drought prone area, by stating: "parts of it … are as dry as the driest parts of the Thar Desert in Rajasthan" (Farmer Focus Groups, personal communication, March 2016). Despite the significant water security challenges conveyed by the farmer focus group discussions, their physical location in a drought prone area implies that they should have coping strategies to deal with moisture deficits.

Other precipitation linked resilience threats to cotton farming discussed during the farmer focus groups include land use change, labour shortages and contract farming. The farmers reported that there was more nature and trees in the past, which has diminished due to rainfall shortages and changing land use practices. Farmers from Dhanapuram shared that changing rainfall patterns led to a significant loss in tree cover by stating:

> Thirty years back the soil was fertile. The soil is becoming hard with the use of fertilizers. The soil was resilient to less rainfall (better moisture holding) than the current soil. There were plenty of trees and water could be accessed at a depth of 20 feet. Now we can only

> access it at 300 feet. Trees grew faster and were healthier then. Trees no longer grow fast due to less rainfall (Farmer Focus Groups, personal communication, March 2016).

Along with changing rainfall patterns, the landscape has been altered for farming, which has resulted in the loss of forests and trees. Farmers from Madire described this change by stating:

> Now, no trees are there, and no forest is available. Fields must be level to hold water. The natural topography has been significantly altered. We have been incentivized to level the fields to have better drainage characteristics for cultivation. Both steep slopes which drain water fast and swamps which retain water like a wetland have been diligently altered to well drained flat land over the years (Farmer Focus Groups, personal communication, March 2016).

The lack of precipitation has also led many farmers and farm workers to migrate at various times of the year to supplement their farming incomes which has led to labour shortages at various times of the year within the study area. Farmers from Chinna Harrivanam commented that "the most acute problem is shortage of labour" conveying the importance of labour to cotton farming operations in the Adoni Mandal which for the most part are not mechanized and rely primarily on human labour for various parts of the cultivation process (Farmer Focus Groups, personal communication, March 2016).

Farmers from G. Hosali also described how farmland is being leased and exploited by entrepreneurs from outside the Adoni Mandal. They described that contract farming is having a detrimental environmental effects on the best farmland in the area by stating the following:

> Entrepreneurs from Guntur lease lands in the Adoni area which have good access to canal water and do intensive cultivation with excessive chemical inputs. After 3 to 4 years of intense profits, when they see soil health decline, they get out of the lease and leave. Farmers who take back such farms can't grow anything without resting and replenishing the soil by

letting shepherds and goatherds use the land to replenish the soils with biomass and organic carbon (Farmer Focus Groups, personal communication, March 2016).

The resilience threats shared by cotton farmers during the focus group discussions were also examined by conducting a survey where the respondents were asked to share the resilience threats or negative events that are most likely to happen to them and how often they occurred in the last five years. More specifically, the respondents were asked to rank the 3 negative events that are most likely to happen to them as most severe, moderate and least severe and how frequent these events were in the last five years (experienced 1 to more than 5 times) from the following 13 options: 1) Drought, 2) Excessive rain, 3) Extremely scarce rain, 4) Heat waves that affected agricultural production, 5) Theft of property or crops, 6) Increase in price of agricultural or livestock inputs, 7) Sharp decline in cotton prices, 8) Cotton pest outbreaks, 9) Livestock diseases, 10) Death or serious illness or injury of family member 11) Major policy changes such as ending of subsidies 12) Other, and 13) None. The most likely resilience threats identified across all the farmers surveyed were weather related including extremely scarce rains, droughts, excessive rain and heat waves (see Figure 14). This result aligns with the information gathered during the farmer focus groups. Declining cotton prices, cotton pest outbreaks, and increasing input costs were also identified as important resilience threats to cotton production. The average number of times that these negative events occurred between 2012 and 2017 ranged from 1.2 to 4.2 times.

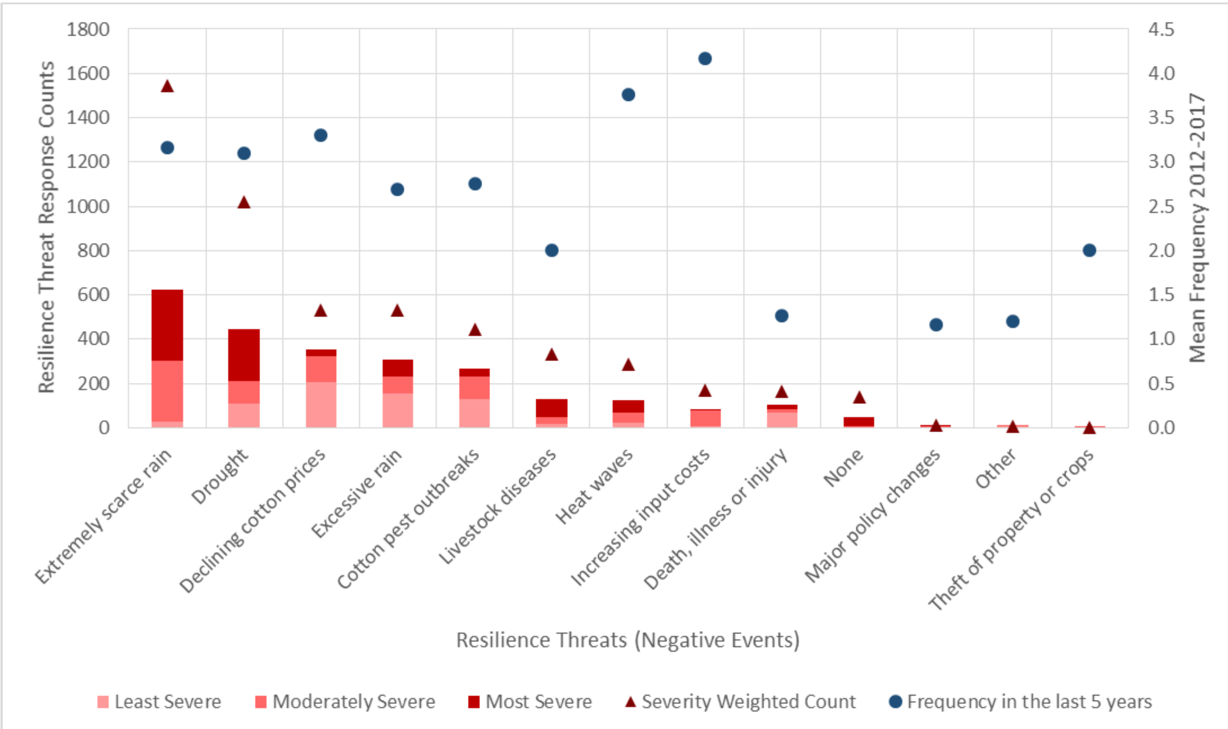

Figure 14 – Resilience threats to cotton farmers in the Adoni Mandal

The coping strategies to the resilience threats discussed identified by the farmers participating in the focus group discussions consisted mainly of finding wage labour via the Mahatma Ghandi National Rural Employment Guarantee Scheme (NREGS)[42] or by temporarily migrating to neighbouring cities. Farmers from Santhekudlur shared that migrating to find wage labour is common when there are no rains by stating: "As there are no rains, some people are migrating, especially those dependent on rainwater. They may go for the 'employment guarantee scheme' to find work" (Farmer Focus Groups, personal communication, March 2016). According to some farmers, supplementing farming incomes has become necessary even when growing conditions are good. Farmers from Madire stated: "Even if there is good rain, they leave after the crop season, at least for 3-4 months (during peak summer). Those without livestock leave to the cities. They got used to getting supplementary income in the city" (Farmer Focus Groups, personal communication, March 2016). At least half of the farmers living in Chinna

[42] The NREGS is based on an act passed in 2005 and implemented country-wide by 2008 which legally entitles every Indian rural household to minimum wage employment for 100 days per year from local public works (Maiorano, 2014).

Harrivanam, Santhekudlur and Ballekal migrated to find wage labour in 2016. Farmers from Ballekal remarked that: “About 50% have gone due to water shortages. Those who have bore wells hang on. Those who depend on rain migrate. They migrate to earn and pay back their loans” (Farmer Focus Groups, personal communication, March 2016).

The need to find wage labour to pay back loans was further explored by asking farmers if they have access to crop insurance. All farmers confirmed that there are no crop insurance programs but that antiquated loan insurance schemes exist which can be detrimental to farming profitability. Farmers from Santhekudlur shared that loan insurance compensations are only possible under specific conditions by stating the following:

> There is no crop insurance. For farming loans, INR 17,000 per INR 100,000 was recovered as insurance against loan defaults. Whether we qualify for loan default insurance depends on a state-wide survey of crop productivity. Last year, this village didn’t qualify for loan waivers. That means we paid the insurance premium and we have to repay the loan also (Farmer Focus Groups, personal communication, March 2016).

Farmers from Pandagavallu and Ballekal further support this sentiment by respectively stating “We have taken insurance, but claims are not settled” and “We have declared it as a drought Mandal but no one has come to report and pay compensations” (Farmer Focus Groups, personal communication, March 2016). Farmers from Naganathana Halli described the mismatch between the current configuration of loan insurance programs and the current farming context in the study area as follows:

> Settlements can take as much as 2 to 3 years. Officials take a lot of time to substantiate crop losses. The old British system is persisting which requires more than 50% losses for it to be considered a crop failure. In those days most farmers were practicing subsistence agriculture without significant farm inputs. Today, a lot of money is spent to practice intensive

agriculture. Even a 20% loss should qualify as crop failure. The government continues to operate under the old system (Farmer Focus Groups, personal communication, March 2016).

The need to migrate and find wage labour is linked to the debt cycles faced by farmers in the study area which is perpetuated by intensive agriculture requiring expensive inputs accessed by taking expensive loans and unfair loan insurance conditions.

With respect to water security, the farmers revealed various coping strategies ranging from establishing water retention infrastructure to farming practices that can retain soil moisture. They were also open to planting trees with sufficient support to do so. Farmers from Baladoor shared that they are digging ponds to store water: "We are digging ponds. There are natural streams where water comes like it does in canals. Such natural flows could be tapped when they come and stored in ponds" (Farmer Focus Groups, personal communication, March 2016). Farmers from Naganathana Halli also stated that they are building water retention structures: "They are digging 10 by 10 feet water ponds in agricultural fields. If you stock water in 1/2 acre, you can cultivate 2 acres" (Farmer Focus Groups, personal communication, March 2016). Farmers from Chinna Harrivanam stated that deep ploughing is helpful to retain soil moisture: "If the ploughing is done deep, it will hold water or moisture when it rains. Even if the rain is 2-3 showers short, deep ploughing will make up for the shortfall" (Farmer Focus Groups, personal communication, March 2016). Farmers were also open to planting trees to improve precipitation patterns provided they were given proper support to nurture them. Farmers from G. Hosali mentioned: "We would consider planting them if we had a ground water source for irrigating them. If the government provides support by drilling bores and improving water access, we can plant a tree per acre and care for it" (Farmer Focus Groups, personal communication, March 2016). Farmers from Naganathana Halli stated: "Trees must be productive and bear fruit that will be an incentive. Growing tamarind trees must be encouraged particularly in dry areas" (Farmer Focus Groups, personal communication, March 2016).

There was surprisingly very little community collaboration to share water resources and virtually no faith in government interventions to improve water security in the study area. Farmers from Virupapuram described government promises as follows: "The government sanctioned some bore wells. But most the time, their promises don't materialize" (Farmer Focus Groups, personal communication, March 2016). Farmers from G. Hosali conveyed their lack of faith in the government by stating: "We don't have any hope in the government. Just like you, they come, and ask for information, write about it and go. Nothing happens after that" (Farmer Focus Groups, personal communication, March 2016). They further stated:

> The government can help build bunds to retain water in the village farms. But we are sure that the government won't do it. The government can build check dams and diversion works on natural drainage with the employment guarantee scheme where people find work and the village can benefit from better water retention in the next season (Farmer Focus Groups, personal communication, March 2016).

Despite the existence of governance structures for sharing water resources, there was conflicting statements concerning water resource sharing between communities. Farmers from Santhekudlur described the water governance structure in the study are as follows: "There are water societies formed by government. The allocation of water from the canal is decided for these villages. The water societies of respective villages are expected to coordinate the sharing as per this arrangement" (Farmer Focus Groups, personal communication, March 2016). Farmers from Virupapuram conveyed that there is no water sharing coordination between villages by stating: "Yours is yours, mine is mine, and this is how villages deal with each other. Even farmers adjacent to each other are quite possessive about their water" (Farmer Focus Groups, personal communication, March 2016).

Farmers from Pandagavallu made a similar statement: "Nobody has anything to share with others. What help can one give when he can't help himself? Even drinking water is a problem. Where do we get water for irrigation?" (Farmer Focus Groups, personal communication, March 2016). There is clearly very little confidence in the government and collaboration between communities to address the water security challenges in the study area.

Switching from cotton to more drought resistant crops was also discussed during the farmer focus group discussions. Cotton remains the main crop grown in the area as it offers farmers superior revenues while requiring relatively less water. Farmers from Naganathana Halli stated: "Cotton also requires less water. For chili, maize and cotton, 5 to 6 wettings are enough during Kharif (June-October) and Rabi (August-December). Paddy and sugarcane requires more water" (Farmer Focus Groups, personal communication, March 2016). It is also preferred over more drought resistant alternatives such as sorghum or millet due to its greater potential for generating revenue. While discussing planting more drought resistant crops, farmers from G. Hosali shared the following: "Even with small showers and less soil moisture sorghum will give reasonable yields. The answer is income. Sorghum fetches less" (Farmer Focus Groups, personal communication, March 2016). Farmers from Pandagavallu shared this same sentiment by stating: "Families need cash for education, healthcare, buying groceries etc. Growing millet or cereals with low market value will not help" (Farmer Focus Groups, personal communication, March 2016). Farmers from Virupapuram shared that cotton is their main crop for generating revenue: "For subsistence, we grow some onion and sorghum. For our income, we grow cotton since we get good yields and market prices. For other crops, such as onion, we lose money" (Farmer Focus Groups, personal communication, March 2016). Farmers from Dhanapuram stated that cotton cultivation remains less risky than the alternatives: "All crops make a loss. Cotton remains the least risky from the mix of factors. Going back 5 years, we used to plant diverse crops. Cotton is now the mainstay" (Farmer Focus Groups, personal communication, March 2016). Farmers from G. Hosali generally described their perspective regarding switching crops as a coping strategy in the following way:

> The first variable is land. If the land holding is small, we avoid risk and plant only cotton. If the land holding is bigger, we might diversify into 2 or more crops with cotton still covering most of the acreage. Others crops could include sunflower, groundnut, chickpea etc. The second variable is rain. If rainfall is good, we can plant two crops per year and diversify by adding crops which need a little more water. Without good rain, we avoid the risks of diversification and stick to cotton as our major crop (Farmer Focus Groups, personal communication, March 2016).

Based on the information shared during the farmer focus group discussions, switching completely from cotton to more drought resistant crops is not a coping strategy favored by the farmers who shared their view during the focus group discussions, as none of the alternatives provide superior or equivalent potential for generating revenues.

The coping strategies explored in the farmer focus groups were also examined by conducting a survey where the respondents were asked to share their coping strategies when faced with resilience threats. More specifically, the farmers were asked to identify and rank the 3 main ways that their households cope with the negative events they experienced in their last production year as most, moderate to least difficult for their households from the following of 12 options: 1) Reduce food consumption, 2) Reduce consumption of other non-essential goods, 3) Postpone debt payment, 4) Sell household items (durable goods; stored grains; jewelry), 5) Sell productive assets (livestock; farmland, business), 6) The entire household migrated or some household members migrated, 7) Start new wage labor, 8) Take children out of school for them to work 9) Switch to other crop cultivation, 10) Change agricultural practices, 11) External support (food; cash; other help) and 12) Other. The main coping strategies identified by all farmers, which partly aligned with the coping strategies shared during the focus group discussions, consisted of postponing debt payments, switching crops and finding wage labour (see Figure 15). Although postponing debt payments was found to be the preferred coping strategy in the farming survey, the farmers who participated in the focus group discussions did not convey that there are favorable programs or schemes for postponing their loans when faced with crop failure. Although switching crops was identified as the second most preferred coping strategy by the farmers surveyed, switching from cotton to more drought resistant crops was not favored by farmers who participated in focus group discussions. This contradiction can be partly explained by the fact that the survey did not specify the crops that are to be switched. Nevertheless, the survey result does convey an openness to switching crops which is contradictory to the steadfast reliance on cultivating cotton conveyed during the focus group discussions. Finding wage labor was the third most preferred coping strategy identified by the survey results which was discussed extensively during the farmer focus group discussions by referring to having to temporarily migrate to find wage labor.

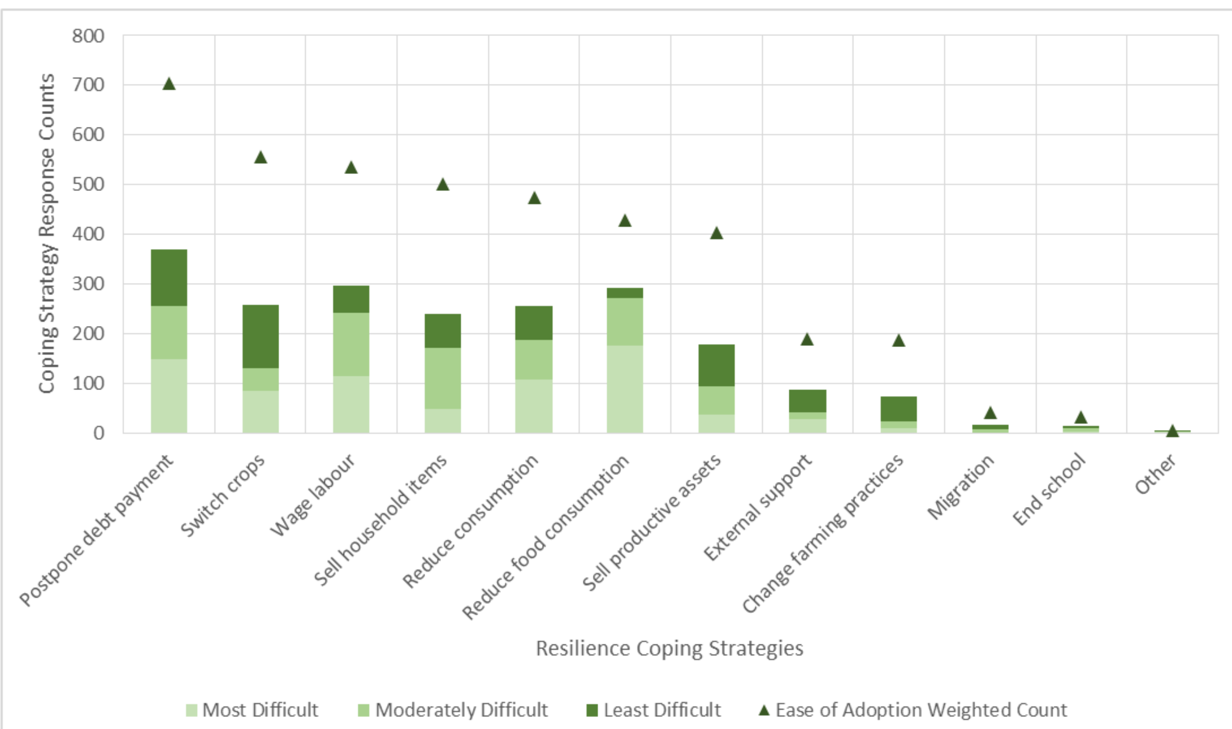

Figure 15 – Coping strategies of cotton farmers in the Adoni Mandal

The BCI standard has farming requirement that are well suited for assisting cotton farmers in the study area to build resilience against the main resilience threats identified by farmer focus group discussions and the farming survey. For instance, the water stewardship principle requires farmers to adopt sustainable water management practices which could assist with building resilience to water insecurity (Better Cotton Initiative, 2018). The standard also requires farmers to adopt practices that enhance biodiversity and land use practices that preserve natural environments both of which can be compatible with preventing water insecurity. With respect to addressing market related challenges, the BCI standard has a principle focused on fiber quality and effective management systems both of which can assist with improving profitability. Lastly, the BCI standard has a principle dedicated to crop protection which should assist cotton farmers deal with cotton pest outbreaks. In terms of coping strategies, the BCI program would likely not have a significant role in directly supporting the majority of the coping strategies examined as part of the farming survey. For instance, the BCI standard does not have specific requirements or provisions that would directly facilitate postponing debt payments, switching crops and finding wage labor. As it pertains to switching crops, farmers who adopt the BCI standard may be more compelled to continue farming cotton to pay back their investment in time and resources to implement the standard. Changing farming practices may be the only exception as the BCI program provides cotton farmers with training to adopt more sustainable farming practices. More specifically, some of the water insecurity coping strategies discussed during the farmer focus group discussions could be supported by BCI training provided on water use efficiency.

It must be noted that the qualitative information collected in 2016 via the farmer focus groups and subsequently in 2017 via the farming survey, to provide context for the study area, is likely to remain relevant into the distant future as the Adoni Mandal is located in a drought prone area (Farmer Focus Groups, personal communication, March 2016). According to Srinivasa Rao et al. (2016), who examined rainfall data collected between 1900 to 2014, rain fed areas in India experience three to four drought years every decade (with two to three being of moderate intensity and one to two being of severe intensity).[43] Although precipitation shortfalls and droughts in the Adoni Mandal have persisted since 2016 till February 2021, the Monsoon rains reached the Adoni Mandal on time in July 2021 indicating more favorable growing conditions for cotton growers (Express News Service, 2021; Rao, 2019; Reddy, 2018; Sudhakar, 2019, 2020, 2021). Nevertheless, the study area is an arid and drought prone zone where parts of the Adoni Mandal was described by a farmer focus groups "as dry as the driest parts of the Thar Desert in Rajasthan" (Farmer Focus Groups, personal communication, March 2016).

Climate change projections indicate that precipitation shortfalls and droughts will continue to challenge cotton farmers in the Adoni Mandal. Guhathakurta et al. (2020) reports that the majority of rain stations in the Kurnool District, where the Adoni Mandal is located, show a decreasing trend in the frequency of heavy rainfall days based on precipitation data collected between 1989 and 2018. Furthermore, Rama Rao et al. (Rama Rao et al., 2013) projects that rainfall in the Kurnool District is expected to decrease in July between 2021 to 2050 and 2071 to 2098 relative to rainfall received between 1961 and 1990. The drought proneness of the Kurnool District was estimated to be 10 to 15% between 1961 and 1990, based on incidences of moderate to severe droughts during this time period, which is expected to decrease by less than 1% between 2071 and 2098 (Rama Rao et al., 2013). Although precipitation and drought projections specific to the Adoni Mandal were not found, a drought monitoring study conducted by the Andhra Pradesh Space Applications Centre (APSAC) Agriculture & Soils Division reported that the Normalized Difference

[43] Moderate and severe drought are characterized respectively by 26 to 50% less rainfall and more than 50% less rainfall compared to the climatological normal over a specific area (Gore et al., 2010).

Vegetation Index (NDVI) for the Adoni Mandal measured using remote sensing imagery taken bi-weekly in July from 2015 to 2020 is categorized as severe, indicating that the study area likely experienced drought during this period (Andhra Pradesh Space Applications Centre, 2020).

5.2 BCI Training Effectiveness

The BCI program offers training to farmers that want to grow BCI verified cotton. Their capacity building efforts is their most direct pathway to affect the general resilience of farming systems. For this reason, the farmers surveyed were asked if they were part of a BCI learning group, if they participated in training sessions across 11 topics and whether they would implement the lessons learned. [44] Training on cotton farming topics was linked to farming and business practices to examine differences in their adoption between farmers who were trained and similar farmers who were not.

5.2.1 Training Participation and Implementation

The farmers surveyed were categorized as participating in the BCI program if they stated that they are part of a BCI learning group or attending BCI training sessions. A total of 191 farmers surveyed responded that they are part of a BCI learning group and 14 farmers stated that they attended BCI training without being part of a BCI learning group. Attendance ranged from 18% to 76% out of 205 farmers participating in the BCI program and only 3% to 29% of attendees indicated a willingness to implement the lessons learned (see Table 9). Training on integrated pest management, soil conservation and fertility and health and safety were better attended while farmers who attended training on natural conservation, water use efficiency and integrated pest management were more likely to implement the lessons learned.

[44] The respondents were asked questions on training attendance, implementation and purveyor related to the following training topics aligned with the BCI standard production criteria: Integrated Pest Management, Soil Conservation/Fertility, Water Use Efficiency, Natural Conservation, Decent Work-Related Issues (labor and child labor rights), Health and Safety, Fiber Quality, Record Keeping for the Farm, Marketing Support (prices, contracts, etc.), Financial Management and Literacy.

Table 9 – BCI program training attendance and willingness to implement lessons learned

BCI Training Topics	Attendance (% of treatment farmers)		Implementing Lessons Learned (% of farmers who attended)	
	Total	Percentage[a]	Total	Percentage[b]
Integrated Pest Management	160	78	33	21
Water Use Efficiency	96	47	23	24
Soil Conservation/Fertility	148	72	26	18
Natural Conservation	89	43	26	29
Decent Work-Related Issues	46	22	4	9
Health and Safety	136	66	20	15
Fibre Quality	50	24	3	6
Record Keeping for the Farm	54	26	2	4
Marketing Support	80	39	5	6
Financial Management	57	27	4	7
Literacy	36	18	1	3
Overall Average	**86**	**42**	**17**	**13**

[a] The percentage is based on total attendance divided by the total number of treatment farmers (205).
[b] The percentage is based on the number of farmers willing to implement the lessons learned divided by the total attendance for a training topic.

The majority of the treatment farmers, 184 out of 205, attended at least one training topic. Close to half, or 87 farmers, attended training on 3 to 4 topics and only 26 farmers attended all 11 training topics (see Table 10). Farmers who attended training on more than one training topic did not show a greater willingness to implement the lessons learned and no clear correlations were observed between the two. A surprising 10 of 12 farmers who attended one training topic were willing to implement the lessons learned on health and safety (6 farmers), IPM (3 farmers) and natural conservation (1 farmer). Most of the farmers willing to implement lessons learned attended 4 training topics. These farmers were primarily willing to implement lessons on IPM (20 farmers), soil conservation (19 farmers), natural conservation (19 farmers) and water use efficiency (16 farmers). None of the farmers who attended training on all 11 topics indicated a willingness to implement the lessons learned.

Table 10 – Number of training topics attended and willingness to implement lessons learned

	Attendance	Willing to Implement Lessons Learned

Number of Training Topics Attended	Total	Percentage[a]	Total	Percentage[b]
1	12	7	10	83
2	13	7	4	31
3	45	24	2	4
4	42	23	20	48
5	17	9	3	18
6	8	4	0	0
7	2	1	1	50
8	3	2	0	0
9	6	3	0	0
10	10	5	1	10
11	26	14	0	0

[a] The percentage is based on the number of farmers who attended 1 to 11 training topics divided by the number of farmers who attended at least one training topic (184).
[b] The percentage is based on number of farmers willing to implement the lessons learned divided by the number of farmers who attended 1 to 11 training topics.

The number farmers who attended training sessions and were willing to implement lessons learned is low. This result is demonstrated by 19 farmers who commented that they were not interested (3 farmers) or planning on implementing the lessons learned (7 farmers). Some farmers referred to implementing the training as too risky (2 farmers) or potentially time consuming (1 farmers). One farmer claimed that no information was given while 4 respondents denied the knowledge shared during the training sessions. One respondent who attended training sessions on all 11 training topics stated "I have attended the meeting but I am not implementing the processes that they have said because it is highly time consuming and the risk factor is high. Up to some extent I follow the teachings which are possible to implement." Only 3 farmers indicated a willingness for partial implementation of the training.

Based on the results obtained, we can expect that a small fraction of the farmers participating in the BCI program will adopt farming and business practices learned from attending BCI training. This indicates that the BCI program is not being implemented effectively to enable more sustainable practices and enable the general resilience of their farming operations in the study area. It also indicates that attributing the adoption of more sustainable and resilient farming and business practices to BCI training is tenuous. Therefore, the BCI program has a limited effect on the general resilience of farming systems via their capacity building efforts in the study area.

Nevertheless, the BCI program could influence farming and business practices not only via its direct training efforts. For instance, access to more lucrative cotton markets, by producing verified BCI cotton, could provide financial incentives for farmers to adopt farming practices that are compliant with the BCI standard. Consequently, more details on whether and how the BCI program is affecting the farming and business practices of cotton farmers in the study area can be insightful for understanding how it is affecting the general resilience of farming systems so that insights on implementing AVSS that build farming resilience can be derived.

5.2.2 Farming Differences

The BCI training effectiveness was further examined by comparing the farming and business practices of farmers who attended BCI training and farmers that are not part of a BCI learning group or did not attend BCI training. The comparison was undertaken by matching similar treatment and control farmers along specific household and farm characteristics (or matching covariates – see Appendix 2 – Covariate Selection and Propensity Score Matching for more information), using kernel matching, to compare their farming and business practices associated with relevant training topics and resilience dimensions and indicators of the AVSS resilience analytical framework (see Figure 16).

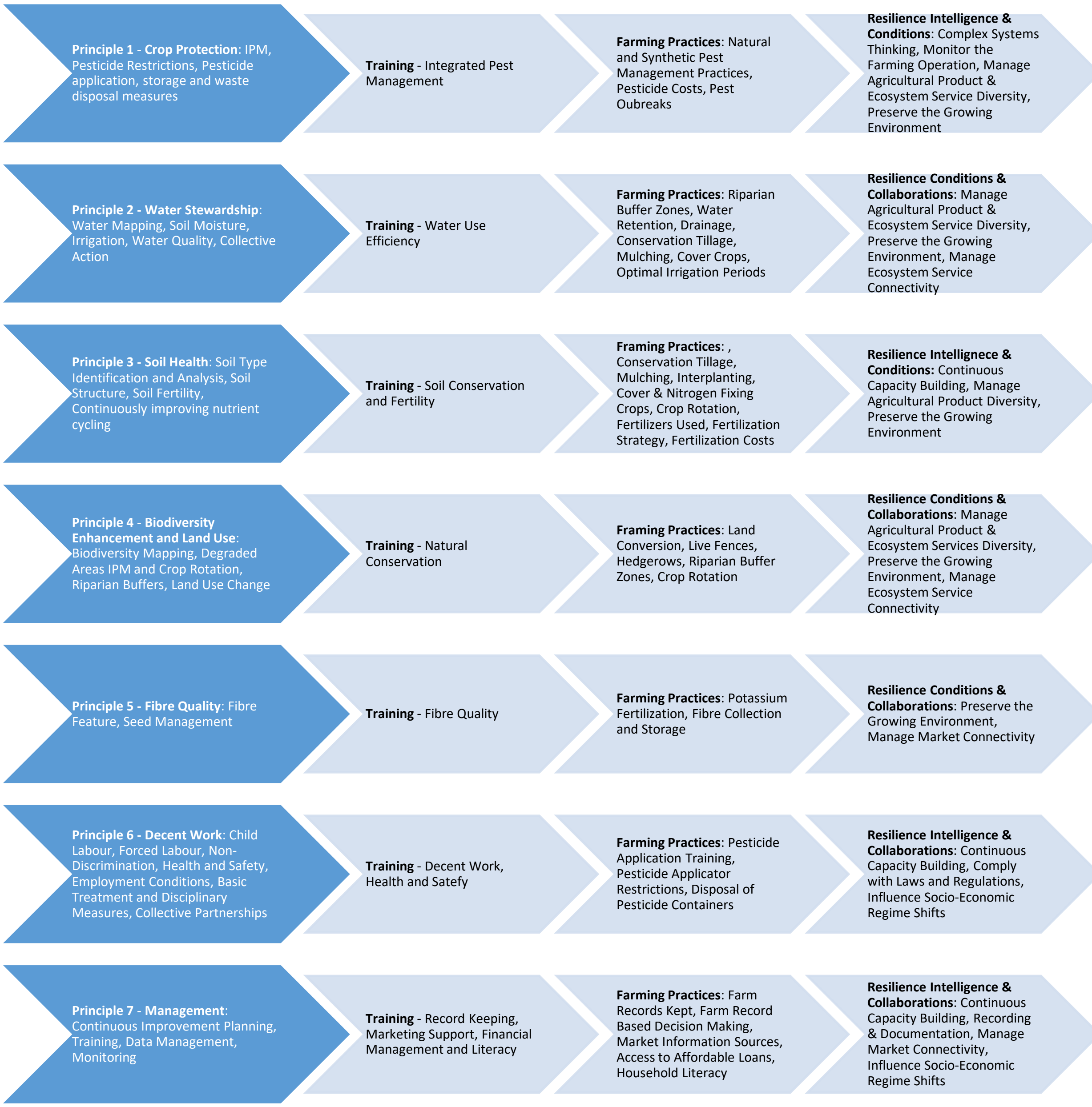

Figure 16 – The BCI program impact pathways in the Adoni Mandal

The number of farmers attending BCI training on different topics varied which resulted in a different number of matched treatment and control farmers for each training topic examined (see Table 11). Farming and business practices that can achieve multiple objectives were examined more than once across the training topics. For instance, conservation tillage can preserve soil moisture and prevent erosion which supports both water and soil conservation and its practice was therefore linked to water use efficiency and soil conservation and fertility training effectiveness.

Table 11 – Number of matched treatment and control farmers per training topic

Training Topics	Number of Matches[a]
Integrated Pest Management	153 matches out of 160 attendants
Water Use Efficiency	94 matches out of 96 attendants
Soil Conservation/Fertility	142 matches out of 146 attendants
Natural Conservation	87 matches out of 89 attendants
Decent Work-Related Issues	N/A[b]
Health and Safety	134 matches out of 136 attendants
Fibre Quality	47 matches out of 50 attendants
Record Keeping for the Farm	52 matches out of 52 attendants
Marketing Support	74 matches out of 80 attendants
Financial Management	55 matches out of 57 attendants
Literacy	36 matches out of 36 attendants

[a] The total matches is the number of treatment farmers that remained in the area of common support to be matched with composites of control farmers along specific covariates using kernel matching.
[b] None of the farming survey information collected could be linked to the decent work related issues training.

The analysis, which is presented in accordance with the seven principles of the BCI standard, allowed for a closer assessment of the BCI program and its potential effects on farming and business practices that can support farming resilience by primarily identifying the ones implemented less by farmers who attended BCI training compared to a counterfactual or farmers that are not participating in the BCI program. To ensure that the observations were not due to randomness, the differences in the mean implementation of agricultural or business practices between matched treatment and control farmers, which were statistically significant with a probability value of 10% or less, were given more attention. The results obtained from the training effectiveness analysis are described and discussed in the subsections below. Findings that were statistically significant with a probability value of 10% or less are italicized in the result tables.

5.2.2.1 ***Integrated Pest Management Training***

To implement Principle 1 – Crop Protection of the BCI standard, which consists of adopting IPM practices, restricting synthetic pesticide use and practicing health and safety measures for its application, storage and waste disposal, IPM training is provided by the BCI program. To examine the linkages between the IPM training, farming practices and the AVSS resilience analytical framework, differences in natural pest management and synthetic pesticide use between treatment and control farmers were ascertained (see Table 12). Using natural pest management techniques requires leveraging natural environments to prevent pest outbreaks requiring pest monitoring and complex systems thinking. All measures that prevent or minimize the use of synthetic pesticides will contribute to maintain the growing environment by preventing toxic effects and pesticide resistances which can result in more frequent and persistent pest outbreaks (Oosthoek, 2013; Søgaard Jørgensen et al., 2020; Yadav et al., 2015). Some crop protection measures can also contribute to crop and ecosystem service diversification, both of which can support farming resilience.

Table 12 – Crop protection practices and AVSS resilience analytical framework linkages

Crop Protection Practices	Resilience Intelligence[a]		Resilience Conditions[b]		
	1	5	7	9	10
Natural Pest Management					
Use of natural pesticides (bio-control agents, pheromones and hormones)					●
Use of biological control methods (e.g. parasitoids, ladybugs)	●			●	●
Monitoring crops for pests, crop damage and beneficial insects		●			
Catch manually crop pests	●				●
Use of pest trap crops, border crops, or intercrops that act a physical barrier to pests and support beneficial insects.	●		●	●	●
Use of crop rotation to reduce weeds			●		●
Use of mechanical means to control pests (i.e. destroying pupae by tilling)					●
Synthetic Pesticide Use					
Limit applications of one class of insecticide				●	●
Rotate insecticide groups				●	●
Use least disruptive insecticides to beneficial insects	●			●	●
Use registered pesticides for targeted pests					●
Apply correct pesticide amount					●
Apply pesticide at the right times with a withholding period					●
Banned pesticides are not used				●	●

[a]Resilience Intelligence Indicators: 1 - Complex Systems Thinking, 5 – Monitoring the Farming Operation
[b]Resilience Conditions Indicators: 7 – Managing the diversification of agricultural products, 9 – Managing the diversification of ecosystem services, 10 – Preserving the growing environment.

Slightly more treatment farmers used synthetic pesticides in the June 2016 to May 2017 production year while there were no differences observed between groups implementing natural pest management practices (see Table 13). Differences in specific natural and synthetic pest management practices were also ascertained. Noticeably more treatment farmers use natural pesticides and crop rotation to reduce weeds, while more control farmers monitor their crops for pests, crop damage and beneficial insects. In terms of synthetic pesticide use, noticeably more treatment farmers limited applications of one class of pesticides, rotated insecticide groups, used registered pesticides for targeted pests, applied correct amounts of pesticides while more control farmers rotated insecticide groups and did not use banned pesticides in the June 2016 to May 2017 production year. In addition to these differences, less treatment farmers experienced pest outbreaks in the June 2016 to May 2017 production year (15.7% versus 21.5%) while incurring on average less synthetic pesticide costs (33,618 INR versus 40,785 INR a difference of INR 7,167 or approximately USD $94.00).

Table 13 – Natural pest management and synthetic pesticide use differences between farmers who did and did not attend BCI integrated pest management training

Crop Protection Practices (153 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Natural Pest Management	**49**	**32%**	**49**	**32%**	**0.0%**
*Use of natural pesticides (bio-control agents, pheromones and hormones)****	*32*	*20.9%*	*17*	*11.0%*	*9.9%*
Use of biological control methods (e.g. parasitoids, ladybugs)	4	2.6%	9	6.0%	-3.4%
*Monitoring crops for pests, crop damage and beneficial insects***	*14*	*9.2%*	*25*	*16.1%*	*-7.0%*
Use of pest trap crops, border crops, or intercrops that act a physical barrier to pests and support beneficial insects[a]	4	2.6%	2	1.2%	1.4%
*Use of crop rotation to reduce weeds****	*28*	*18.3%*	*13*	*8.8%*	*9.5%*
Use of mechanical means to control pests (i.e. destroying pupae by tilling)	1	0.7%	0	0.2%	0.4%
Catch manually crop pests	0	0.0%	1	0.7%	-0.7%
Synthetic Pesticide Use	**97**	**63%**	**90**	**59%**	**4%**
*Limit applications of one class of insecticide***	*20*	*13.1%*	*11*	*7.0%*	*6.1%*
*Rotate insecticide groups****	*20*	*13.1%*	*37*	*24.0%*	*-10.9%*

Crop Protection Practices (153 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Use least disruptive insecticides to beneficial insects	5	3.3%	3	1.8%	1.4%
*Use registered pesticides for targeted pests**	*56*	*36.6%*	*44*	*29.0%*	*7.6%*
*Apply correct pesticide amount***	*72*	*47.1%*	*57*	*37.1%*	*9.9%*
Apply pesticide at the right times with a withholding period	37	24.2%	35	23.1%	1.1%
*Banned pesticides[b] are not used****	*2*	*1.3%*	*9*	*6.0%*	*-4.7%*

Difference in means is + when treated average is greater and – when treated average is lower than untreated average. *, **, *** denotes statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

[a] These can include castor, sunflower, bendi or okra, maize, sorghum and pearl millet.

[b] The following 12 banned pesticides that were listed in the survey: Aldrin, chlordane, chloredecone, dieldrin, DDT, endrin, heptachlor, hexachlorobenzene, hexachlorocyclohexane, lindane, mirex and toxaphene.

More pronounced crop protection differences were expected between the matched treatment and control groups, indicating that the IPM training was mostly ineffective. Despite being more inclined to use natural pesticides and crop rotation, very few treatment farmers monitor their agricultural fields and use biological control methods to protect their crops indicating that shifts in agricultural practices that require complex systems thinking, such as leveraging pest predators and border crops instead of relying on chemical inputs or mechanical interventions, can be more difficult to adopt (Søgaard Jørgensen et al., 2020). This observation is also supported by the limited number of farmers who apply least disruptive insecticides to beneficial insects, which would require knowing and the ability to identify beneficial insects. Another striking result was the limited number of farmers that do not use banned pesticides which have significant ecological and health and safety impacts on the resilience conditions of the farm (Yadav et al., 2015). Despite these differences and similarities, less treatment farmers experienced pest outbreaks in the June 2016 to May 2017 production year while spending slightly less on synthetic pesticides, indicating that their crop protection approach could be more effective compared to the control group.

5.2.2.2 ***Water Use Efficiency Training***

To implement Principle 2 - Water Stewardship of the BCI standard, which consists of mapping water resources, maintaining soil moisture, adopting water conserving irrigation practices, preventing water quality impacts and collective action for sustainable water resource management, water use efficiency training was provided. To examine the linkages between the water use efficiency training, farming practices and the AVSS resilience analytical framework, differences in surface water protection, water retention and drainage, soil moisture and irrigation measures between treatment and control farmers were ascertained (see Table 14). Establishing riparian buffer zones can protect surface water from agricultural runoff, which can enhance the diversification of ecosystems services and assist with managing the farm's connectivity with its surrounding natural environments. Water retention and drainage structures within agricultural fields can assist with adaptation to scarce or excess precipitation. Maintaining soil moisture preserves the growing environment as it maintains biological and structural properties essential to maintain soil fertility. Excess irrigation can lead to soil salinization, which can negatively affect the growing environment (E. M. Bennett et al., 2014).

Table 14 – Water stewardship practices and AVSS resilience analytical framework linkages

Water Stewardship	Resilience Conditions[b]			Resilience Collaborations[c]
	7	9	10	13
Surface Water Protection				
Riparian Buffer Zones		•		•
Water Retention and Drainage				
Bunds				•
Water Retention Structures				•
Drainage			•	•
Soil Moisture				
Conservation Tillage			•	
Mulching			•	
Cover Crops	•		•	
Irrigation				
Optimal Irrigation Periods			•	

[b]Resilience Conditions Indicators: 7 – Managing the diversification of agricultural products, 9 – Managing the diversification of ecosystem services, 10 – Preserving the growing environment.
[c]Resilience Collaborations Indicator: 13 – Manage ecological connectivity

Very few of the matched farmers (only 2 treatment farmers and 1 control farmer) implement riparian buffer zones (see Table 15). More treatment farmers implemented measures to retain water using bunds and drain water from their fields using drainage channels or diversion ditches, while more control farmers use water retention structures on their fields to retain rainwater for irrigation (see Table 15). In terms soil moisture practices, more treatment farmers implement conservation tillage and cover crops, while very farmers in both groups use mulching. Only 18 and 20 farmers from the matched treatment and control groups respectively irrigate their cotton mostly with water sourced from retention structures (Treatment – Canal = 4, Water Retention Structure = 14 Control – Canal = 4, Water Retention Structure = 16). Very few of these farmers irrigate their cotton fields at optimal periods (first square to first flower - 30 to 50 days after planting and first flower to peak bloom - 50 to 70 days after planting) to conserve water and optimize fiber growth and quality.

Table 15 – Water stewardship differences between farmers who did and did not attend BCI water use efficiency training

Water Stewardship Measures (94 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Surface Water Protection					
Riparian Buffer Zones	2	2.1%	1	1.1%	1.0%
Water Retention and Drainage					
Bunds	40	42.6%	38	40.4%	2.2%
Water Retention Structures	14	14.9%	16	16.9%	-2.0%
*Drainage****	*29*	*30.9%*	*9*	*10.0%*	*20.9%*
Soil Moisture					
*Conservation Tillage***	*31*	*33.0%*	*19*	*20.1%*	*12.9%*
Mulching	1	1.1%	2	2.2%	-1.1%
*Cover Crops****	*49*	*52.1%*	*23*	*24.8%*	*27.3%*
Irrigation Practice & Timing	**18**	**19%**	**20**	**21%**	**2.1%**
Emergence to first square (0 to 30 days after planting)	2	2.1%	5	5.2%	-3.0%
First square to first flower (30 to 50 days after planting)	1	1.1%	1	0.8%	0.3%
First flower to peak bloom (50 to 70 days after planting)	3	3.2%	1	1.6%	1.6%
Peak bloom to open bolls (70 to 90 days after planting)	7	7.4%	7	7.2%	0.2%

Difference in means is + when treated average is greater and – when treated average is lower than untreated average. *, **, *** denotes statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

The low adoption of water conservation measures by the treatment group coupled with the fact that water scarcity is the main resilience threat to cotton farming in the study area indicates that the BCI training on water use efficiency was ineffective. For instance, water retention structures in the form of earthen bunds are implemented by a little more than 40% of the treatment farmers. Even implementing cover crops which have soil fertility and soil moisture retention as well as crop diversification benefits was low. Other practices such as more permanent water retention structures and mulching may not have been possible due to a lack of resources in the form of building materials and adequate biomass. Even farmers who cultivate irrigated cotton could improve water use efficiency via better irrigation timing.[45] Although unusually dry conditions may be influencing farmers to irrigate mostly at the end of plant growth, on cotton plants that have yield potential, the optimal irrigation periods for yields and fiber quality is between 30 to 70 days after planting. Nevertheless, water conservation measures are important if there are water resources to conserve. For instance, the lack of water bodies in the study area provides an explanation for the low adoption of riparian buffer zones. Farmers who cultivate rain fed cotton rightly point out that precipitation, which has been declining over time, is not within their control but this argument bolsters the need for water scarcity adaptation strategies (Farmer Focus Groups, personal communication, March 2016). As water availability is the main resilience threat in the study area, a greater adoption of water use efficiency and water stewardship measures was expected in both sample groups.

5.2.2.3 ***Soil Conservation and Fertility Training***

To implement Principle 3 – Soil Health of the BCI standard, which consists of identifying and analyzing the soil types and fertility of the farming operation and implementing measures that

[45] Most of the farmers in both groups irrigate their crop during peak bloom to open bolls (70 to 90 days after planting). During this stage of plant growth, water stress could result in the loss of bolls and affect fiber quality (length and micronaire) but the cotton plants should be allowed to become water stressed after boll opening to improve harvesting conditions (Cotton Incorporated, 2017).

maintain structure and fertility, soil conservation and fertility training is provided by the BCI program. To examine the linkages between the soil conservation and fertility training, farming practices and the AVSS resilience analytical framework, differences in soil erosion prevention, soil fertility maintenance, fertilization sources and decision-making approaches between treatment and control farmers were ascertained (see Table 16). All measures that maintain the soil health of agricultural fields contribute to preserving the growing environment. Soil erosion protection practices such as conservation tillage and mulching can contribute to adapting to extreme weather events by preventing soil erosion and maintaining soil moisture. Interplanting and cover crops can also prevent soil erosion while diversifying crop production, an adaptation strategy that can mitigate against crop losses. Soil fertility can be maintained by planting nitrogen fixing crops and rotating crops which can also diversify crop production. Using natural versus chemical fertilizers can affect soil health over the long term. For instance, excess chemical fertilizers can negatively affect soil microorganisms that support soil health (Tripathi et al., 2020). Farmers in Madire confirmed that excessive fertilizer use is negatively impacting the health of their soils by stating: “Earlier we were not using fertilizers. Now we use urea, DAP (Diammonium Phosphate). These days we are using more urea. That is why the soil is degrading” (Farmer Focus Groups, personal communication, March 2016). For this reason, fertilization decisions need to be based on the best available knowledge on soil conditions and crop requirements.

Table 16 – Soil health practices and AVSS resilience analytical framework linkages

Soil Health Practices	Resilience Intelligence[a]		Resilience Conditions[b]
	4	7	10
Soil Erosion Protection			
Conservation Tillage			•
Mulching			•
Interplanting		•	•
Cover Crops		•	•

Soil Health Practices	Resilience Intelligence[a]		Resilience Conditions[b]
	4	7	10
Soil Fertility			
Nitrogen fixing or perennial plants		•	•
Crop Rotation		•	•
Fertilization Sources			
Natural fertilizers			•
Chemical fertilizers			
Fertilization Decision-Making	•		•

[a]Resilience Intelligence Indicator: 4 – Continuous Capacity Building
[b]Resilience Conditions Indicators: 7 – Managing the diversification of agricultural products, 10 – Preserving the growing environment.

More treatment farmers use nitrogen fixing or perennial plants, while more control farmers use interplanting and crop rotation to prevent soil erosion and maintain soil fertility (see Table 17). Both sample groups almost equally rely on natural and synthetic fertilizers. More treatment farmers tend to apply fertilizers based on general advice and/or professional assessments compared to control farmers who tend to rely more on their own knowledge and experience related to the nutrients in their soils. There were no significant differences in fertilizer costs incurred during the June 2016 to May 2017 production year (Natural Fertilizers Cost + Synthetic Fertilizer Cost = Total Fertilizer - Treatment Farmers: 12,135 INR + 35,687 INR = 47,822 INR, Control Farmers: 10,737 INR + 33,836 INR = 44,573 INR). Based on the results obtained, opportunities to adopt soil erosion protection and soil fertility practices exist as less than 30% of farmers that attended BCI soil conservation and fertility training implement these measures.

Table 17 – Soil conservation differences between farmers who did and did not attend BCI soil conservation and fertility training

Soil Health Measures (142 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Soil Erosion Protection					
Conservation Tillage	31	21.8%	22	15.6%	6.2%
Mulching	1	0.7%	3	2.2%	-1.5%
*Interplanting****	*21*	*14.8%*	*51*	*36.2%*	*-21.4%*
Cover Crops	10	7.0%	8	5.3%	1.7%

Soil Health Measures (142 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Soil Fertility					
*Nitrogen fixing or perennial plants****	*40*	*28.2%*	*21*	*14.9%*	*13.3%*
*Crop Rotation****	*17*	*12.0%*	*40*	*28.5%*	*-16.5%*
Fertilization Sources					
Natural fertilizers	129	90.8%	132	93.0%	-2.2%
*Chemical fertilizers****	*139*	*97.9%*	*129*	*90.7%*	*7.2%*
Fertilization Decision-Making					
*Application is insufficient and based on what can be can afforded or obtained***	*32*	*22.5%*	*18*	*12.9%*	*9.7%*
*Application based on personal knowledge of soil nutrients and cotton plant requirements****	*23*	*16.2%*	*65*	*45.6%*	*-29.4%*
*Application based on regional advice for cotton****	*93*	*65.5%*	*63*	*44.5%*	*21.0%*
*Application based on professional assessment of soils and cotton plant requirements****	*46*	*32.4%*	*23*	*16.1%*	*16.3%*

Difference in means is + when treated average is greater and – when treated average is lower than untreated average. ***
*, **, *** denotes statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

As soil health is fundamental for preserving the growing environment, a greater adoption of soil conservation and fertility measures among the treatment group was expected. More control farmers practice interplanting and crop rotation while more treatment farmers rely on nitrogen fixing plants as well as more diverse and sounder sources of information for making fertilization decisions. Interplanting and crop rotation, both promoted by the BCI standard to maintain soil health, can also enable adaptation to varying growing environments such as changing climatic conditions and pest abundance. For this reason, a greater adoption of measures, such as interplanting, cover crops and crop rotation, which can simultaneously enhance soil health and diversify crops and enable adaptation was expected within the treatment group. Although more treatment farmers use nitrogen fixing plants to fertilize their agricultural fields, both groups almost equally rely on natural as well as chemical fertilizers to maintain soil fertility. Treatment farmers tend to rely on more sources of information to make fertilization decisions, indicating an openness for continuous capacity building pertaining to fertilizer application. Nevertheless, despite the importance of soil health to agricultural production, the farmers who attended BCI soil conservation and fertility training implement on average less soil erosion prevention and soil fertility maintenance practices examined than the matched control farmers, conveying that the soil conservation and fertility training was mostly ineffective.

5.2.2.4 ***Natural Conservation Training***

To implement Principle 4 - Biodiversity Enhancement and Land Use of the BCI standard, which consists of mapping biodiversity, restoring degraded areas, adopting integrated pest management, crop rotation, establishing riparian buffers zone and implementing land use change practices that minimize biodiversity impacts, the BCI program offers training on natural conservation. To examine the linkages between the natural conservation training, farming practices and the AVSS resilience analytical framework, differences in land use practices and natural conservation measures between treatment and control farmers were ascertained (see Table 18). Land use practices that enhance natural environments can diversify ecosystem services and enhance ecological connectivity both of which can support agricultural production (TEEB, 2015). Natural conservation measures such as maintaining natural habitats on agricultural lands as well as crop rotation can support biodiversity (TEEB, 2015).

Table 18 – Biodiversity enhancement and land use practices and AVSS resilience analytical framework linkages

Biodiversity enhancement and land use practices	Resilience Conditions[a]			Resilience Collaborations[b]
	7	9	10	13
Land Use				
Converted cotton field to temporary fallow or set-aside		●		●
Converted natural area to cotton field			●	
Natural Conservation				
Live Fences		●		●
Hedgerows		●		●
Riparian Buffer Zones		●		●
Crop Rotation	●		●	

[a]Resilience Conditions Indicators: 7 – Managing the diversification of agricultural products, 9 – Managing the diversification of ecosystem services, 10 – Preserving the growing environment.
[b]Resilience Collaborations Indicator: 13 – Managing ecological connectivity.

Only one farmer in both groups stated converting cotton cultivation area into temporary fallow or a set-aside in the June 2016 to May 2017 production year (see Table 19). None of the treatment farmers converted natural areas for cotton cultivation area in the same production year, while 12.6% of the control group did. Very few farmers in both groups implement live fences, hedgerows and riparian buffer zones. More control farmers implement crop rotation which can prevent pest and disease buildup (Better Cotton Initiative, 2018).

Table 19 – Land use and natural conservation measure differences between farmers who did and did not attend BCI land use and natural conservation training

Biodiversity Enhancement and Land Use (87 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Land Use					
Converted cotton field to temporary fallow or set-aside	1	1.1%	1	1.1%	0.0%
*Converted natural area to cotton field****	*0*	*0.0%*	*11*	*12.6%*	*-12.6%*
Natural Conservation					
Live Fences	2	2.3%	1	1.0%	1.3%
*Hedgerows***	*0*	*0.0%*	*1*	*0.6%*	*-0.6%*
Riparian Buffer Zones	2	2.3%	1	1.3%	1.0%
*Crop Rotation****	*13*	*14.9%*	*25*	*28.5%*	*-13.6%*

Difference in means is + when treated average is greater and – when treated average is lower than untreated average. ***
*, **, *** denotes statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

Despite the limited number of treatment farmers who implement natural conservation measures, the BCI natural conservation training may have had some effect on land use practices that enhance biodiversity and natural environments. None of the farmers who attended BCI natural conservation training cleared natural areas for cotton cultivation. Nevertheless, despite the inclusion of crop rotation in the biodiversity mapping requirement of the BCI standard, fewer farmers who attended BCI natural conservation training use this practice compared to control farmers (Better Cotton Initiative, 2018). Furthermore, a negligible number of treatment farmers implemented the agricultural practices examined to conserve natural environments and biodiversity. Consequently, the BCI program likely had a very little effect on farmers that attended their natural conservation training. This finding is supported by information collected during the farmer focus group discussions, which conveyed that farmers are willing to plant trees if they get external support in terms of access to saplings and sufficient water for them to grow and sustain themselves.

5.2.2.5 ***Fiber Quality Training***

To implement Principle 5 - Fiber Quality of the BCI standard, which consists of enabling better fiber features and better seed management, fiber quality training is provided by the BCI program. Linkages between the fiber quality training, farming practices and the AVSS resilience analytical framework were examined via cotton storage bag materials and locations as well as potassium fertilization differences between treatment and control farmers (see Table 20). Cotton fiber quality is affected by cultivation practices, such as fertilization and irrigation practices, but also by how the product is stored. Market access can significantly be affected by the quality of cotton fiber that is ultimately sold, which is dictated by its physical properties, such as staple length, but also its impurities or trash content. Therefore, fiber quality can significantly impact the market access and connectivity of cotton farmers in the study area.

Table 20 – Fiber quality and AVSS resilience analytical framework linkages

Fiber Quality Practices	Resilience Collaborations[a]	Resilience Collaborations[b]
	10	15
Farming Practices		
Potassium Fertilization	●	●
Storage Practices		
Storage bag material	●	●
Storage location	●	●

[a]Resilience Conditions Indicator: 10 – Preserving the growing environment
[b]Resilience Collaborations Indicator: 15 – Managing market connectivity.

The farmers who attended the BCI training were more inclined to apply potassium fertilizers to their cotton fields for improving fiber quality (68.1% of the treatment farmers compared to 24.8% of the control farmers) (see Table 21). The majority of the treatment farmers store their harvest in polypropylene bags, while control farmers use a greater variety of bag materials to store their cotton. White cotton storage bags are ideal for storing cotton fibers as there is little potential for contamination, readily available polypropylene bags can be a source of contamination (Sluijs & Hunter, 2017). Both sample groups store their cotton at home instead of selling the cotton right away. Storing cotton in the home will contaminate the harvest over time unless care is taken.

Table 21 – Cotton fiber storage differences between farmers who did and did not attend BCI fiber quality training

Cotton Fiber Storage Practices (47 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Fertilization					
*Potassium application for improved fiber quality****	*32*	*68.1%*	*12*	*24.8%*	*43.3%*
Storage Bag Material					
Cotton Bags	0	0.0%	2	4.7%	-4.7%
Jute	0	0.0%	0	0.9%	-0.9%
Plastic Bags	0	0.0%	7	15.0%	-15.0%
Polyester Bags	4	8.5%	15	31.4%	-22.9%
*Polypropylene Bags****	*43*	*91.5%*	*22*	*47.5%*	*44.0%*
Storage Location					
Home	45	95.7%	46	97.9%	-2.1%
Sold right away	1	2.1%	0	0.0%	2.1%

Difference in means is + when treated average is greater and – when treated average is lower than untreated average. ***
*, **, *** denotes statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

Enhancing and maintaining fiber is one important pathway for cotton farmers to manage and improve the market connectivity of their farming operations. Better quality product can also translate into better returns which can then be invested to improve farming resilience. Cotton fiber quality starts with the type of cottonseed sown, the cotton plant growing conditions and how the fibers are harvested and stored before they are sold. The BCI standards has a number of requirements and recommendations for improving fiber quality such as fertilization, irrigation and harvesting and storage requirement (Better Cotton Initiative, 2018). Potassium, an important input for fiber length, is applied by the treatment group more commonly than the control group, indicating that fiber quality training may have had some positive effects on the farmers in attendance. Nevertheless, the treatment group uses only contaminating bag materials to store their cotton fiber, which is contradictory to the BCI standard which specifies "no polypropylene, polyethylene or any synthetic bags are used during the harvesting of cotton by hand, nor during storage and transportation (Better Cotton Initiative, 2018, p. 69)" as an improvement indicator for small, medium and large farms. Consequently, the BCI fiber quality training yielded mixed results with some fiber quality enhancement practices being implemented when and where feasible.

5.2.2.6 ***Decent Work and Health & Safety Training***

To implement Principle 6 - Decent Work of the BCI standard, which focuses on eliminating child labor, forced labor, workplace discrimination and improving worker health and safety, employment conditions, basic treatment and disciplinary measures as well as establishing collective partnerships, training on decent work and health and safety issues is provided by the BCI program. The survey data collected did not support examining the linkages between decent work training and farming practices. The linkages between health & safety training, farming practices and the AVSS resilience analytical framework, were examined by assessing differences in pesticide training, handling, application and disposal measures between treatment and control farmers (see Table 22). Safe pesticide handling is important as it can result in negative health and ecological impacts (Yadav et al., 2015). It can also ensure that they remain compliant with toxic waste disposal regulations.

Table 22 – Health & Safety and AVSS resilience analytical framework linkages

Health & Safety	Resilience Intelligence[a]	Resilience Collaborations[c]	
	4	16	18
Pesticide Application Training			
Workers using synthetic pesticides are trained	•		
Pesticide Applicator Restrictions			
Workers using synthetic pesticides are healthy and 18 years and older			•
Workers using synthetic pesticides are not pregnant or lactating			•
Disposal of Pesticide Containers			
Synthetic pesticide containers are not used for the household or other purposes		•	
Synthetic pesticide containers are disposed of safely		•	

[a]Resilience Intelligence Indicator: 4 – Continuous capacity building.
[c]Resilience Collaborations Indicators: 16 – Comply with laws and regulations, 18 – Influence socio-economic regime shifts.

With the exception of pesticide container handling and disposal, no major differences were observed between the treatment and control groups pertaining to decent work and health and safety. The proper handling, application and disposal of synthetic pesticides constitutes an important source of injury and illness for cotton farmers in the region (Mancini et al., 2008; Yadav et al., 2015). Very few farmers in both groups provide training for the proper use of synthetic pesticides (see Table 23). Both groups ensure that only workers 18 years and older that are not pregnant or lactating apply synthetic pesticides. There were significant differences between the treatment and control groups related to safe handling and disposal of synthetic pesticide containers.

Table 23 – Synthetic pesticide health and safety practice differences between farmers who did and did not attend BCI health and safety training

Health & Safety (134 Matched Farmers)	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Safe Pesticides Handling (134 Matched Farmers)					
Workers using synthetic pesticides are trained	7	5.2%	10	7.1%	-1.9%
Workers using synthetic pesticides are healthy and 18 years and older	57	42.5%	53	39.3%	3.2%
Workers using synthetic pesticides are not pregnant or lactating	52	38.8%	43	32.4%	6.5%
*Synthetic pesticide containers are not used for the household or other purposes****	*48*	*35.8%*	*31*	*23.0%*	*12.8%*
*Synthetic pesticide containers are disposed of safely***	*48*	*35.8%*	*32*	*24.0%*	*11.8%*

Difference in means is + when treated average is greater and – when treated average is lower than untreated average. *** *, **, *** denotes statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

Since health and safety is an important component of the BCI standard[46], the response level for the safe application, handling and disposal of synthetic pesticides was expected to be higher within the treatment group. The low level of pesticide use training provided to workers by both groups may be due to a lack of reliance on external labor. Some noticeable differences were

[46] There are 5 specific criteria focused on health and safety included in the BCI standard which require access to adequate drinking water, clean places to eat, adequate medical care, health and safety training, identify work hazards to address them and measures to deal with accidents and emergencies (Better Cotton Initiative, 2018).

identified in the proper and safe handling and disposal of synthetic pesticide containers with treatment farmers more likely to not use pesticide containers for other purposes and dispose them safely. With the exception of safely handling and disposing of pesticide containers, the BCI health and safety training was mostly ineffective.

5.2.2.7 ***Record Keeping, Marketing Support, Financial Management and Literacy Training***

To implement Principle 7 – Management of the BCI standard, which focuses on enabling continuous improvement, proper planning, adequate training, better data management and monitoring related to cotton farming operations, training on record keeping, marketing support, financial management and literacy is provided by the BCI program. The linkages between the record keeping, marketing support, financial management and literacy training, farming practices and the AVSS resilience analytical framework were examined by assessing differences in record keeping, cotton price information and affordable loan access as well as household literacy (see Table 24). Keeping records of the farming operation allows farmers to learn from their experiences and adjust their practices to be more resilient. To examine the effectiveness of the BCI marketing support training, access to cotton market information differences between the matched farmers was examined. This information can keep farmers informed and connected with various market channels to sell their product and negotiate their sale price. The financial management of agricultural operations consist of the economic aspects of the farming business. Accessing affordable loans, which conveys a lending entity's perception of a farming operation's profitability, was used to examine the effectiveness of the BCI financial management training. This measure can also convey market connectivity since loan access can be directly linked to cotton production sales involving supply chain stakeholders. Household literacy can facilitate capacity building, which can be instrumental for building resilience intelligence.

Table 24 – Management and AVSS resilience analytical framework linkages

Management	Resilience Intelligence[a]		Resilience Collaborations[b]	
	4	6	15	18
Record Keeping		●		
Sources of Cotton Price Information Accessed	●		●	
Access to Affordable Loans			●	
Household Literacy	●			●

[a]Resilience Intelligence Indicators: 4 – Continuous capacity building, 6 – Recording and documenting
[b]Resilience Collaborations Indicators: 15 – Manage market connectivity, 18 Influence socio-economic regime shifts.

Less than 20% of treatment and control farmers keep records of their farming operations (10 and 9 out of 52 treatment and control farmers respectively), out of which only 60% or less use their records for decision-marking (6 treatment and 4 control farmers) (see Table 25). Most of the farmers who keep records track their fertilizer and pesticide use. Although the majority of the treatment and control farmers rely on one source of cotton price information to sell their cotton, less treatment farmers access cotton price information from more than one source. More control farmers can access affordable loans from formal lending institutions such as private banks and government lending agencies. The household literacy average between the matched treatment and control groups was 1 and 1.2 people per household respectively.

Table 25 – Record keeping, cotton market information and loan access differences between farmers who did and did not attend BCI record keeping, marketing support, financial management and literacy training

Management	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Record Keeping (52 Matched Farmers)	10	19.0%	9	17.0%	2.0%
Fertilizer and pesticide use	9	17.3%	8	14.6%	2.7%
Crop diseases or damage	3	5.8%	1	1.6%	4.2%
*Payments for labor***	*7*	*13.5%*	*2*	*3.6%*	*9.9%*
Cotton production and sales	4	7.7%	2	4.1%	3.6%
Cotton Price Information Accessed (74 Matched Farmers)					
No Sources	1	1.4%	1	1.4%	0.0%
*One Source***	*64*	*86.5%*	*53*	*71.6%*	*14.9%*
*More Than One Source***	*9*	*12.2%*	*20*	*27.0%*	*-14.9%*
Other sources	9	12.2%	7	9.4%	2.8%

Management	Treated		Untreated		Difference in Means
	Total Count	Average	Total Count	Average	
Access to Affordable Loans (55 Matched Farmers)					
Buyer or supply chain stakeholder (processor, input provider, exporter)	12	21.8%	11	20.3%	1.5%
Informal local lender	34	61.8%	29	52.2%	9.6%
*Formal lender (bank, government lending agency)***	*21*	*38.2%*	*30*	*55.1%*	*-16.9%*
Household literacy (36 Matched Farmers)	37	1.0%	42	1.2%	0.2%

Difference in means is + when treated average is greater and – when treated average is lower than untreated average. ***
*, **, *** denotes statistical significance at the 0.10, 0.05 and 0.01 levels, respectively.

Overall there was only one major difference identified between both groups across the surveyed information analyzed. Significantly more control farmers obtain prices from more than one source compared to treatment farmers, indicating that BCI marketing support training was ineffective in convincing treatment farmers to access a greater variety of cotton price information sources. The limited number of farmers in the study area that keep records of their farming operations may be a missed opportunity for them to learn from their year to year experiences, which can assist with building farming resilience. Consequently, the BCI program should prioritize their capacity building efforts on record keeping for cotton operations in the Adoni Mandal. The BCI program could also play a more important role in enabling access to affordable loans among prospective buyers and supply chain stakeholders as well as formal lending agencies such as private and government lending agencies.[47] Although there were no major differences were found in household literacy between both groups, the assessment was limited to 36 farmers who attended BCI literacy training, which resulted in non-optimal balance diagnostics for the kernel matching analysis.[48] Consequently, the results obtained on household literacy differences should be interpreted

[47] Deferring debt payments was the main coping strategy identified by matched treatment and control farmers.
[48] The matching balance diagnostics gave a Ruben's R value outside of 0.5 and 2 indicating that treatment and control farmers could not be properly matched along the matching variables used for the assessment.

with care. Overall the findings indicate that the BCI record keeping, marketing support, financial management training had minimal effects on farmers who attended.

5.2.2.8 ***Building Cotton Farming Resilience***

With some exceptions, the BCI training did not seem to have much of an effect on the farming practices of the farmers who were in attendance. Even where there was higher attendance in some of the training topics such as integrated pest management, soil conservation and fertility and health and safety, there were few major differences in farming practices between the treatment and control groups. As water use efficiency training is directly relevant to address water security, the main resilience threat to cotton farming in the study area, a greater level of adoption of water conservation measures among the farmers who attended BCI the training was expected. Nevertheless, with the exception of drainage practices (useful during times of water excess), conservation tillage and cover crops, all other water use efficiency measures with marked implementation differences between groups and a high level of adoption remains low. These findings are aligned with the results obtained from Section 5.2.1 which concluded that only 13% of farmers who attended BCI training indicated a willingness to implement lessons learned, which is, albeit, distinctively different than implementing farming and business practices examined in Section 5.2.2.

To draw more definitive conclusions on the BCI training effectiveness, it is worth taking a closer look at the farming and business practices found to have more pronounced differences in adoption levels between the treatment and control groups. To this end, the findings obtained from the training effectiveness that had equal or less than a 10% chance of being due to randomness are summarized in Figure 17. The practices shown in quadrant A and B are those where their average implementation is greater among treatment farmers compared to control farmers, while the opposite is true for those practices found in quadrants C and D. Practices located on the figure where the treatment group had a higher average implementation compared to the control group coupled with a higher level of adoption indicates a greater probability that the BCI training could have influenced their adoption. More specifically, the good practices found in quadrant A are those where the treatment group has a greater average implementation and an adoption level of greater than 50%, indicating that the BCI training was probably effective in influencing their adoption. The good practices found in quadrant B are those where the treatment group has a greater average implementation and an adoption level of less than 50%, indicating that the BCI training was potentially effective in influencing their adoption. The good practices found in quadrant C are those where the treatment group has a lower average implementation and an adoption level of more than 50%, indicating that the BCI training was likely inconsequential in influencing their adoption. The good practices found in quadrant D are those where the treatment group has a lower average implementation and an adoption level of less than 50%, indicating that the BCI program was likely ineffective in influencing their adoption. The opposite is true for bad practices where the BCI training was likely ineffective for practices found in quadrant A and probably effective for practices found in quadrant D. It must be noted that the threshold established for characterizing the training effectiveness was arbitrarily chosen based on reviewing the willingness to implement lessons learned and implementation levels of the practices examined. The threshold could have been established at a lower level of adoption but due to potential confounding factors and to keep the assessment more intuitive, a 50% level of adoption threshold was used.

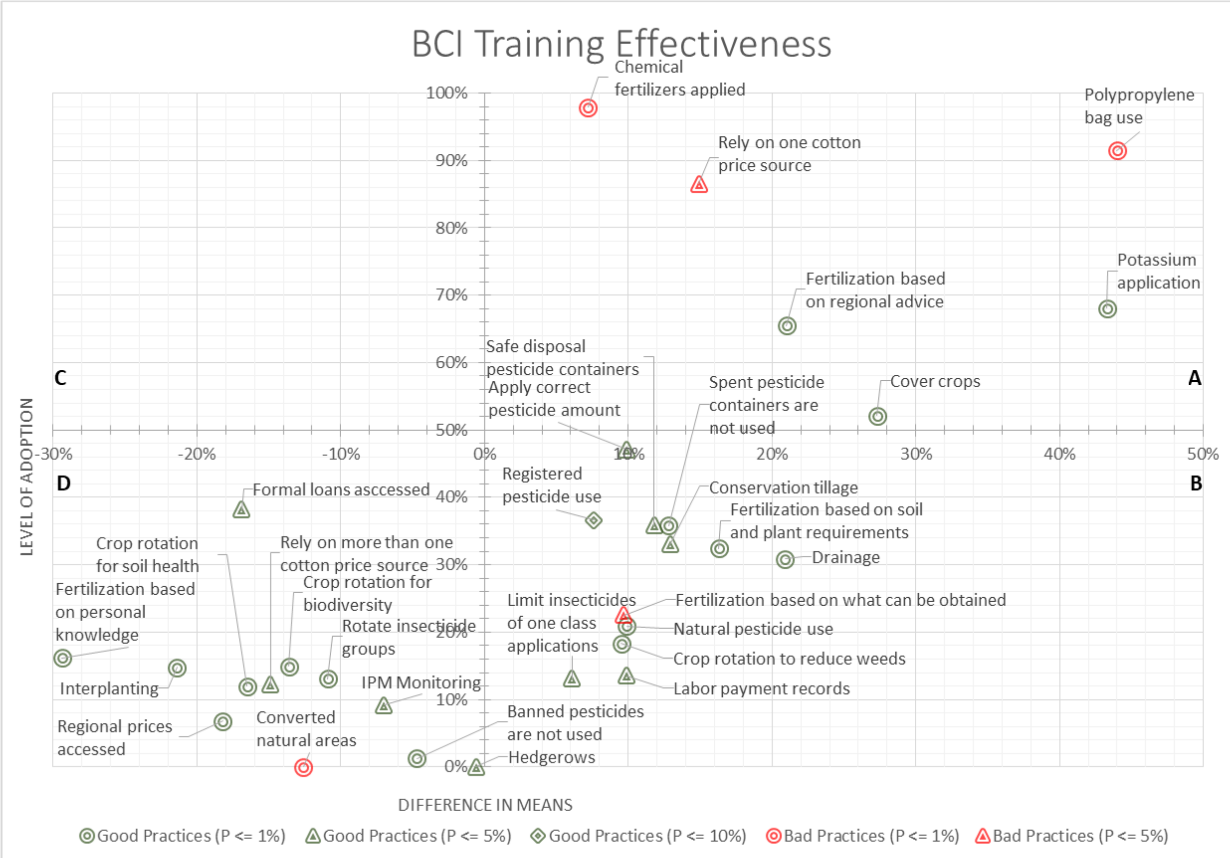

Figure 17 – BCI training effectiveness based on farming practice adoption differences and level of adoption

There were fourteen good practices where the treatment group had a higher implementation average compared to the control group, out of which only three had a level of adoption of more than 50%.[49] The practices located in quadrant A are linked to the continuous capacity building, adaptation strategies, diversifying agricultural products, preserving the growing environment and managing market connectivity indicators of the AVSS resilience analytical framework, all of which can support farming resilience. More specifically, sowing cover crops diversifies agricultural

[49] The good practices 'Cover crops' and 'Fertilization based on experts' were each derived from two similar practices which were combined. More specifically, 'Cover crops' was derived from 'Cover crops' examined in the water use efficiency training and 'Nitrogen fixing or perennial plants' examined in the soil conservation/fertility training. 'Fertilization based on experts' was derived from 'Application based on regional advice for cotton' and 'Application based on professional assessment of soils and cotton plant requirements' in soil conservation/fertility training. In both instances, the practices with the higher level of implementation was selected (in the case of 'Cover crops' – 'Cover crops' in water use efficiency training and for 'Fertilization based on experts' – 'Application based on regional advice for cotton' in Soil conservation and fertility training).

production buffering the farming operation against crop failure (Resilience Intelligence – Adaptation Strategies and Resilience Conditions - Managing agricultural production diversification). Cover crops can also maintain soil moisture and fertility by preventing erosion and potentially replenishing nutrients if they are nitrogen fixing (Resilience Conditions – Preserving the growing environment). For the practices found in quadrant A, we can say that the BCI training likely had a role in raising its level of adoption within the treatment group, which could improve, in one way or another, the general resilience of their cotton farming operations. Nevertheless, market connectivity gains obtained from potassium application, linked to improved cotton fiber quality, may be curtailed by the continued use of polypropylene bags, which introduces impurities or trash content in the final product, potentially limiting market access. In contrast to these practices, there were eleven good practices found in quadrant D where the control group had a higher implementation average with a level of adoption of less than 50% among the treatment group. Here opportunities exist for the BCI program to improve its training approach in the study area. For example, very few treatment farmers stated that they do not use banned pesticides, a core requirement of the BCI standard, despite their negative ecological and health and safety ramifications (Dudley et al., 2017; Oosthoek, 2013; Yadav et al., 2015). Overall the training provided by the BCI program seemed to be effective at influencing only the adoption and implementation of a few good farming practices (cover crops, fertilization based on experts, potassium application) with potential to build farming resilience.

To further strengthen this conclusion, the resilience threats and coping strategies of matched treatment and control farmers were examined if differences between groups could be identified. Examining the resilience threat of matched treatment and control farmers revealed that the treatment group was more susceptible to be affected by 9 out of the 13 negative events examined (see Figure 18). The treatment group were more susceptible to be affected by extremely scarce rains, declining cotton prices, excessive rains, heat waves and increased input costs, while the control group reported to be more susceptible to be affected by droughts and cotton pest outbreaks. For both the treatment and control groups, negative events categorized as theft of property or crops, major policy changes such as ending subsidies and other were seldom identified as important resilience threats. Postponing debt payment, finding wage labor, reducing consumption of non-essential goods, switching crops and selling household items were the most prominent and least difficult coping strategies for both the treatment and control groups to deal with the resilience threats that they face (see Figure 19). The treatment group identified these coping strategies as being easier to adopt compared to the control group.

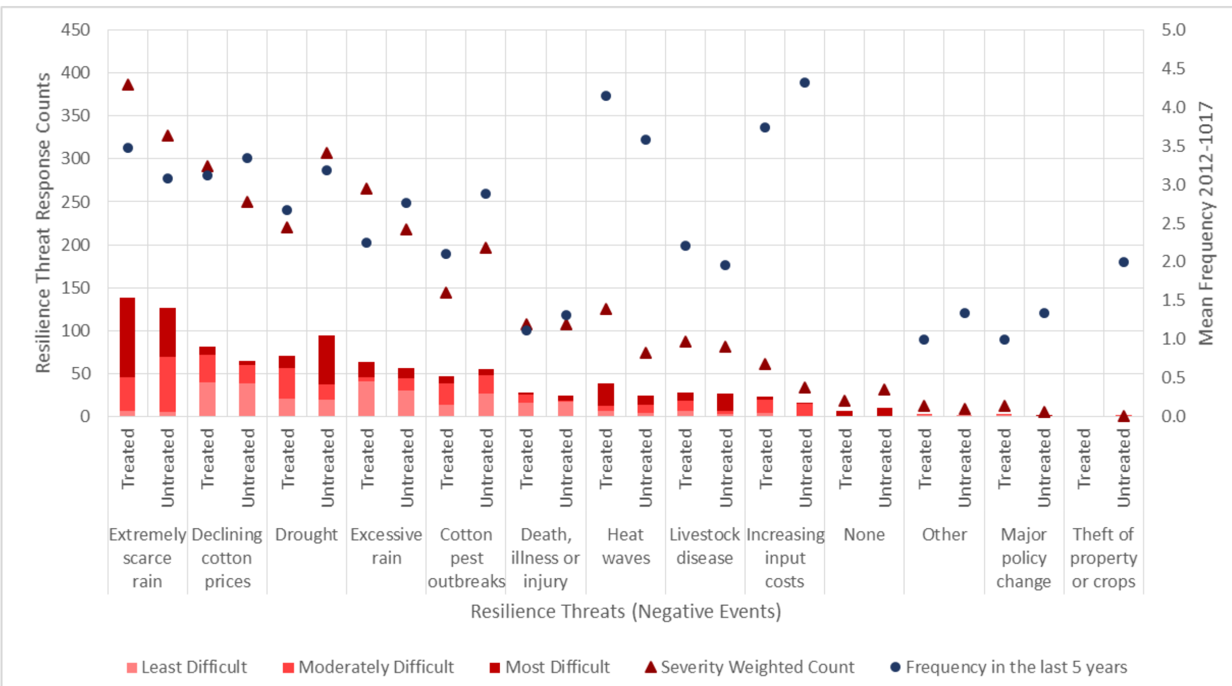

Figure 18 – Resilience threats to cotton farmers in the Adoni Mandal disaggregated by farmers that are (Treated) and are not (Untreated) participating in the BCI program

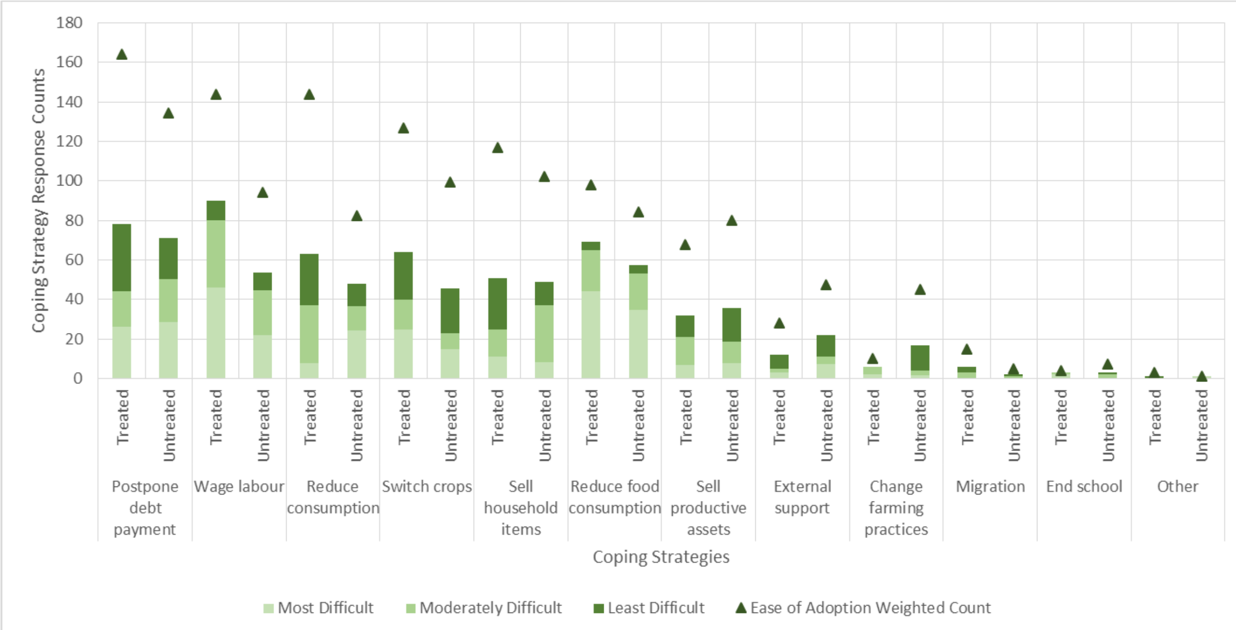

Figure 19 – Coping strategies of cotton farmers in the Adoni Mandal disaggregated by farmers that are (Treated) and are not (Untreated) participating in the BCI program

Based on the results obtained, there is no clear indication that the BCI program has had significant effects in addressing the resilience threats or enabling the coping strategies of the treatment farmers in the study area. For example, treatment farmers identified extremely scarce rains, excessive rains and heat waves as being more severe than the control farmers, revealing that participation in the BCI program is not improving farming resilience to water shortages and excesses. Nevertheless, treatment farmers reported droughts as being less severe compared to the control group, contradicting their greater vulnerability to extremely scarce rains. On the whole, there were no clear indications that the treatment group was significantly less vulnerable to a range of resilience threats facing cotton farmers, suggesting that the BCI program had no effect on the general resilience of cotton farming systems in the study area. With respect to the coping strategies, changing farming practices, the only strategy that can be directly impacted by the BCI program, was favoured by the control group, further indicating that the BCI program, and its training interventions, had very little to no influence on the adoption of coping strategies in the study area.

5.3 BCI and Organizational Networks

The BCI standard requires farmers to collaborate with external entities to promote sustainable water use[50] and decent work conditions[51], both of which align with the AVSS resilience analytical framework indicator – engage with external stakeholders and governance structures. To determine how the BCI program is potentially facilitating engagement with external stakeholders and governance structures, the positioning and potential function of the Participatory Rural Development Initiatives Society (PRDIS), the BCI's implementing partner, in organizational water and food security networks in the study area was examined.

Water security was identified by the farmer focus group discussions and the farming survey results presented in Sections 5.1 and 5.2 as the main resilience threat to cotton farming in the Adoni Mandal. For this reason, the network analysis focused on the organizational water and food security networks in the Adoni Mandal which are closely linked. Moisture deficits due to insufficient rainfall have been devastating for rural livelihoods in the area which rely primarily on agriculture (Reddy, 2018; Special Correspondent, 2017; Sudhakar, 2019). Furthermore, cotton farmers are more inclined to continue cultivating cotton and working in neighboring cities instead of cultivating more drought resistant food crops (Farmer Focus Groups, personal communication, March 2016). Consequently, examining how the organizations involved in enabling water and food security interact in the Adoni Mandal and the network positioning and potential function of the PRDIS is of direct relevance to farming resilience.

The composition of the networks were first examined by focusing on the nature of the organizations and their relationships which consisted of identifying their institutional and

[50] Under Principle 2 – Water Stewardship, the BCI standard requires farmers to engage "in collaboration and collective action to promote sustainable water use.

[51] Under Principle 6 – Decent Work of the BCI standard requires farmers to "develop partnership and collaboration on decent work at local, regional or national level." Decent work refers to forced and child labor, labor rights and workplace health and safety

jurisdictional focus as well as the areas of collaboration (see Section 4.3.1). The organizational relationships were then organized into different network actor categories to examine the frequency and diversity of organizational relationships that the BCI program is enabling within the water and food security networks (see Section 4.3.2). Lastly, the network function and positioning of the BCI program within the water and food security networks were examined and compared to similar organizations in the Adoni Mandal (see Section 4.3.3). The network analysis allowed for examining BCI's potential for enabling connectivity among the organizations working on water and food security in the study area and building the collective resilience of cotton farming communities.

5.3.1 Network Composition

Thirty-two organizations were surveyed to construct the water and food security networks, respectively comprised of 54 and 53 entities or nodes and 157 and 129 inter-organizational relationships or edges. The majority of the organizations surveyed were government departments (14 entities) operating at the Mandal to National jurisdictional levels, followed by community leadership (13 entities) within villages and one municipal ward followed by academic and non-government organizations (NGOs) (5 entities) (see Table 26). The network organizations that were not surveyed were mostly government agencies operating at the District and Mandal jurisdictional levels (11 out of 22 nodes for the water security network and 11 out of 21 nodes for the food security network).

Partly due to the nature of the organizations surveyed, the relational survey revealed that the majority of the organizations collaborating on water and food security in the Adoni Mandal were government departments followed by community leadership, non-government organizations (NGOs), academic institutions and private sector entities. There were only two mentions of private organizations involved in food security at the Mandal level. Out of the 14 community leadership organizations that were surveyed, seven villages and one municipal ward were participating in the

BCI program. Categorizing the organizations identified as working on water and food security in the study area into institutional and jurisdictional categories was not always clear. For instance, the Krishi Vigyan Kendras (KVK) was categorized as operating at the Mandal level since they have a dedicated office for providing services to the farmers of the Adoni Mandal even though they are comprised of a network of organizations providing agricultural extension working across India, while the Water Management Board, which is a water governance structure setup across the State of Andhra Pradesh, was categorized as operating at the state level since they were identified by a state government agency as having a role in enabling water security in the study area. Broad references to organizations, such as local NGOs and private organizations, were also kept to construct the water and food security networks of the Adoni Mandal.

Table 26 – Water and food security network organizations

Network Organizations	
Community Leadership	
Village & Ward	***Surveyed (13)*:** | **Treatment Villages (8) -** Baladoor (VBAR), Chinna Harrivanam (VCHI), Dibbanakal (VDIB), Madire (VMAD),), Salakalakonda (VSAL), Santhekudlur (VSAN), Virupapuram (VVIR), Parvathapuram (WPAR) | **Control Villages (5) -** G. Hosali (VGHO), Ballekal (VBAL), Dhanapuram (VDHA), Naganathana Halli (VNAG), Pandavagallu (VPAN
State	***Not Surveyed Water Security*:** Water Management Board (WMB)
Government Department	
Municipality	***Not Surveyed Water & Food Security (1)*:** Municipality of Adoni (AT)
Mandal	***Surveyed (5)*:** Agriculture Extension (MAE), Agriculture Office (MAO), Development Office (MDO), Engineering Dept. (MED), Integrated Water Management Program (IMWP) | ***Not Surveyed Water Security (4)*:** Panchayat Raj (MPR), Revenue Office (MRO), Water Management Agency (MDWMA), Education (ME) | ***Not Surveyed Food Security (5)*:** Agriculture Market Committees (AMC), Child Development Office (CDO), Water Mngmt Agency (MDWMA), Revenue Office (MRO), Animal Husbandry (MAH)
District	***Surveyed (5)*:** Agriculture Office Adoni (DAOA), Groundwater (DG), Irrigation (DI), Micro Irrigation Project (DMIP), Water Management Agency (DWMA) | ***Not Surveyed Water Security (7)*:** Chief Planning Office (CPO), Collector (DC), Forest Office (DFO), Horticulture (DH), Panchayat Office (DPO), Sericulture (DS), Animal Husbandry and Fisheries (DAHF) | ***Not Surveyed Food Security (6)*:** Animal Husbandry and Fisheries (DAHF), Consumer Affairs, Food & Civil Supplies (DCAFCS), Forest Office (DFO), Horticulture (DH), Rural Development Agency (DRDA), Welfare Department for Women and Children (DWWC)
State	***Surveyed (3)*:** Animal Husbandry and Fisheries (SAHF), Environment, Forestry and Technology (SEFT), Water Resources (SWR) | ***Not Surveyed Water Security (5)*:** Southern Power Distribution Company (SPDCL), NTR Jala Siri programme (NTRJS), Agriculture and Cooperation (SAC), Lands and Survey (SLR), Panchayat Raj (SPR) | ***Not Surveyed Food Security (4)*:** Girijan Cooperative Corporation (GCC), Civil Supply (SCS), Commission on Agriculture (SCA), Agriculture & Cooperation (SAC)
National	***Surveyed (1)*:** National Bank for Agriculture & Rural Development (NABARD) | ***Not Surveyed Water Security (1)*:** Water Resources, River Development & Ganga Rejuvenation (NWR) | ***Not Surveyed Food Security (1)*:** National Seeds Corp. (NSC)
Academic & NGO	
Mandal	***Surveyed (1)*:** Krishi Vigyan Kendras (KVK) | ***Not Surveyed Water Security (1)*:** Local NGOs (MNGO)
District	***Surveyed (1)*:** Adoni Area Rural Development Initiatives Programme | ***Not Surveyed Food Security (1)*:** Regional Agriculture Research Stations (RARS)
State	***Not Surveyed Food Security (1)*:** Centre for Sustainable Agriculture (CSA)
National	***Surveyed (3)*:** Centre for Economic and Social Studies (CESS), Participatory Rural Development Initiatives Society (PRDIS), Reliance Foundation (RF)
International	***Not Surveyed Water Security (2)*:** International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), United Nations International Children's Emergency Fund (UNICEF) | ***Not Surveyed Food Security (1)*:** International Crops Research Institute for the Semi-Arid Tropics (ICRISAT),
Private Sector	
Mandal	***Not Surveyed Food Security (1)*:** Private Organizations (PO)

The strength of the organizational relationships in both the water and food security networks compiled were determined by the number of water and food security aspects that are collaborated on, which averaged 2.8 out of 7 for water security aspects and 3.1 out of 9 for food security aspects (see the networks compiled in Figure 20 and Figure 21). The organizations surveyed tended to collaborate more on water retention, irrigation and groundwater for water security, whereas they tended to collaborate more on soils, cash crops and food crops for food security (see Table 27). Overall, there were very few reported reciprocal organizational relationships in both the water and food security networks (18 for the water security network and 7 for the food security network).

Table 27 – Organizational relationships by water and food security aspects collaborated on

Water and Food Security Aspects	Relationships	Reciprocal Relationships	PRDIS Outgoing Relationships	PRDIS Incoming Relationships
Water Security				
Irrigation	84	17	-	-
Groundwater	78	15	1	-
Surface Water	57	14	-	-
Water Retention	87	16	-	-
Water Quality	36	6	-	-
Water Treatment	31	7	-	-
Other	59	8	10	-
Food Security				
Soils	65	6	8	2
Food Crops	54	4	-	-
Cash Crops	65	6	8	4
Wild Food	8	-	-	-
Livestock	48	3	-	-
Food Preservation	20	-	-	-
Food Processing	21	-	-	-
Pest Management	44	5	8	2
Other	74	7	8	2

The organizational relationships reported manifest a pattern within both networks where entities working at a particular jurisdictional level tend to report relationships with organizations working at the same or one level above or below their jurisdictional level (see Figure 20 and

Figure 21).[52] For example, District government departments interact only with each other and with Mandal and State government departments. On the other hand, village level leadership reported interacting with mostly Mandal and District government departments as well as some State level government departments. This observation points to the potential importance of enabling organizational connectivity across jurisdictional levels to enable water and food security in the Adoni Mandal.

[52] The government structure in the State of Andhra Pradesh is comprised of State, District, Mandal and Municipalities government agencies who then oversee Panchayat Raj or Village leadership and Municipal Wards respectively. State level agencies are superseded by national government departments.

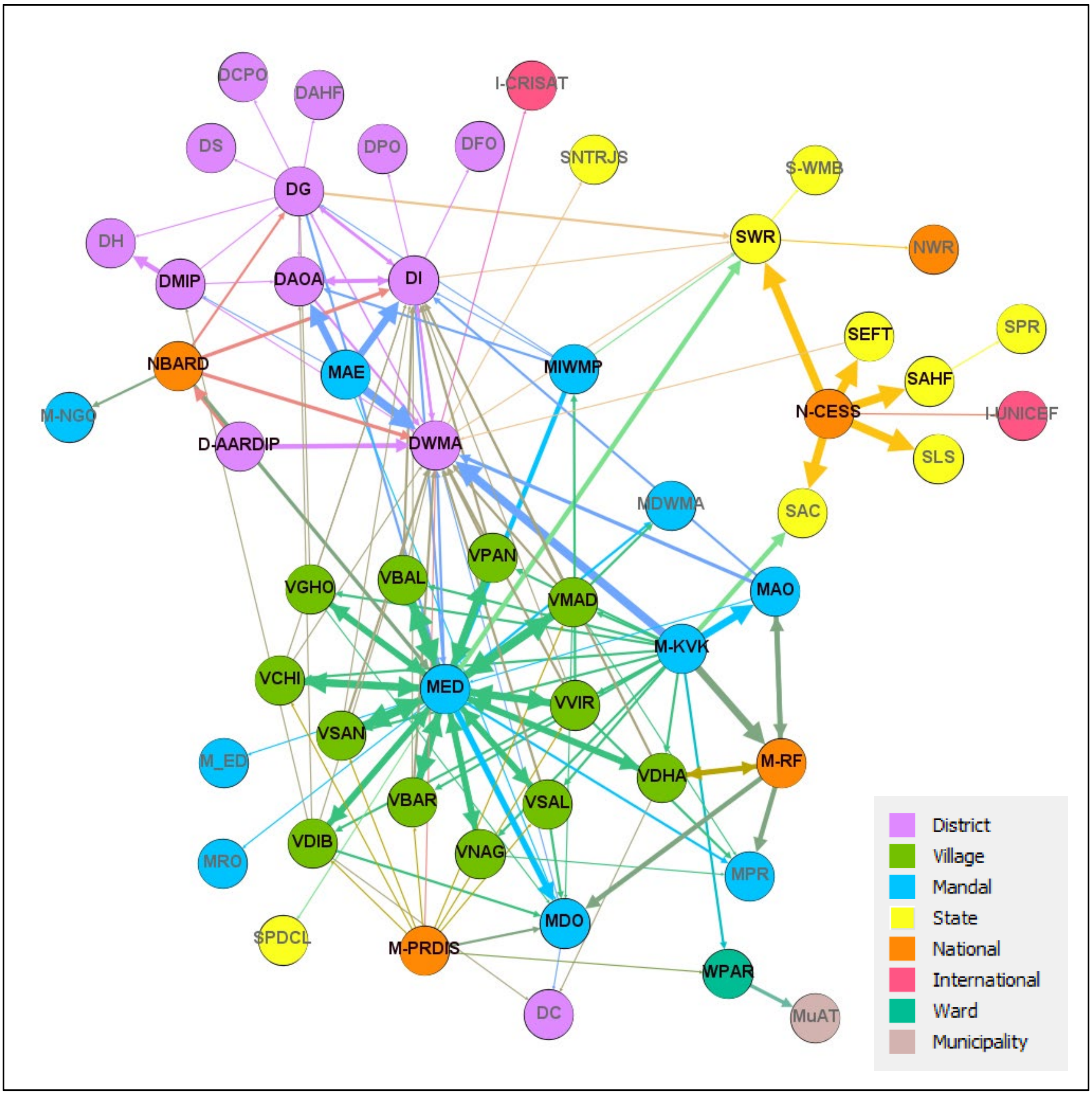

Figure 20 – Network of entities working on water security in the Adoni Mandal

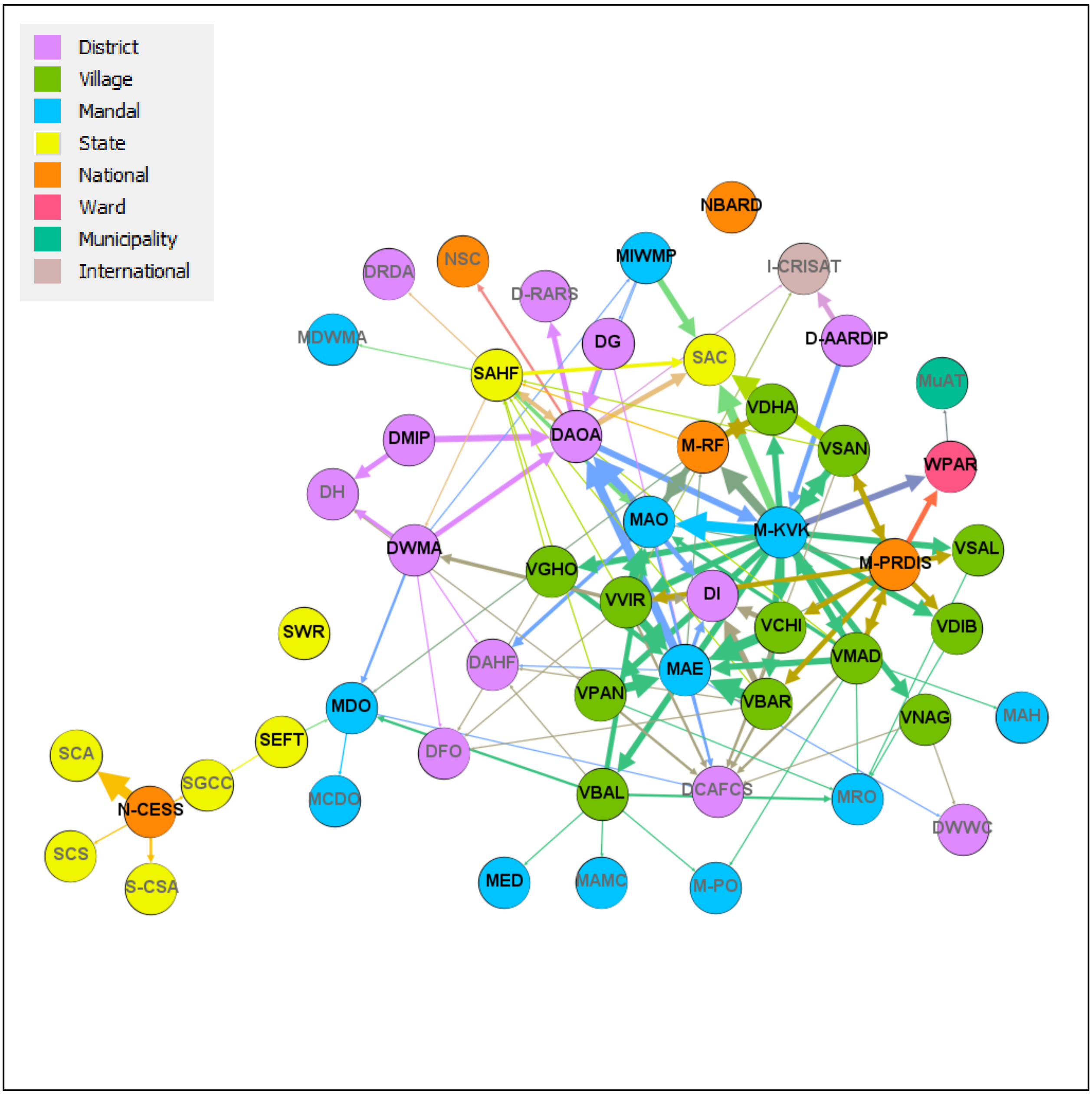

Figure 21 – Network of entities working on food security in the Adoni Mandal

The networks shown in Figure 20 and Figure 21 convey that the PRDIS has a limited function in the water security network and a more important function in the food security network. The PRDIS reported that it collaborates with 10 organizations mostly on one water security activity characterized as "other" which can be attributed to the water use efficiency training they provide (see Table 27). None of the organizations surveyed identified PRDIS as an organization that it collaborates with on water security, including the villages and municipal ward where the BCI program was being implemented (Baladoor, Dibbanakal, Chinna Harrivanam, Madire, Salakalakonda, Santhekudlur, Virupapuram and Parvathapuram). The PRDIS reported that it collaborates with 8 organizations on soils, cash crops, pest management and "other" food security measures while two villages (Madire and Santhekudlur) as well the Mandal agriculture extension (MAE) and Mandal agriculture office (MAO) reported that it collaborates with the PRDIS on food security related activities (see Table 27).

The PRDIS have been cooperating closely with the MAE and the MAO since 2015 and have low levels of interaction with the Mandal development of office (MDO) as they are responsible for managing the Mahatma Gandhi National Rural Employment Guarantee Scheme (NREGS)[53] which supports water security projects (i.e. landscape levelling, conservation trenches, bunding and silt traps) (B. J. Singh, personal communication, June 22, 2018). The MAE and MAO characterized their relationship with the PRDIS as being mostly focussed on cash crops. The village leadership of Santhekudlur and Virupapurum characterized the PRDIS as an organization focused on training for growing cash and food crops and agricultural practices such as pest management as well as its involvement in supporting check dam and plantation projects. Although the PRDIS reported that they have organizational relationships with the village and municipal ward leadership in which they operate in, this was for the most part not reciprocal. The village leadership of Madire mentioned that they were not contacted by the PRDIS, conveying a lack of reciprocal collaboration with village leadership.

Despite the BCI's requirement for farmers to engage with external entities, these preliminary results indicate that the PRDIS has a limited function enabling connectivity with other organizations working on water and food security in the study area. Furthermore, the PRDIS is not perceived by the majority of the village leadership surveyed, where the BCI program is being implemented, as an entity that it collaborates with on water and food security. Although this is partly due to the PRDIS's mandate to organize farmers into learning groups and

[53] The Mahatma Gandhi National Rural Employment Guarantee Scheme or NREGS guarantees Indian rural residents with 100 days minimum wage work to support public infrastructure projects (Maiorano, 2014; Ong & De, 2016).

train them on sustainable cotton farming practices, this outcome points to a potential lack of communication with village and ward leadership on their training activities which could impede resilience building efforts in the study area. Nevertheless, a more in depth examination of the BCI program's effects on organizational network connectivity for water and food security is required to draw more rigorous conclusions.

5.3.2 Organizational Relationship Diversity and Frequency

The institutional and jurisdictional diversity and frequency of the water and food security network organizational relationships of the PRDIS is used as a proxy for assessing its potential for enabling inter-jurisdictional collaborations for collective resilience. This assessment is based on the assumption that organizations connected to a diversity of organizations operating with different institutional orientations and at different jurisdictional levels within a network may be predisposed to enable coordinated responses across jurisdictions to resilience threats (Biggs et al., 2015; Carlisle & Gruby, 2017). This assumption aligns with observations by Carlisle & Gruby (2017) who maintain that the existence of organizational relationships are needed to enable processes of cooperation, competition, conflict and conflict resolution, which are fundamental for enabling polycentric governance which is, according to Biggs et al. (2015), essential for building resilience.

The network actor categories derived for the assessment is based on institutional groupings and jurisdictional focus, which yielded the following 14 network actor categories across the water and food security networks: **Academic & NGO** - International, National, State, District, Mandal, **Community Leadership** – State, Village and Ward, **Government** - National, State, District, Mandal and Municipality and **Private Sector** – Mandal. Determining the diversity of organizational relationships consisted of examining if the PRDIS has an organizational relationship in each one of the network actor categories. Determining the frequency of organizational relationships consisted of identifying the number of PRDIS's relationships within each network actor category and normalizing this number relative to a theoretical maximum number of organizational relationships that could be reached in each category based on the networks constructed (see Table 28). The number of water and food security aspects that organizations collaborate on are taken into account by ascribing a corresponding weight to the organizational relationship. For instance, a weight of 3 corresponds to collaboration on 3 water or food security aspects between two organizations. For this assessment, all organizational relationships reported were assumed to be reciprocal.

Table 28 – Theoretical maximum number of organizational relationships

Network Actor Categories based on Institutional and Jurisdictional Focus	Water Security Network	Food Security Network
Academic & NGO		
District	1	2
International	2	1
Mandal	4	3
National	1	1
State	-	1
Community Leadership		
State	1	-
Village	12	12
Ward	1	1
Government		
District	12	11
Mandal	9	10
Municipality	1	1
National	2	2
State	8	7
Private Sector		
Mandal	-	1
Total	54	53

The diversity and frequency of the PRDIS organizational relationships were assessed and compared to the organizational relationships of the Reliance Foundation (RF) and the KVK, two organizations with similar objectives and activities working closely with farmers in the study area. The RF is an NGO working in 2 villages in the Adoni Mandal who take a holistic and long-term approach to development and the KVK is an academic or NGO affiliated government supported organization providing extension services to all villages in the Adoni Mandal (Krishi

Vigyan Kendra Knowledge Network, n.d.; Reliance Foundation, 2019). The PRDIS has been operating in the Adoni Mandal since 2013, while the RF has been working with rural villages in the area since 2014 (L. Adapa, personal communication, March 24, 2017). In the case of the KVK their presence spans multiple decades providing agricultural extension services in the area (Krishi Vigyan Kendra Knowledge Network, n.d.).

Within the water security network, the PRDIS, KVK and RF have no organizational relationships with academic and NGO organizations working at the international, national, state and district levels as well as government entities working at the national and municipality levels (see Figure 22). Most of the water security relationships reported by all three NGOs were with community leadership at the village and municipal ward levels. The PRDIS has at least one organizational relationship with 4 out of the 12 network actor categories, while the KVK has at least one organizational relationship with 6 out of the 12 network actor categories and the RF has at least one organizational relationship with 3 out of the 12 network actor categories. Aside from its community leadership relationships, the PRDIS has one relationship with a government department working at the District and Mandal jurisdictional levels (1 out of 12 District level government agencies and 1 out of 9 Mandal level agencies). The PRDIS does not collaborate on more than one aspect of water security across all of its organizational relationships. The KVK has organizational relationships with all the villages and the municipal ward in the water security network. Outside of its community leadership relationships, the KVK collaborates with one organization within each network actor category where it is connected, on at least 2 and up to 7 water security aspects. It also collaborates with the RF on 6 water security aspects (the organizational relationship in the Academic & NGO network actor category shown in Figure 22). The RF is connected to 3 out of a possible 9 government departments working at the Mandal level and collaborates on 4 to 6 water security aspects across all of their organizational relationships.

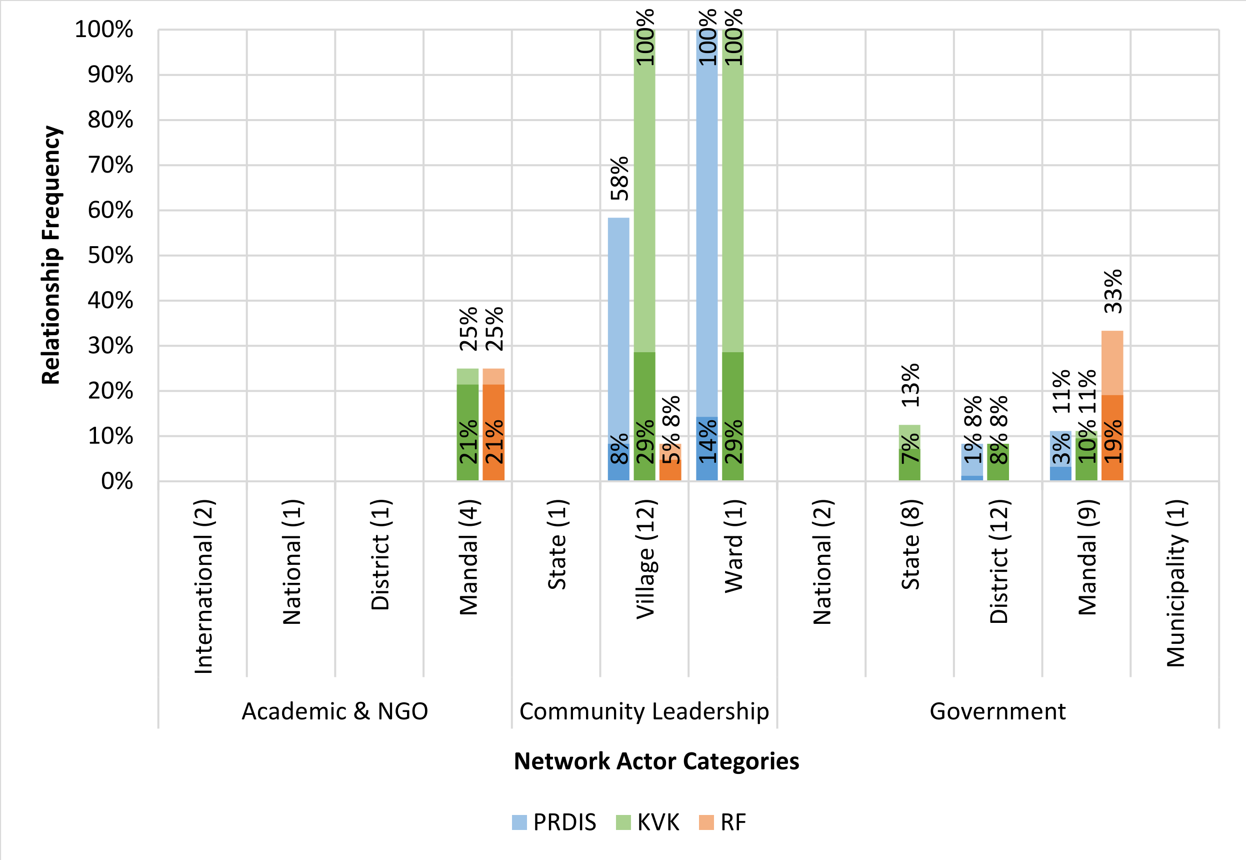

Figure 22 – Organizational relationship diversity and frequency within the water security network

Within the food security network, the PRDIS, KVK and RF have no organizational relationships with Academic & NGO organizations working at the international, national, and state levels as well as government entities working at the national and municipality levels and the private sector working at the Mandal level (see Figure 23). Most of the food security relationships reported by all three NGOs were with community leadership organizations at the village and municipal ward levels. The PRDIS has at least one organizational relationship with 3 out of 13 network actor categories, while the KVK and the RF have at least one organizational relationships in 7 and 4 of the 13 network actor categories, respectively. The PRDIS has organizational relationships with the leadership of 7 villages and 1 municipal ward and 2 out of 9 government departments working at the Mandal level. The PRDIS collaborates on 4 food security aspects with the leadership of the villages and the municipal ward and 1 food security aspect with the Mandal government departments. The KVK has organizational relationships with all the leadership of the villages and municipal ward in the food security network. Outside of its community leadership relationships, the KVK collaborates with one organization, within each one of the network actor categories where it is connected, on 4 to 8 food security aspects. It also collaborates with the RF on 6 water security aspects (the organizational relationship in the Academic & NGO working at the Mandal jurisdictional level network actor category). The RF is connected to 3 out of a possible 10 government departments and collaborates on at least 1 to 7 food security aspects across their organizational relationships.

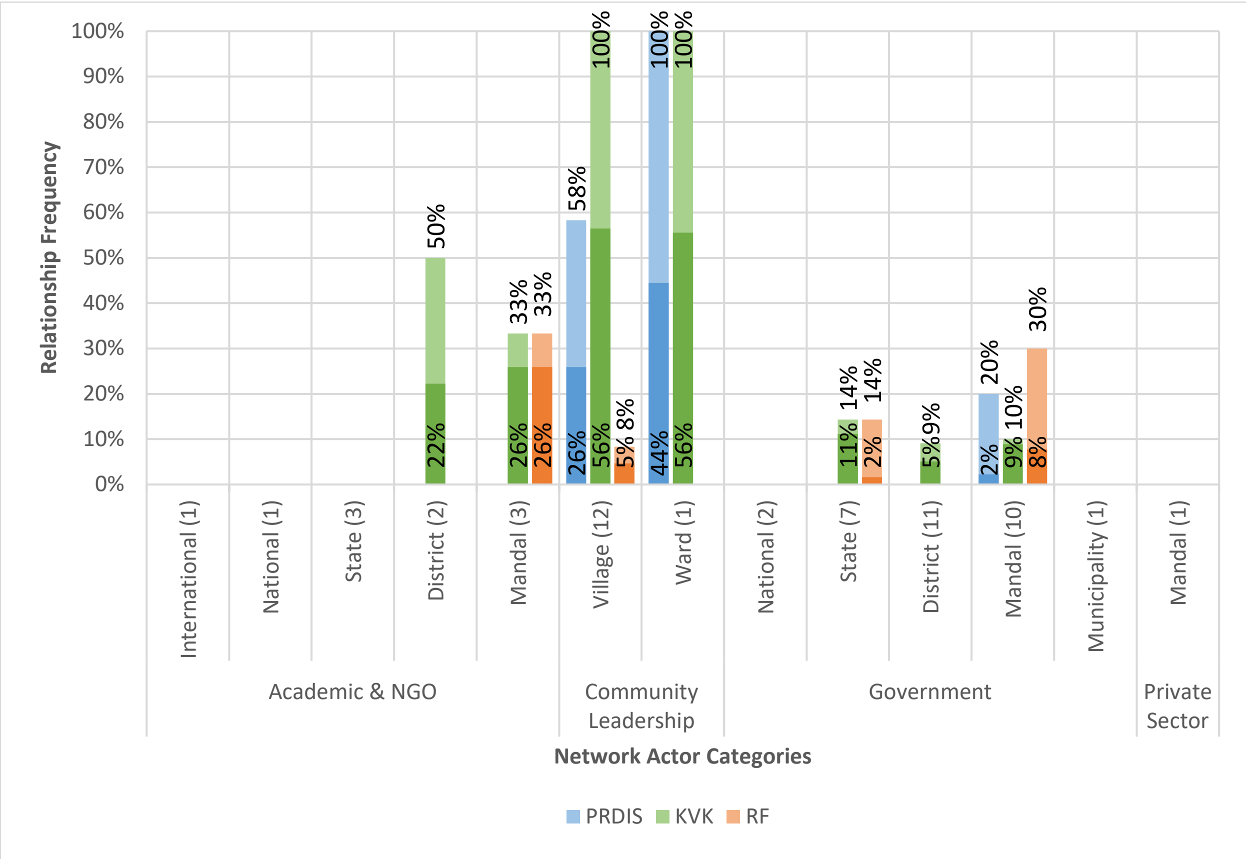

Figure 23 – Organizational relationship diversity and frequency within the food security network

The PRDIS has no organizational relationships with other Academic and NGO institutions and very few relationships with government entities working on water and food security in the Adoni Mandal. The majority of its organizational relationships are with the villages and the municipal ward where the BCI program was being implemented. The number of water security aspects that it collaborates on was limited to one across all of its organizational relationships, while it collaborated on four food security aspects with villages and municipal ward and one food security aspect with government entities.

For these reason, the PRDIS is not well placed to directly enable multi-jurisdictional collaboration for water and food security in the study area. This conclusion is further supported by comparing the diversity and frequency of the PRDIS to the KVK and the RF, its closest analogues in the water and food security networks. When excluding the community leadership category, the PRDIS had lower organizational relationship diversities and frequencies across the network actor categories examined for both the water and food security networks compared to the KVK and the RF.

The PRDIS could expand its organizational relationships to enable water and food security in the study area. For instance, it could collaborate with the KVK which provides extension services to several villages in the Adoni Mandal and have resources and facilities that could be leveraged to train farmers and build resilience intelligence (Wood et al., 2014). It could also collaborate with the RF who both work in the village of Dibbanakal. Establishing these organizational relationships could assist with enabling resilience collaborations for cotton farming in the study area.

5.3.3 Network Positioning and Potential Function

The network positioning and potential function of the PRDIS is examined to better understand how it may be enabling organizational connectivity for water and food security, beyond its direct organizational relationships. Understanding how organizations within a network are connected and positioned can be insightful to ascertain their importance for enabling resilience collaborations. To focus on the presence or absence of organizational relationships, undirected and unweighted water and food security networks and sub-networks were first compiled by only keeping surveyed organizations. Assessing strictly the network and nodal metrics of the organizations surveyed was necessary to avoid getting network structure and node positioning and function results influenced by network actors that were not given an opportunity to identify their organizational relationships. Examining the presence or absence of inter-organizational relationships allowed for assessing them free of their importance conveyed by the survey respondents which can evolve over time.

Network, community and nodal level metrics were then calculated allowing for comparing the network positioning and potential function of the PRDIS with the KVK and RF, two NGOs with similar mandates operating in the Adoni Mandal (see Section 5.3.3.1). The potential influence that the PRDIS may have had on the connectivity of the villages and the municipal ward where the BCI program is being implemented (treatment villages) within the water and food security networks was then examined by comparing their network positioning and potential function with villages where the BCI program was not implemented (control villages) (see Section 5.3.3.2). This assessment was undertaken by first eliminating the organizational relationships of the treatment villages with the PRDIS and then comparing their network centrality metrics with that of the control villages.

5.3.3.1 Network, Community and Node Level Metrics

To assess the network positioning and potential function of the organizations in the water and food security networks and sub-networks of the Adoni Mandal, the network density, degree centralization and communities as well as the betweenness centrality of their organizations or nodes were calculated. Betweenness centrality can be insightful for determining an organization's potential for enabling connectivity. A greater betweenness centrality indicates that more organizations need to go through a particular node (or organization) to efficiently reach all other organizations (Oldham et al., 2019). Consequently, organizations with higher betweenness centralities can act as gatekeepers within networks as they may be better positioned to facilitate and/or prevent information and resources to efficiently reach all other organizations in a network. Furthermore, organizations with high betweenness centralities can expose network structure vulnerabilities as removing them could potentially affect the composition of the water and food security networks. The direct relationships of the water and food security network organizations, or degree centrality, were examined in detail in Sections 5.3.1 and 5.3.2 and are included in this section strictly as a reference to better understand the betweenness centralities derived.

The water and food security networks were disaggregated into the sub-networks listed in Table 29. To specifically examine water and food security aspects where the PRDIS should be active in accordance with the orientation of the training they provide, a hybrid water and food security network was constructed by combining the water conservation and agricultural practices sub-networks. Examining the water and food security networks and sub-networks as well as the hybrid network allowed for determining if the PRDIS is strategically positioned within them to enable water and food security (see Appendix 3 – Water and Food Security Networks and Sub-Networks).

Table 29 – Water and food security networks and sub-networks

Network	Sub-Network	Security Aspects
Water Security	Water Resources	Surface Water Groundwater
	Water Conservation	Irrigation Water Retention Other Water Security Aspects
	Water Quality	Water Treatment Water Quality
Food Security	Agricultural Products	Food Crops Cash Crop Livestock
	Agricultural Practices	Soil Conservation Pest Management Other Food Security Aspects
	Post-Harvest	Food Preservation Food Processing
Water & Food Security	Water Conservation Agricultural Practices	Irrigation Water Retention Other Water Security Aspects Soil Conservation Pest Management Other Food Security Aspects

The water and food security aspects listed in Table 29 adequately reflect the Adoni Mandal context, a recognized cotton production area, located in the drier part of the State of Andhra Pradesh where surface water and groundwater sources are scarce (Kumar et al., 2015). Many agricultural producers rely on rain fed agriculture and precipitation retention measures such as water retention ponds and earth bunds to support productivity. Irrigation is enabled via water retention measures or by accessing canals which service some villages. Water quality and treatment are concerns that tend to focus on drinking water. Farmers primarily produce cash crops, such as cotton, red chili and groundnuts, as opposed to food crops such as sorghum, millet and lentils. Milk from livestock can be an important source of protein (Kumar et al., 2015). Soil and pest management remain important aspects of agriculture in the area (Farmer Focus Groups, personal communication, March 2016). Efforts to improve food preservation and processing could increase household food security.

The network, community and node level metrics compiled for the water and food security networks and sub-networks as well as the hybrid water & food security network are shown in Table 30). The water and food security networks and sub-networks have low network densities ranging from 0.028 to 0.232 and a degree centralization ranging from 0.359 to 0.559. This indicates that the organizational relationships of the networks and sub-networks examined are fairly sparse and concentrated within some nodes in the networks since a fully connected network centered around one organization would have yielded a network diameter and degree centralization of 1 (Prell, 2011).

The Louvain method, was used to detect the presence of network communities within the networks and sub-networks (Blondel et al., 2008).[54] The water and food security networks and sub-networks had low modularity indicating that network communities were not clearly detected as the organizations are for the most part densely connected to each other. High

[54] The modularity statistical tool was run with a probability of 0.85 and epsilon of resolution of 1.0.

modularity would have indicated dense organizational relationships within network communities with limited organizational relationships between network communities (Newman, 2006). Networks with high modularity may be less susceptible to the spread of disturbances between communities but more susceptible to loosing connectivity between communities (Kharrazi et al., 2020). The water and food security networks are comprised of organizations that are fairly well connected to each other such that resources and disturbances are likely to spread more easily within these networks and the loss of organizations or organizational relationships are less likely to affect network connectivity and composition.

Table 30 – Water and food security networks and sub-networks density, degree centralization and communities as well as degree and betweenness centralities of the PRDIS, KVK and RF

Networks & Sub-Networks	Density & Centralization	Modularity & Network Communities	Degree Centrality			Betweenness Centrality		
			PRDIS	KVK	RF	PRDIS	KVK	RF
Water Network								
Overall (32 Nodes, 108 Edges, 1 component)	0.218 0.559	0.197 4	10	16	4	0.037	0.125	0.003
Water Conservation (32 Nodes, 92 Edges, 1 component)	0.185 0.422	0.228 4	10	16	4	0.054	0.147	0.003
Water Resources (30 Nodes, 59 Edges, 3 components)	0.119 0.483	0.306 6	1	3	4	0.000	0.008	0.018
Water Quality (26 Nodes, 26 Edges, 8 components)	0.052 0.477	0.557 10	0	3	1	0.000	0.084	0.000
Food Network								
Overall (29 Nodes, 69 Edges, 4 components)	0.139 0.470	0.247 6	10	17	6	0.046	0.352	0.057
Agricultural Practices (29 Nodes, 58 Edges, 4 components)	0.117 0.499	0.324 7	8	17	4	0.035	0.431	0.037
Agricultural Products (26 Nodes, 59 Edges, 7 components)	0.119 0.540	0.231 10	10	17	4	0.054	0.304	0.005
Post-Harvest (14 Nodes, 14 Edges, 20 components)	0.028 0.359	0.418 21	0	2	1	0.000	0.022	0.000
Water & Food Security Network (32 Nodes, 115 Edges, 1 component)	0.232 0.406	0.172 5	10	18	4	0.037	0.167	0.003

The PRDIS is present in the water conservation, water resources, agricultural products and agricultural practices sub-networks. Its presence in the water conservation sub-network is likely attributed to the water use conservation training that it provides to cotton farmers, which is characterized as "other water security aspects". It is also present in the water resources sub-network as it collaborates with one organization on groundwater. It is not present in the water quality sub-network which is primarily associated with access to water of sufficient quality for drinking as opposed to agricultural production water quality impacts. The presence of the PRDIS in the food security sub-networks is more extensive as it collaborates on soil conservation, pest management, cash crops as well as agricultural production training characterized as "other food security aspects". The absence of the PRDIS in the post-harvest sub-network was expected due to its mandate focused on training cotton farmers aspiring to become BCI verified. The KVK and the RF were both found to be active in all the water and food security networks and sub-networks examined - both NGOs had at least one organizational relationship (a degree centrality of one or more) within the networks and sub-networks examined.

Focusing on the betweenness centralities calculated for the water security network and sub-networks reveals that the KVK consistently has a greater betweenness centrality compared to the PRDIS (see Table 30). However, the PRDIS has a greater betweenness centrality compared to the RF except within the water resources and water quality sub-networks where it has very little to no presence. Within the food security network and sub-networks, the PRDIS consistently had greater betweenness centralities compared to the RF where it was present. On the other hand, the KVK had greater betweenness centralities compared to the PRDIS across the food security network and sub-networks examined. Assessing the network positioning and function of the PRDIS, KVK and RF within the hybrid water and food security network yields similar results where the PRDIS has greater betweenness centrality compared to the RF, but lower betweenness centrality compared to the KVK.

Although the PRDIS is not as well positioned as the KVK, it is better positioned compared to the RF to enable coordinated responses to resilience threats and facilitate collective resilience. These result can be partly due to the mandates of the organizations compared, targeted on specific beneficiary communities (RF = 2 villages, PRDIS = 7 villages and 1 municipal ward, KVK = all villages where there is agricultural production). Nevertheless, these NGOs are part of broader organizations operating nationally, which should result in relationships with government and NGOs that could be leveraged to enable water and food security in the Adoni Mandal which intersects with their mandates. It must be noted that the PRDIS, KVK and RF all have direct organizational relationships with community leadership which are closest to the likely beneficiaries of water and food security interventions.

5.3.3.2 Community Leadership Connectivity

The degree and betweenness centralities of the treatment and control villages of the Adoni Mandal are compiled and compared to determine the potential indirect role that the PRDIS may have had on the connectivity of community leadership within the water and food security networks. The PRDIS and its organizational relationships were first removed from the water and food security networks to examine its potential effects on the network positioning and potential function of villages and municipal ward participating in the BCI program (treatment villages) in relation to villages that are not participating in the BCI program (control villages). The communities examined consist of the following seven treatment villages and municipal ward – Baladoor, Chinna Harrivanam, Dibbanakal, Madire, Parvathapuram, Salakalakonda, Santhekudlur and Virupapuram, and five control villages – Ballekal, Dhanapuram, G. Hosali, Naganathana Halli and Pandagavallu.

Removing the PRDIS from the water and food security networks did not significantly affect their network structures as the number of network components remained the same. Based on these high level results, we can expect that the effects on the removal of the PRDIS will have minimal effects on the node level metrics of the villages participating in the BCI program. The average degree and betweennees centralities calculated for the treatment and control villages within the water and food security networks with and without the PRDIS are shown in Table 31. Within the water security network without the PRDIS, the treatment villages have a slightly greater mean degree centrality and betweenness centrality compared to the control villages, while in the food security network, the treatment villages have a greater mean degree centrality, but a significantly lower betweenness centrality. Although the results obtained may be simply attributed to the limited and uneven treatment and control samples, more pronounced node centred metric differences favouring the treatment villages could have indicated that the PRDIS is enabling engagement with external stakeholders and governance entities working on water and food security in the Adoni Mandal.

Table 31 – Average degree and betweenness centralities of village leadership where the BCI program is (Treatment Villages) and is not (Control Village) implemented in the water and food security networks

Network	Water Network		Food Network	
Mean Node Metric	Degree	Betweenness	Degree	Betweenness
Without PRDIS				
Control Villages	3,80	0,0027	2,60	0,0183
Treatment Villages	4,13	0,0030	2,88	0,0059
With PRDIS				
Control Villages	3,80	0,0023	2,60	0,0173
Treatment Villages	5,13	0,0044	3,88	0,0070
Relative Changes				
Control Villages	0%	19%	0%	5%
Treatment Villages	-20%	-32%	-26%	-16%

The analysis conveys that the PRDIS is not having a significant effect on the water and food security network organizational structures in the Adoni Mandal and the connectivity of villages participating in the BCI program. Furthermore, the PRDIS could facilitate village leadership relationships between the villages and municipal ward where they are implementing the BCI program, which were reported as inexistent during the relational survey.

6 Discussion

This dissertation answers the central question ***How can AVSS enable the general resilience of farming systems?*** by focusing on their design and implementation so they can be improved to support farming resilience (Sub-Research Question 1: ***How are AVSS designs affecting the general resilience of farming systems?*** and Sub-Research Question 2: ***How are AVSS implementation approaches affecting the general resilience of farming systems?***). To this end, the AVSS Resilience Analytical Framework was developed providing an analytical lens to assess AVSS designs and the implementation of one AVSS as a critical and revelatory case to test the framework. This research dissertation offers insights to improve AVSS as substantive research on how they comprehensively affect farming resilience has not been undertaken. The results obtained from applying the framework is first examined and linked to the farming resilience literature (Section 6.1), the AVSS Resilience Analytical Framework composition is then critically examined (Section 6.2), followed by a discussion of how this research contributes to developing AVSS that can build the general resilience of farming systems (Section 6.3). The case study is revisited to discuss what could have been observed it the BCI program enabled cotton farming resilience in the Adoni Mandal (Section 6.4). The need for AVSS to adopt a culture that can deal with uncertainties within its supply chains is then briefly discussed (Section 6.5). Lastly, some final thoughts are provided on the potential for using farming resilience to re-imagine AVSS are discussed (Section 6.6).

6.1 AVSS and Farming Resilience

A benchmarking effort and a case study were undertaken to examine how AVSS designs and their implementation affects the general resilience of farming systems. Although AVSS have design features and implementation approaches that support farming resilience, focusing on gaps and limitations provides the best insights on how they could be re-imagined and reshaped towards enabling the general resilience of farming systems. The main AVSS design gaps that were identified, targeted experimentation, developing adaptation strategies and managing the diversification of agricultural products and economic activity, are first discussed (see Section 6.1.1), followed by AVSS implementation limitations associated with continuous capacity building and engaging with external stakeholders and governance structures (see Section 6.1.2).

6.1.1 Designing AVSS for Farming Resilience

The benchmarking effort revealed that, for the most part, AVSS do not require farming operations to experiment, develop adaptation strategies and manage the diversification of agricultural products and economic activities, which have been identified as important for enabling farming system resilience (Ashkenazy et al., 2018; E. M. Bennett et al., 2014; Biggs et al., 2015; Meuwissen et al., 2019, 2021; Verburg et al., 2019a). Incorporating measures that support these resilience aspects within AVSS could strengthen their potential for building the general resilience of farming systems. These farming resilience gaps are discussed and thoughts are provided to address them.

AVSS need to incorporate production criteria that require their farmers to **experiment** so they can develop more effective adaptation strategies to potential disturbances that farming operations are likely to face in the future. Although this requirement would have to be manageable for farmers to implement, the literature indicates that it is reasonable to expect farmers with varying levels of capacities and resources to experiment (Hockett & Richardson, 2018; Klocker et al., 2018; McCord et al., 2018). Hockett and Richardson (2018) study the experimentation practices of smallholder Malawian farmers and conclude that "Smallholders have a great capacity for experimentation, and their knowledge, experience, preferences and priorities – if properly understood and incorporated – could ultimately benefit both future agricultural development projects and their participants" (Hockett & Richardson, 2018, p. 45). Furthermore, Caves et al. (2020) argue that supporting Australian farmers to "tinker" or experiment could be a more effective policy for enabling agricultural resilience than access to crop insurance. Agricultural producers need to continuously build place-based experiential knowledge or indigenous knowledge to ensure that they are making the best decisions to resist, adapt and transform their farming operations to potential disturbances (Biggs et al., 2015; Chowdhooree, 2019; Ford et al., 2020; Gómez-Baggethun et al., 2012; Kandal et al., 2019; Ladio & Lozada, 2009; Uddin et al., 2020). "There is strong evidence across diverse contexts that indigenous knowledge is a major source of resilience in that it acts as a repository of accumulated experience and is closely linked to the other place-based elements through shaping belief systems" (Ford et al., 2020, p. 538). Building experiential knowledge and skills can empower farmers via their generation of information that can be unique and valuable for farming communities. Šūmane et al. (2018) describe the need to recognize and integrate the experiential knowledge of farmers as follows: "All stakeholders, including farmers, need to be recognized as equal co-authors of knowledge generation, and all kinds of knowledge, both formal and informal, need be brought together in innovation processes" (Šūmane et al., 2018, p. 223). To further value and leverage farmer experiential knowledge, AVSS can establish exchange platforms which could be used to collectively build farming resilience. "Knowledge networking and multi-actor knowledge networks that facilitate knowledge exchanges, joint learning and the generation of new more integrated solutions, are crucial if agriculture is to become sustainable and resilient" (Šūmane et al., 2018, p. 223). AVSS targeted experimentation requirements will need to be flexible and remain open to addressing a farmer's need for discovery which will be dynamic and constantly changing. These could include testing different types of seeds under changing conditions, farming technologies, community consultation strategies and/or training approaches. A well-crafted targeted experimentation requirement within AVSS will allow farmers to gain experiential knowledge that is most relevant to meet their needs, which could then be recognized and valued by offering them with opportunities or platforms to share and collectively build farming resilience. This would imply that the targeted experimentation requirement would have to be flexible requiring farmers to convey how the knowledge gained from this requirement supports the general resilience of their farming operation.

All the AVSS examined do not directly require the development of **adaptation strategies**. The Fairtrade Smallholder Producer Organization standard comes closest to meeting this resilience indicator by recommending farmers to "implement measures on adaptation to climate change" (Fairtrade International, 2019, p. 33).[55] To address this gap, AVSS need to require, as opposed to recommend, the development of adaptation strategies oriented towards enabling the general resilience of farming systems instead of being narrowly focused on particular disturbances such as climate change (J. E. Ensor et al., 2018). Nevertheless, all the AVSS examined have requirements for undertaking various types of emergency response plans as well as risk and impact assessments associated with farming operations, providing a good foundation to develop adaptation strategies. Adding targeted experimentation requirements could also be leveraged to fine-tune and update adaptation strategies to changing contexts. Based on the complex and dire nature of the disturbances that are projected to undermine farming systems (i.e. accelerated climate change, increasing human pandemics etc.), the importance and urgency associated with incorporating AVSS requirements for developing adaptation strategies cannot be overstated (E. M. Bennett et al., 2014; Meuwissen et al., 2019). The recent COVID-19 pandemic is evidence that farming systems need to have in place adaptation strategies to face known and unknown disturbances (Anderson et al., 2020; Gowdy, 2020; Henry, 2020; Pu & Zhong, 2020; Stephens et al., 2020).

For AVSS to require farmers to develop effective adaptation strategies, they will have to be oriented towards enabling farming operations to adjust to known as well as unknown disturbances as opposed to being strictly focused on known disturbances (J. E. Ensor et al., 2018). Folke (2003) captures this need by advocating for moving away from trying to control and

[55] The guidance provided in the Fairtrade Smallholder producer organization standard to implement this climate change adaptation recommendation is the following: "The adaptation measures and activities depend on identified risks and existing practices in your region/product and are in line with the human and financial capacity of your organization and members. Examples of adaptation practices include: adjustments in crop planting dates to avoid periods with high temperature stress, installation of facilities for rain water collection and use, soil cover/mulch application, use of drought resistant crop varieties, crops diversification, and improved pruning practices." (Fairtrade International, 2019, p. 33).

prevent system change to sustain and enhance their capacities to deal with change. Consequently, building on the various risk and impact assessments required by AVSS only provides a starting point for farmers to work towards developing effective adaptation strategies (Meuwissen et al., 2019). For instance, assessing the trade-offs and synergies associated with various adaptation strategies can strengthen their effectiveness (Akinyi et al., 2021). AVSS could also require farmers to develop compatible adaptation strategies with existing adaptation efforts at the community level or targeted towards specific demographics. For instance, national adaptation programs of action with elements focused on farming could provide farmers with insights to develop compatible adaptation strategies for their farms (UNFCCC, 2021). Wise et al. (2016) prioritized rural livelihood adaptation strategies in parts of Indonesia by examining their compatibility with climate compatible development criteria and the following three adaptation pathway principles: "interventions should be (1) 'no regrets' and maintain reversibility to avoid mal-adaptation; (2) address both proximate and underlying systemic drivers of community vulnerability; and (3) linked across spatial scales and jurisdictional levels to promote coordination" (Wise et al., 2016, p. 100). Although requiring farmers to develop highly compatible adaptation strategies may not be possible in all cases, it could at the very least encourage farmers to manage connectivity with their surrounding community and or engage with external stakeholders and governance structures. AVSS will have to adequately support farmers in the development of effective and compatible adaptation strategies which could take many different forms such as offering training, information and expertise.   The main role of AVSS is to guide farmers in leveraging existing adaptation efforts to develop strategies that are best suited for their farming operations and to provide support where there might be important adaptation knowledge gaps in specific geographies and sectors. They might also have a role in ensuring that adaptation strategies unique to the agricultural supply chains they work in are promoted. Perhaps most importantly, requiring farmers to develop adaptation strategies will instill in them a clear recognition for the need to formally manage uncertainty and change and establish coping strategies to deal with them (J. E. Ensor et al., 2018; Roe, 2020). For AVSS designs to enable farming resilience, they will have to incorporate direct requirements in their production standards to develop effective and compatible adaptation strategies for farming operations to be better prepared to disturbances.

The AVSS examined have very little requirements for directly managing the **diversification of agricultural products and economic activities** of the farming operation. This is problematic as diversification is identified in the scientific literature as one of the main strategies for building the general resilience of any system including farming systems (E. M. Bennett et al., 2014; Biggs et al., 2015; J. E. Ensor et al., 2018; Meuwissen et al., 2019). In fact, Bitzer and Steijn (2018) criticize AVSS for potentially narrowing smallholder farmer livelihoods to the production of standard-compliant agricultural products by stating the following: "If VSS encourage increased specialisation of agricultural production without considering producers' livelihood decisions, including engagement in off-farm activities, they restrict their potential for poverty alleviation" (Bitzer & Steijn, 2018, p. 3). The adoption of AVSS also provide strong incentives to specialize in the production of cash crops at the expense of food crops, which can undermine food security and gender equity as women are often responsible for growing crops to feed households (Bitzer & Steijn, 2018). Although diversifying the agricultural production and economic activities supported by farming systems could assist with enabling their resilience, the various trade-offs in doing so need to be carefully weighed. Hence the need for AVSS to require **managing** diversification as opposed to simply requiring diversification. Ashkenazy et al. (2018) capture this need by stating: "helping farmers to develop their entrepreneurial skills can increase their adaptability, but the additional time spent on 'running a business' may be at the expense of running basic farm operations" (Ashkenazy et al., 2018, p. 220). Part of managing the diversification of farming systems will be to adequately assess trade-offs between additional capacities and resources required to diversify versus potential farming resilience gains. Consequently, requiring farmers to develop and implement farming diversification plans encompassing agricultural product and economic activity diversification objectives could provide farming operations with a roadmap to work towards achieving an optimal level of diversification, to be regularly reviewed and adjusted to reflect changing contexts.

It is worth thinking about managing the diversification of agricultural production and economic activities separately as they support different resilience capacities. Managing the diversification of agricultural products focuses on growing an appropriately diverse set of crops and or livestock to weather a range of disturbances, while managing the diversification of economic activities focuses on enabling a diverse set of revenue generating activities other than agricultural production that can sustain the farming system when agricultural production may be significantly affected. When thinking about resilient farming systems managing the diversification of agricultural products may be more aligned with the persistence and adaptability of farming systems, while managing the diversification of the economic activities supported by the farm aligns with adaptability but also transformability of farming systems. Ensuring that farming systems are both managing the diversification of agricultural production and economic activities could allow farming systems to persist, adapt but also transform when faced with disturbances (Meuwissen et al., 2019). Although the AVSS examined do have a number of requirements that intersect with managing the diversification of agricultural products, such as crop rotation measures, intercropping and cover crops for managing soils, pests and diseases, very few have direct requirements for managing the diversification of agricultural production. The only clear examples include the RSB requirements to enhance local food security and prioritize indigenous crops and the FHL recommendation for diversifying agricultural production to enhance biodiversity (Fairtrade International, 2014a; Roundtable for Sustainable Biomaterials, 2016b). Consequently, incorporating direct AVSS requirements to manage the diversification of agricultural products will build on existing practices and will be formally integrated in farming decision-making and management processes. Integrating requirements to manage the diversification of economic activities supported by farming systems is different as it can deviate significantly from the activities that farming systems are oriented towards, hence their potential for enabling adaptation as well as transformation in the face of disturbances. There may be contexts where transforming the farming system could result in more resilience. Agroforestry represents such an instance where going from a monoculture to a more diverse landscape supporting a variety of trees and crops may result in lower yields for a given crop but may be more favorable for building farming system resilience as a whole (Amadu et al., 2020; Andres et al., 2016; De Beenhouwer et al., 2013). For the most part, the AVSS examined do not have any production requirements to manage the diversification of the economic activities supported by the farm. The LEAF standard requires their farmers to develop an integrated farm management policy that is relevant to all food and non-food related business activities, the RA standard recommends group management to support their members with diversifying their incomes[56] and the FHL and RA standards recommend adopting agroforestry for shade-tolerant crops. Explicit requirements for managing the diversification of agricultural production and economic activities supported by farming systems need to be incorporated into AVSS to ensure that farming systems have the capacities required to remain resilient, which includes enabling transformation.

6.1.2 Implementing AVSS for Farming Resilience

A case study was undertaken to examine how implementing an AVSS affects the general resilience of farming systems and provide insights on applying the AVSS resilience analytical framework within a specific context. Although the specific insights gained from the case study are only applicable to the context examined, they provide research leads in other contexts to further assess the resilience effects of AVSS. The farming and relational surveys, conducted as part of the case study, allowed for examining the effects of the BCI program on two indicators of the AVSS resilience analytical framework: 1) **continuous capacity building** and 2)

[56] The Rainforest Alliance specifies the following indicator to track income diversification strategies: "number and gender of group members that diversify their income through at least one of the following: 1) other income generating activity (specified per type), 2) upgrading of the product (e.g. wet processing)" (Rainforest Alliance, 2020, p. 23).

engaging with external stakeholder and governance structures. These resilience aspects are discussed by focusing on specific elements of implementing the BCI program from two perspectives: 1) the implementation of the BCI program for the adoption of the BCI standard (training provided and organizational network involvement) and 2) the potential outcomes associated with implementing the BCI standard on the farm and farming communities (changes in farming practices and network positioning of farming communities). BCI's training effectiveness is first examined (results from the farming survey) followed by its involvement in the water and food security organizational networks of the Adoni Mandal (results from the relational survey).

The BCI program provided training to farmers aspiring to become BCI-verified cotton farmers. The effectiveness of the BCI training was assessed by gauging the willingness of farmers who attended the training to implement the lessons provided. The overall average of farmers who attended and expressed a willingness to implement the BCI training was only 13%, indicating that BCI training was mostly ineffective. The lack of training effectiveness found in the case study raises important concerns as training is the most important means by which the BCI program enables farmers to implement their standard. Furthermore, the majority of the farmers who received BCI training are smallholders with limited resources, and time invested attending ineffective training could be better spent towards improving the sustainability and resilience of their farming operations (Kumar et al., 2019b).

To further examine the potential outcomes of the BCI training provided, the farming practices of farmers who attended and did not attend BCI training were compared. Only three agricultural practices (cover crops, fertilization based on experts, potassium application) were implemented by a greater average of farmers who attended BCI training compared to farmers who did not (with a difference in means having a statistical significant difference of 99%) with a level of adoption of 50% or more. In addition, approximately 90% of surveyed farmers who attended BCI training rely on only one source of cotton price information and use polypropylene bags for harvesting their cotton, which is a widely recognized source of fibre contamination. The general lack of differences in farming practices between farmers who attended BCI training and those who did not conveys that the BCI program is not positively affecting the general resilience of cotton farming systems in the Adoni Mandal via its training and capacity building efforts. Consequently, we can infer that the effects of the BCI training on farming resilience was mostly inconsequential both in terms of the implementation of the BCI program efforts for the adoption of the BCI standard among farmers and potential outcomes associated with implementing the BCI standard on the farm.

As capacity building efforts are often needed to implement AVSS, the training they provide to farmers needs to be effective, relevant and should contribute to building farming resilience. To ensure that AVSS training is well received, it must meet pressing farming needs which should include addressing resilience threats (Mancini et al., 2008). Furthermore, involving farmers in the development and delivery of AVSS training could improve the uptake of lessons learned and their implementation (Kansanga et al., 2021; Nakano et al., 2018). AVSS must also ensure that their capacity building efforts remain flexible and adaptable to changing conditions so that farming operations have the right skills, capacities and information needed to implement their standard as well as build the general resilience of their farming operations. Training on farming resilience could also be offered covering the resilience capacities described by Meuwissen (2019) as robustness (withstand disturbances), adaptation (adjust the existing farming operation) and transformation (reconfigure the farming operation). Nevertheless, continuous capacity building was found to be a consistent requirement across the AVSS examined in the benchmarking effort as they ascribe to continuous improvement approaches[57] and farmers are required to be involved in training, monitoring and recording efforts associated with the farming operations. Underlying these farming resilience capacity building directions, is the need for AVSS

[57] Continuous improvement approaches refers to requiring farmers to meet minimum sustainable farming requirements with commitments to improve towards more sustainable farming practices over time.

to recognize farming resilience as one of their overall goals to ensure that it is reflected in their capacity building efforts and adoption of their standard which can then be tracked and verified for impact. The challenge remains for AVSS to require farming operations to be engaged in and to provide the right types of capacity building efforts that capitalize their resources to build farming resilience

The BCI standard requires farmers to **engage with external stakeholders and governance structures** to enable decent work conditions and sustainable water management (Better Cotton Initiative, 2018). Engaging with external stakeholders and governance structures is also of great importance for farming resilience to establish strategic partnerships and collaborations needed to better face resilience threats but also to collectively build resilience of the socio-ecological system in which farms are located. To assess the BCI program's effects on engaging with external stakeholders and governance structures, the network positioning and potential function of the PRDIS (BCI's implementing partner) within the water and food security organizational networks and sub-networks of the Adoni Mandal were examined. The network degree and betweenness centralities of the PRDIS were first assessed and compared with the KVK and the RF, two NGOs with similar mandates working in the Adoni Mandal. The potential effects of the BCI program on the village leadership network function and positioning in the water and food security networks in the Adoni Mandal were then examined by assessing and comparing their network degree and betweenness centralities with and without the PRDIS in the networks.

The analysis revealed that the PRDIS has very few reciprocal relationships with the village leadership where the BCI program is being implemented, does not collaborate with the KVK and RF, and cannot enable multi-jurisdictional collaborations based on its direct relationships. Nevertheless, the betweenness centralities calculated for the water and food security networks and sub-networks indicated that the PRDIS is not as well positioned as the KVK but better positioned than the RF to enable coordinated responses to disturbances and facilitate collective resilience. When examining the degree and betweenness centralities of the village leadership in the Adoni Mandal, with and without the PRDIS, no important differences were observed between the network function and positioning of villages participating in the BCI program and those that were not. Furthermore, there was no organizational relationships between the villages and municipal ward participating in the BCI program, something that the PRDIS could have facilitated. These results indicate that the PRDIS is enabling very limited engagement with external stakeholders and governance structures associated with water and food security in the Adoni Mandal.

Engaging with external stakeholders and governance structures underpins the development of polycentric governance systems which are fundamental for building the resilience of socio-ecological systems (Biggs et al., 2015; Carlisle & Gruby, 2017; Galaz et al., 2012). To enable farming resilience, AVSS need to link relevant stakeholders into polycentric governance systems and must empower farmers to be engaged in governance processes to build their resilience and contribute to building collective resilience. This is especially true for smallholder farmers who are often isolated and cannot access the services and support they need to become and remain resilient (Abid et al., 2017; Rockenbauch & Sakdapolrak, 2017). For instance, Cadger et al. (2016) remarked that farmers in six communities in Ghana participating in development projects were more likely to be part of larger networks as well as adopt and adapt more diverse agricultural production practices aligned with agroecology. Their findings suggests that farmers implementing AVSS could be better networked than their counterparts. For instance, the BCI program offers cotton farmers in the Adoni Mandal a new network that can be leveraged for farming resilience.

In many ways, establishing polycentric governance systems that build resilient socio-ecological systems can be more impactful than working with individual farmers to adopt more sustainable and resilient farming practices. For instance, enabling effective polycentric governance systems for water security is critical for agriculture to remain viable in the Adoni

Mandal (Srikanth, 2017). AVSS have potential to build the resilience of farming and socio-ecological systems by enabling organizational relationships between entities working at various scales of governance to facilitate coordination and collaboration to address resilience threats (Rockenbauch & Sakdapolrak, 2017). For instance, there is very little inter-village cooperation in the Adoni Mandal to address water security issues which could be facilitated by the BCI program to collectively address resilience threats (Farmer Focus Groups, personal communication, March 2016). Furthermore, when looking at the inter-village connections of the 12 villages surveyed, only 5 reported being connected to at least one other village, out of which only 2 reported being connected to more than 2 villages. At the very least, one could expect that the PRDIS could connect the villages and the municipal ward participating in the BCI program and collaborate with the PRDIS and the KVK, who are both involved in building the capacities of farmers in the Adoni Mandal which can improve farming resilience.

AVSS have contributed to establishing vertical governance systems for the production of agricultural commodities where supply chain stakeholders work together to enable more sustainable supply and value chains (Komives & Jackson, 2014). For instance, the BCI program enables cotton supply chain governance to address sustainability issues in the cotton sector by bringing together brands, corporations, spinners, ginners, producer organizations, researchers, and NGOs around shared sustainability objectives. They have been less active enabling horizontal governance systems which are critical to support sustainable and resilient farming systems that underpin agricultural supply chains. Verburg (2019a) specifically criticizes AVSS in the coffee sector for their limitation in enabling landscape integration which requires horizontally integrated governance processes. "Although some landscape aspects are addressed in certification, such as the deforestation commitments, landscape integration is beyond the capabilities and remits of current certification schemes" (Verburg et al., 2019a, p. 21). Furthermore, supply chain stakeholder dependence on agricultural products can result in perverse situations where farming operations are incentivized to maintain the status quo and avoid adapting or transforming towards more sustainable and resilient farming systems (Bitzer & Steijn, 2018; Buitenhuis et al., 2020). To contribute to enabling resilient farming and socio-ecological systems, AVSS need to facilitate the integration of vertical and horizontal polycentric governance structures for sustainable and resilient agricultural production. This can be achieved by bringing together supply chain stakeholders (i.e. farmer groups, traders, manufacturers, retailers and consumer groups) and agricultural landscape stakeholders (farmer groups, local governments, regional governments, national governments civil society, non-government organizations) to facilitate the information exchange and decision-making processes needed to support sustainable and resilient agricultural production (see Figure 24).

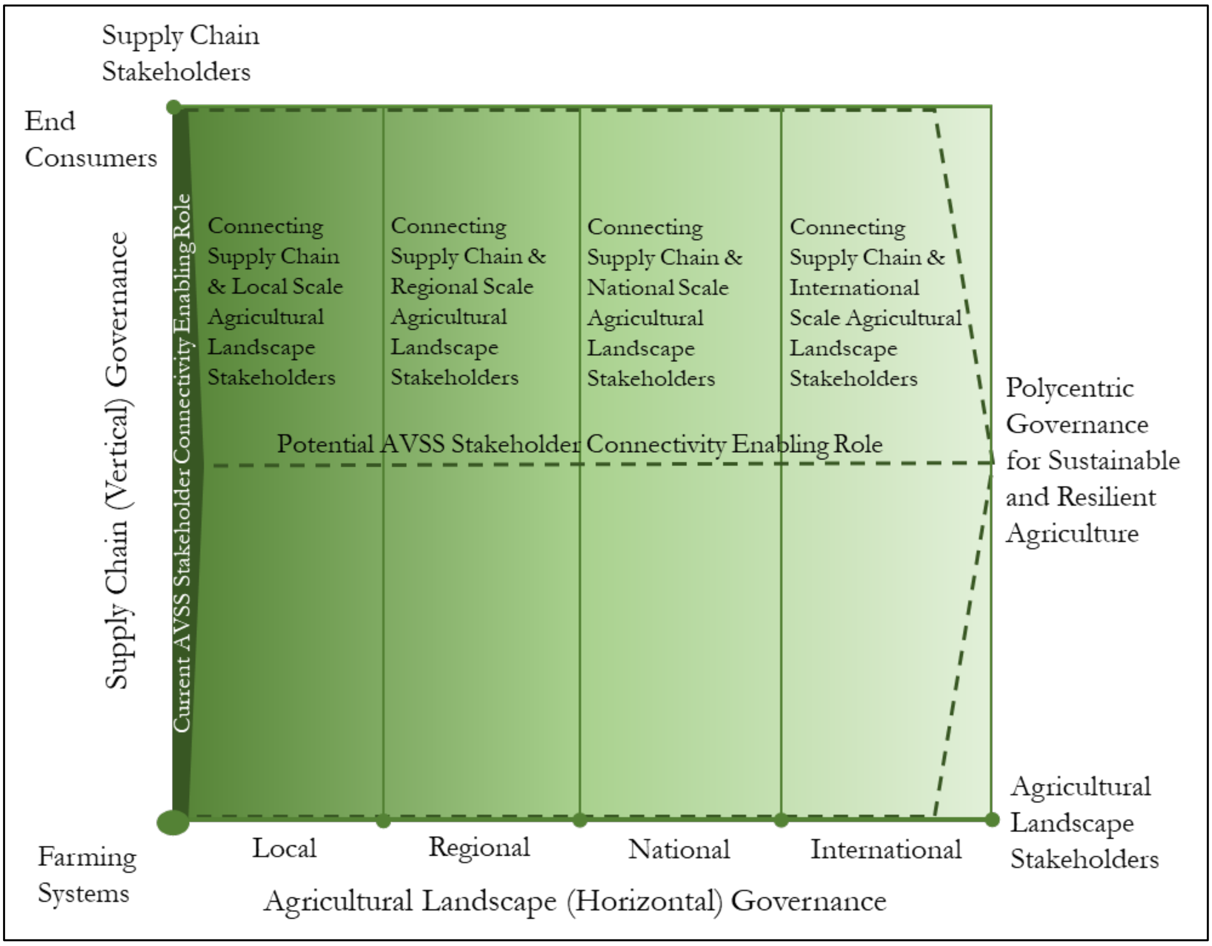

Figure 24 – AVSS can enable sustainable and resilient farming polycentric governance systems to emerge

6.2 Framework Strengths and Limitations

The AVSS resilience analytical framework is reflected on to identify its main strengths and limitations. The framework's resilience intelligence, conditions and collaborations dimensions and respective indicators were proposed to provide a means to ascertain how AVSS affect the resilience of farming systems. Although the framework's focus on the three main spatial extents of farming systems, namely farmers, farms and its surroundings, offered a useful approach for sorting out the potential resilience effects of interventions, disentangling their effects on farming resilience remained challenging. Furthermore, the framework does not explicitly address the temporal dimension of resilience, but for a dynamic perspective it could be applied at different times to monitor how farming resilience is evolving.

The main challenge in applying the framework was disentangling how an intervention could affect the various interconnected resilience indicators, leaving plenty of room for personal interpretation especially when applied without context. For instance, recording the activities of the farming operation implies that there has been some form of monitoring which contributes to capacity building. Although this challenge is reduced when applying the framework to a particular context, which provides more specificity to ascertain an intervention's farming resilience effects, subjective interpretation cannot be avoided. For instance, the framework provided a basis to explore the linkages between the BCI training, farming and business practices implemented by farmers and their potential effect on farming resilience. Nevertheless, applying the framework was particularly challenging for exploring socio-economic characteristics such as health and safety and literacy which can influence many aspects of farming resilience. This challenge calls into question the usefulness of the framework for examining the full breadth of how AVSS affect the general resilience of farming systems.

Nevertheless, the most useful feature of the framework to disentangle how interventions intersect with the various resilience indicators was its three spatially oriented dimensions (resilience intelligence focused on the farmer, resilience conditions focused on the farm and resilience collaborations focused on the farm's surroundings). Adding a category between the dimensions and indicators could potentially improve the usefulness of the framework (see Table 32). For instance, the complex systems thinking, targeted experimentation and adaptation strategies are oriented towards dealing with the "unknown" since they seek to identify interconnections, discover and develop strategies to disturbances that could potentially emerge. Continuous capacity building, monitoring and recording the farming operation are oriented towards the "knowable" or gaining and retaining knowledge to build resilience. In this way both sets of indicators are complementary.

Table 32 – The AVSS resilience analytical framework dimensions and indicators grouped into sub-categories

Dimension	Sub-Category	Indicator
Resilience Intelligence	Establishing faculties for dealing with risks and uncertainty	Adopting complex systems thinking
		Targeted experimentation
		Establishing adaptation strategies
	Establishing faculties for dealing with the knowable	Continuous capacity building
		Monitoring the farming operation
		Recording the farming operation
Resilience Conditions	Diversifying and enhancing livelihood resources	Managing agricultural products diversification
		Managing economic activities diversification
		Managing Ecosystem Services diversification
		Preserving the growing environment
	Diversifying and enhancing human resources	Broadening participation
		Internal governance structures
Resilience Collaborations	Managing relationships with immediate surroundings	Managing ecosystem connectivity
		Managing community connectivity
		Managing market connectivity[58]
	Managing relationships with remote surroundings	Engaging with external stakeholders and governance structures
		Complying with laws and regulations
		Enabling socio-economic regime shifts

A temporal dimension could be added to the framework to examine "resilience over what timeframe", which has important implications for planning farming resilience (Helfgott, 2018). For instance, establishing the timeframe within which the growing environment of a farming operation needs to remain resilient can allow for mobilizing the resources needed to withstand,

[58] Managing market connectivity can be thought of within the context of farm gate sales where consumers order agricultural products at a given price leaving the farm gate. Transporation costs could be initially borne by aggregators, traders or the farmers themselves which is then recovered once the product is delivered (farm gate price + transportation costs).

adapt and transform to cope with disturbances brought on by climate change which are expected to become more unpredictable with time (Masson-Delmotte et al., 2021). Nevertheless, the framework can be used to assess the resilience intelligence, conditions and collaborations at different points in time to provide some understanding as to how a farming resilience is evolving.

The AVSS resilience analytical framework was useful for examining the intersection between AVSS and farming resilience specifically in terms of their designs but also in terms of testing elements of their implementation. Similarly to other frameworks, the AVSS resilience analytical framework must be viewed as a heuristic which can be modified to fit the context examined and improved over time. For instance, the framework's indicators may need to be modified to examine farmers who do not record their activities due to their belief systems or lack of capacity. In this way, the AVSS resilience analytical framework allows "…to find unexpected forms and factors of resilience and to develop theory through the encounter with the empirical practices, instead of applying a fixed set of variables to shoe-horned cases" (Meuwissen et al., 2019, p. 8). Thus, the AVSS resilience analytical framework could be modified to examine the effects of interventions on the general resilience of systems generally other than being limited to examining the effects of AVSS on the general resilience of farming systems.

6.3 Rethinking AVSS for Farming Resilience

Establishing how AVSS designs and an AVSS implementation affect the general resilience of farming systems allows for reflecting on what an AVSS that enables sustainable and resilient farming could look like. AVSS have been designed to enable sustainable farming systems and have yet to be oriented towards enabling their general resilience. To address this limitation, AVSS need to reconcile differences between farming sustainability and resilience, provide flexible conditions for farmers to deal with disturbances under extreme circumstances and require production practices that facilitate the resilience of the socio-ecological systems in which farms are located. To do so, AVSS will have to engage more deeply with the farmers, their farming operations and socio-ecological contexts where they are being implemented (E. A. Bennett, 2017).

AVSS need to integrate the sustainability and resilience concepts in their standard, which is an ongoing debate in the scientific literature (Roostaie et al., 2019). In their revision of the sustainability and resilience concepts, Roostaie et al. (2019) state: "whereas the core idea of sustainability is to reduce negative impacts on the environment to avoid changes, resiliency is about adaptation to change" (Roostaie et al., 2019, p. 135). This simplified description conveys that sustainability is oriented towards preventing negative impacts now and into the future, while resiliency is a process to respond to dynamic and changing environments. To reconcile their compatible yet different orientations, sustainable and resilient farming needs to be guided by a shared set of values to ensure that it can result in positive outcomes. "Resilience does not always imply a normatively positive nature or a desired state, because a system could be highly resilient without achieving sustainability goals" (Roostaie et al., 2019, p. 141). AVSS are currently guided by sustainable development principles reflecting the values of supply chain stakeholders hoping to improve the sustainability of their businesses which requires a steady supply of raw materials. Consequently, AVSS focus on addressing various sustainability challenges, such as climate change, which can intersect with farming resilience (E. M. Bennett et al., 2014; Roostaie et al., 2019). For instance, the BCI standard requires farmers to conserve soil and water resources which can enhance the climate resilience of their farming operations (Better Cotton Initiative, 2018). AVSS that enable both sustainable and resilient farming systems will need to be guided by values and objectives shared and developed by all supply chain stakeholders, including farmers, so they can be more grounded and oriented towards enabling both sustainable and resilient farming operations, which are vital for producing the raw materials that supply chains depend on (E. A. Bennett, 2017).

Although AVSS can support farming resilience in different ways, they can also impede it as requiring farmers to implement specific farming practices in varying contexts can be constraining and counterproductive to building resilience. AVSS are designed to address various sustainability challenges in agriculture which are dynamic and manifested differently in different parts of the world. To encourage farmers to embark on a journey towards more sustainable agricultural practices, they have started implementing a continuous improvement approach which also provides some flexibility to better fit the contexts in which they are being implemented. Nevertheless, to move beyond this standards and resilience contradiction, a shift from prescriptive and dogmatic requirements towards flexible and pragmatic requirements will be needed to prevent farming constraints when faced with disturbances. AVSS that enable farming resilience will be comprised of requirements that enable farming operations to remain flexible when faced with difficult circumstances. For instance, the RA standard has addressed this need for flexibility by establishing an exceptional use policy for the pesticides that they prohibit (Rainforest Alliance, 2021b). As a result, RA certified farmers who were dealing with the coffee leaf rust disease had more options compared to Organic certified coffee farmers who are prohibited from using synthetic pesticides under any circumstances (Craves, 2013; Torres Castillo et al., 2020). Similar policies could be established to provide farmers with flexibility within defined limits to address other disturbances under difficult circumstances. This example highlights the need to clearly define the range of allowable farming practices permissible under difficult circumstances, which will require engagement with all parts of the supply chain including farmers (E. A. Bennett, 2017).

The RA exceptional use policy for prohibited pesticides example also highlights the need for AVSS to integrate production criteria that build the resilience capacities of farming systems so they can withstand, adapt and even transform in response to a broad range of disturbances (Meuwissen et al., 2019). In their current configuration, AVSS have some production criteria that can enable the robustness and adaptability capacities of farming systems but not their transformational capacity (Gosnell et al., 2019; Verburg et al., 2019a). For instance, the RA exceptional use policy for prohibited pesticides allows farming systems to resort to unsustainable farming practices to withstand disturbances and maintain short-term viability (robustness resilience capacity), effectively preventing their potential adaptation and transformation, which can undermine their long-term sustainability and resilience (Berardi et al., 2011). Ashkenazy (2018) speaks to this trade-off by stating that "while persistence, adaptability and transformability can coexist, they can also undermine one another … no single strategy can amplify all three aspects of resilience simultaneously" (Ashkenazy et al., 2018, p. 220). Furthermore, there are very few production criteria that directly focus on transforming the farming systems such as requiring managing the diversification of the economic activities supported by the farming operation (see Section 6.1.1). Underlying the tension between the persistence, adaptation and transformation aspects of resilience is the aforementioned need to reconcile potential differences between sustainable and resilient farming as well as addressing controversial trade-offs between ecological and socio-economic priorities. For instance, farmers may use agrochemicals to boost agricultural production at the expense of human and environmental health. Shifting the focus of AVSS from the sustainable production of agricultural commodities to maintaining sustainable ***and*** resilient livelihoods could potentially address this tension (Bitzer & Steijn, 2018). What is clear is that AVSS would have to integrate measures in their standard that support the persistence (or robustness), adaptation and transformation of farming operations to maintain resilience.

AVSS must also require farming systems to contribute towards collectively building the resilience of the socio-ecological systems in which they are embedded. Engagement with their immediate surroundings and beyond can assist farming systems with building their persistence, adaptability and even transformability to remain resilient (Biggs et al., 2015). AVSS requirements are primarily focused on farm-level measures to preserve the resource base needed to continue farming. Verberg et al. (2019a) remark that AVSS in the coffee sector are not currently configured to enable landscape-scale resilience and although they can support system adaptation, transformational adaptation is beyond their capability. Based on monitoring the resilience of 11 farming systems since 2017, Meuwissen et al. (2021) found that managing connectivity as well as diversity considerably contributed to maintaining farming resilience to the challenges posed by the COVID-19 pandemic. Furthermore, involvement in governance structures working on farming resilience threats (i.e. climate change, water sustainability, land use chance, biodiversity conservation) represents important opportunities for collaborative and coordinated actions needed to build the resilience of the socio-ecological systems in which farms are embedded (Biggs et al., 2015).

6.4 Enabling Farming Resilience in the Adoni Mandal

To summarize the main points discussed, it is worth imagining what outcomes could have been observed if the BCI standard enabled cotton farming resilience in the Adoni Mandal. Measures to improve cotton farming resilience could have significantly benefited the study area as climatic changes have hit cotton farmers particularly hard in recent years (ETV Andhra Pradesh, 2015; Farmer Focus Groups, personal communication, March 2016; Kumar et al., 2019b; Rao, 2019; Reddy, 2018; Special Correspondent, 2017; Sudhakar, 2019, 2021). Recommendations are tabled for the BCI program to enable farming resilience in the Adoni Mandal which are largely supported by Kumar et al. (2019b) who studied the sustainability impacts of the BCI program in the Adoni Mandal from 2015 to 2018.

Cotton farmers aspiring to implement the BCI standard are organized into BCI Producer Unit Learning Groups who receive training from the PRDIS. The learning groups need to be consulted to establish training which is oriented towards the adoption of the BCI standard but also addresses the main resilience threats to their livelihoods, namely climatic challenges, profitability and pests and diseases. This position is supported by Kumar et al. (2019b) who recommended that the BCI program capacity building efforts should be oriented as follows: "the methods for facilitating learning should be tailored to context, designed by participants to reflect their needs" (Kumar et al., 2019b, p. xii). They also observed that experiential learning, which can significantly support farming resilience, was sorely lacking in the implementation of the BCI program: "… the current study did not include strong experiential learning as facilitated in farmer field schools and farmer networks, yet the latter may be more effective in achieving change where there are strong countervailing forces" (Kumar et al., 2019b, p. xiii). Resilience training should also be offered as part of the overall capacity building efforts of the PRDIS so that farmers can learn why it is important and how to operate more resilient cotton farms capable of weathering known and unknown disturbances. In essence this would require instilling a resilience awareness within farmers allowing them to wisely choose among options so they can maintain farming resilience while remaining standard-compliant. In principle, the BCI Producer Unit Learning Groups need to act as a platform for farmers to exchange information and support in the production of BCI-verified cotton and building farming resilience (Wood et al., 2014). However, Kumar et al (2019b) remarked that the producer units were not fully functional in offering services to its members, suggesting that information and support exchanges were likely not occurring as of 2018. The training needs to instill in the cotton farmers they train a desire to learn to build their resilience (**continuous capacity building**).

Measures to address resilience threats need to be implemented by farmers participating in the BCI program. For instance, water retention measures such as bunds and retention ponds should be in place to retain precipitation and overcome water shortages. Cotton fields should be inter-planted with drought tolerant crops, such as sorghum, and covered by cover crops (i.e. chickpeas and red gram) and mulch to maintain soil moisture and diversify agricultural production (**manage the diversification of agricultural products**). The BCI standard should require the cotton farmers of the Adoni Mandal to experiment so that they can be better equipped to face known and unknown disturbances, which will vary over time and space. For instance, drought tolerant trees could be grown to assess their potential to influence micro-climates (**targeted experimentation**). It should also be possible for farmers to be involved in other economic activities which can include transportation, small-scale cotton ginning and food processing and should be registered to benefit from the national rural employment guarantee scheme (**manage the diversification of economic activities**). This recommendation is supported by Kumar el al. (2019b) who advocate for "exploring livelihood diversification strategies as part of farming a systems approach is also important, beyond the focus solely on cotton for all farmers" (Kumar et al., 2019b, p. xii). Farmers need to develop adaptation strategies that go beyond their main coping strategies (postponing debt payments, switching crops and finding wage labour) which can be inspired by consulting farmers from more drought prone areas, such as Alur located just south of the Adoni Mandal (**developing adaptation strategies**). The diversification of farming systems needs to be actively managed to find an optimal level for farming resilience.

The BCI program should be collaborating with other NGOs in the Adoni Mandal with similar mandates to leverage resources and achieve common objectives. For instance, the PRDIS does not interact with the KVK and the RF when they could have been working closely with them to build the capacity of cotton farmers. The BCI program needs to liaise with local governments to ensure that the main resilience threats to cotton farming are being addressed. For instance, the PRDIS could have been actively engaging with village leadership and relevant Mandal government departments and enabling inter-village collaborations for them to better deal with resilience threats (**managing community connectivity**). Furthermore, BCI learning groups could be connected to key government departments, such as the MED for water security and the DAOA for food security, two well-connected government departments within the water and food security networks of the Adoni Mandal (**engaging with external stakeholders and governance structures**). Kumar et al. (2019b) support this recommendation by advocating for engaging with a diversity of stakeholders including local authorities and state governments as "such an approach could help to identify and build area based partnerships from the outset" (Kumar et al., 2019b, p. xii). They further advocate for stakeholder engagement to collectively establish problems and solutions and enable adaptive management. Cotton farmers in the Adoni Mandal need to understand the importance of managing the connectivity of their cotton farming operations to maintain their resilience and actively seek to contribute towards building collective resilience (Meuwissen et al., 2021).[59]

6.5 Standardizing Uncertainties

Over the longer-term, AVSS will need to establish a culture[60] that is able to deal with uncertainties within its supply chains if they are to enable effective and enduring forms of farming resilience. Uncertainties stems from the fact that socio-ecological systems, such as farming systems, are far too complex to be controlled. Roe (2020) describes this complexity in the following way:

> The world cannot be controlled to be only one way; it is far too complex for that, with many components, each component having multiple functions … and the many interconnections between and among components, functions and the wider environments in which these are embedded enable all manner of interpretations, explanations and descriptions (Roe, 2020, p. 80).

Consequently, uncertainties becomes integral to dealing with socio-ecological systems and can be thought of as a spectrum spanning from partial to inexistent knowledge (unknown-unknowns) associated with potential future events and their outcomes (Roe, 2020; Scoones & Stirling, 2020).[61] Unlike risks, uncertainties cannot be defined by probable outcomes and their consequences (Roe, 2020; Scoones & Stirling, 2020). The argument for AVSS to establish a culture able to deal with uncertainties is strengthened by Scoones and Stirling (2020) who state in their book on the Politics of Uncertainty "in a complex, interconnected world, uncertainties are central to our common futures – and to normative ideas of sustainability and development"

[59] Although examining the connectivity of individual farmers was beyond the scope of this research dissertation it would be valuable to establish how the implementation of AVSS could affect the connectivity of individual farmers participating in their programs so it can be compared and contrasted with farmers that are not adding an additional means to measure the potential impacts of AVSS on farming resilience.

[60] Culture can be viewed as "as the webs of meanings and significance that people weave about their lives. The analysis of culture is therefore … an interpretive one in search of meaning. As people search for this meaning, they bring culture into being" (Arora-Jonsson, 2016, p. 100).

[61] Scoones and Stirling further describe uncertainties as having five dimensions – uncertainties are constructs of possible futures, have material origins and effects, are experienced differently, are reflected by how we think and feel, and in how we act (Scoones & Stirling, 2020, p. 14).

(Scoones & Stirling, 2020, p. 14). AVSS will need to substantively engage with and address the challenges and opportunities associated with uncertainties if they are to fulfill their current 'raison d'être', which is to enable more sustainable agricultural production.

Establishing a culture able to deal with uncertainties will require working with plural forms of knowledge that allows for creative dialogues to co-create shared understandings of and strategies to deal with uncertainties (Mehta & Srivastava, 2020). Mehta et al. (2020) refer to this process as defining uncertainties from above and below where scientific and experiential knowledge are used to co-create and fine-tune climate projections. In the case of AVSS, all relevant stakeholders, including farmers, will need to be engaged in this process, which will require embracing uncertainties as a constitutive part of farming resilience processes, where experiential and scientific knowledges are valued to enable transformative processes. In this way, the objective moves away from trying to 'tame' uncertainties to learning from past experiences of coping with unexpected disturbances and how resilience processes emerge.

Translating an AVSS culture able to deal with uncertainties down to the farming system, will require grappling with trade-offs between focussing on product uniformity and verifiability and enabling farming resilience to respond to a range of disturbances, including unpredictable and unforeseeable ones (unknown-unknowns). As farming resilience must include persistence, adaptation as well as transformation, so as not to limit potential responses to disturbances, it can be incompatible with maintaining production and product uniformity and verifiability. To examine this challenge, Roe's (2020) reference to interlinked system inputs, processes and outputs to describe how to deal with operational unpredictabilities can be insightful. As system input variance increases, it becomes more difficult to minimize process and output variance. Since AVSS have very little control over disturbances (input variance) to farming systems and can only influence agricultural production through their production standards (process variance), they must allow for production flexibility if they are to maintain some level of product uniformity (output variance). There may be situations where maintaining product uniformity may not be possible, despite allowing for production flexibility, which means that AVSS may need to integrate measures that allow for agricultural production (process variance) as well as product (output variance) flexibility to maintain farming resilience. In other words, trade-offs will need to be reconciled between AVSS uniformization and verifiability objectives and farming resilience, understood as a system staying within its stability domain and capable of transforming into new stability domains if a critical threshold is passed.

To accommodate more production and product variance within supply chains to maintain farming resilience implies that AVSS will need to create demand for more sustainable and resilient agricultural production approaches supported by flexible standards and assurance systems. To create this demand, AVSS will need to educate consumers on the need for agriculture to become more resilient, which includes managing and coping with uncertainties. The objective would be to shift customer focus from end-product uniformity to supporting farmers committed to more sustainable and resilient forms of production which need to be flexible to maintain viable farming operations in the face of disturbances. Enabling this shift in consumer focus is likely to become easier as populations across the globe become increasingly subjected to disturbances requiring more resilience not limited to agricultural production systems (Masson-Delmotte et al., 2021; Stephens et al., 2020).

To meet potential consumer demands for more sustainable and resilient farming and their products, AVSS need to establish production standards that require farmers to adopt values, commitments and practices compatible with sustainable and resilient agriculture. These production standards will need to be co-created with relevant stakeholders as well as regularly reviewed and modified to align with changing contexts. As remarked by Bahadur and Tanner (2014), operationalizing resilience thinking is a significant challenge, particularly where power imbalances and competing interests may be at play. "There can be trade-offs among different groups seeking resilience where resilience for one could lead to heightened vulnerability for another" (Bahadur & Tanner, 2014, p. 203). Nevertheless, the process of co-creating AVSS production standards for sustainable and resilient farming sets a foundation for shaping a culture oriented towards dealing with uncertainties.

Integrating shared beliefs and values related to dealing with uncertainties within AVSS production standards may provide a place to start as they are more likely to be maintained even when farmers need to transform their farming operations to remain resilient production and product uniformity. Furthermore, as remarked by Bahadur and Tanner (2014) "individual values, meanings and beliefs play a critical role in any programme of managing risk" (Bahadur & Tanner, 2014, p. 209). These production standards would also likely have a greater emphasis on ongoing efforts instead of specific outcomes, which would align with Roe (2020) who advocates for moving beyond controlling to managing and coping with uncertainties where farmers will also need to 'cope ahead' (or move towards less vulnerable states) when faced with new disturbances. In essence, AVSS need to develop flexible production standards and assurance systems that embark and keep farmers on a journey towards more sustainable and resilient farming.

The COVID-19 pandemic provides a case in point for AVSS to adopt a culture oriented towards dealing with uncertainties. As described by Auld and Renckens (2021) a number transnational private sustainability regulators (which include standard-setting bodies) have had to modify their assurance systems to accommodate health and safety and logistical challenges associated with the pandemic. By reviewing the changes in the assurance approaches of 98 transnational private sustainability regulators, they found that approximately half modified their auditing procedures while only seven modified and established exemptions to their production standards to accommodate for COVID-19 disturbances (Auld & Renckens, 2021). In many ways their finding is less surprising when contrasted with, Bahadur and Tanner's (2014) position that "resilience, with its emphasis on foresight, flexible systems and the acknowledgement of uncertainties, is incongruent in policy environments that are dominated by centralized command and control strategies, short termism and preservation of the status quo, manageable steady states and predictability" (p.204). AVSS congruent with farming resilience may have been better able to deal with disturbances such as the COVID-19 pandemic. Nevertheless, AVSS can also offer advantages as standard-compliant producers accustomed to following protocols where found to be better able to adopt newly introduced COVID-19 measures (S. Elder, 2021). As remarked by Bahadur and Tanner, the COVID-19 pandemic provides an important and timely opportunity for AVSS to foster a culture oriented towards dealing with uncertainties. "Despite robust empirical evidence of organizations and institutions changing to enhance resilience following shocks, there is little empirical study of how radical institutional change can be induced prospectively, based on foresight or minor creeping changes before disaster events occur" (Bahadur & Tanner, 2014, p. 204). Reimagining AVSS so they can facilitate both sustainable and resilient farming will require adopting a culture conducive to dealing with uncertainties.

AVSS assurance systems that rely on top-down and bottom-up monitoring processes leveraging advances in technology and local communities could be devised to better deal with uncertainties related to monitoring AVSS-compliance. Top-down monitoring processes could include using remote sensing, video, audio and environmental censor technologies which could support and perhaps replace external audits. Bottom-up monitoring processes would rely on local populations to provide ensure that farming operations in their communities are operating in accordance with the AVSS. This local decentralized approach could be designed similar to the blockchain where information produced is confirmed with others to ensure that it is valid and accurate. Bottom-up monitoring processes could also better adapt to unpredictable situations potentially, build local capacities and strengthen local governance. Top and bottom-up monitoring processes could be used to move towards monitoring farming operations in real-time to offer farmers opportunities to course correct their operations and provide customers with better information to make informed purchasing decisions.

6.6 Final Thoughts

To conclude, resilience offers an opportunity for AVSS to be re-imagined towards enabling both sustainable and resilient farming systems. Doing so will require addressing some of its main shortcomings such as the need for AVSS to involve farmers in their design and implementation and enable polycentric governance for sustainable and resilient agricultural production by bridging together horizontal (agricultural landscapes) and vertical (supply chain) governance structures (E. A. Bennett, 2017; Bitzer & Steijn, 2018; Verburg et al., 2019a). AVSS will also have to establish a culture comfortable and able to deal with uncertainties to deal with unforeseeable disturbances such as the COVID-19 pandemic. This research dissertation provides a foundation upon which to examine the effects of AVSS on farming resilience, providing the insights required to guide their development towards enabling sustainable ***and*** resilient farming systems.

7 Conclusion

As humanity is approaching and surpassing interconnected critical thresholds, global agricultural production systems will need to become resilient to face more frequent, precipitous and unpredictable disturbances (E. M. Bennett et al., 2014; Boltz et al., 2019; Masson-Delmotte et al., 2021; Rockstrom, 2009; Steffen et al., 2018).[62] To do so, interventions in agriculture will need to be oriented towards building the general resilience of farming systems instead of being focussed on specific disturbances such as climate change. Farming resilience refers to farming systems that continue functioning when faced with disturbances by persisting (or withstanding), adapting and transforming (E. M. Bennett et al., 2014; Meuwissen et al., 2019).[63] AVSS offer an opportunity to build farming resilience as they have grown significantly in number and market share in recent years in some agricultural commodity sectors (Meier et al., 2020; Potts et al., 2014). Nevertheless, their orientation towards enabling more sustainable forms of agriculture has yielded mixed results (DeFries et al., 2017; Oya et al., 2018). For this reason, assessing their potential for enabling farming resilience provides a starting point to re-imagine their design and implementation for enabling sustainable as well as resilient farming systems. Doing so will benefit from an analytical framework designed to assess their potential to enable farming resilience. As agriculture needs to be resilient if it is to be sustainable, developing AVSS that enable sustainable and resilient farming systems has become vital (E. M. Bennett et al., 2014; Biggs et al., 2015; Meuwissen et al., 2019).

[62] Steffen et al. (2018) estimates that without significantly dropping greenhouse gas emissions, self-reinforcing feedbacks could put the earth systems on a trajectory towards surpassing a plantery threshold that could prevent it from stabilizing global temperatures at an intermediate level.

[63] "Robustness is the farming system's capacity to withstand stresses and (un)anticipated shocks. Adaptability is the capacity to change the composition of inputs, production, marketing and risk management in response to shocks and stresses but without changing the structures and feedback mechanisms of the farming system. Transformability is the capacity to significantly change the internal structure and feedback mechanisms of the farming system in response to either severe shocks or enduring stress that make business as usual impossible. Such transformations may also entail changes in the functions of the farming system" (Meuwissen et al., 2019, pp. 4–5).

7.1 Research Question

To address this challenge, this research dissertation sought to answer the question: ***How can AVSS enable the general resilience of farming systems?*** To account for differences between AVSS aspirational goals as expressed by their designs and AVSS impacts associated with their implementation, the following two sub-questions were formulated:

1. *How are AVSS designs affecting the general resilience of farming systems?*
2. *How are AVSS implementation approaches affecting the general resilience of farming systems?*

Examining the design and implementation of AVSS provides a basis to provide insights on how they could be re-imagined towards enabling farming resilience.

7.2 The AVSS Resilience Analytical Framework

To address the research questions, the AVSS resilience analytical framework depicted in Figure 25 was developed and applied. The framework, described in more detail below, is comprised of three interconnected dimensions and eighteen indicators.

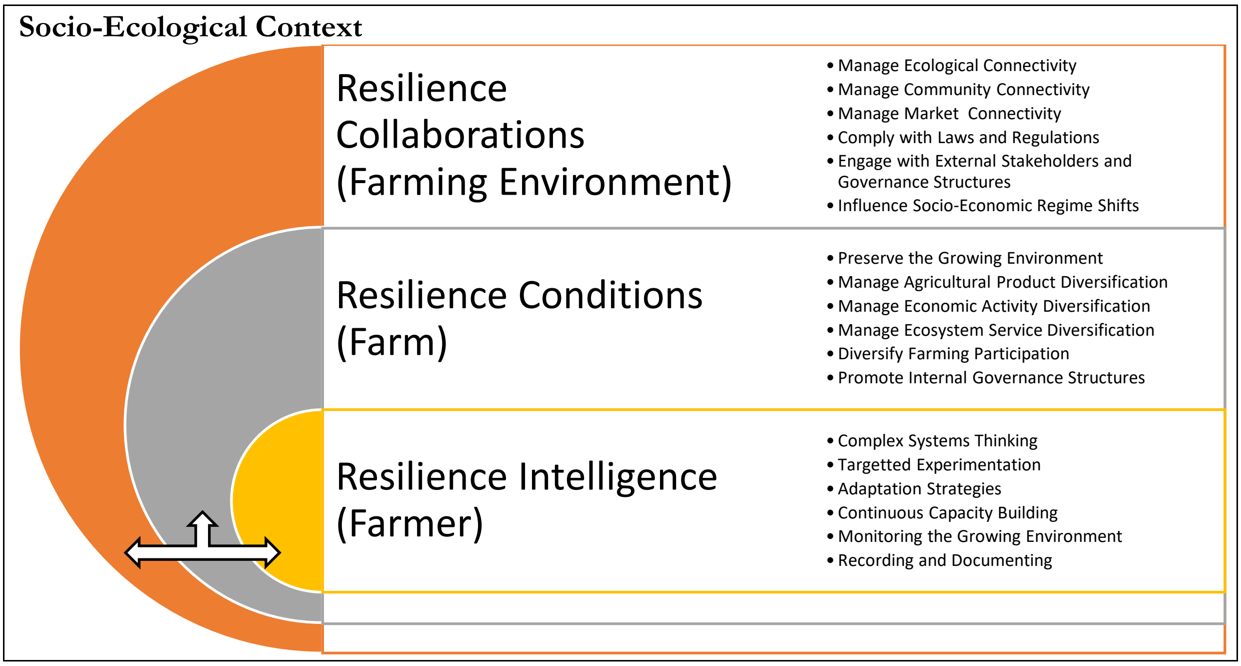

Figure 25 – The AVSS Resilience Analytical Framework

The resilience intelligence dimension focuses on the people involved in managing the farming system and whether or not a particular intervention is expanding the capacities and the imaginary of people to face various disturbances. In this way, the resilience intelligence dimension allows for examining the resilience mindset and culture of people managing the farming system, which is crucial as disturbances can be viewed as setbacks or opportunities. The resilience intelligence dimension is centrally located within the framework as it shapes the other two dimensions, placing farming resilience squarely in the hands of the people involved in its activities - which contrasts with AVSS often developed without adequate consultation with the farmers who implement them (E. A. Bennett, 2017; Bitzer & Steijn, 2018). The resilience intelligence indicators, complex systems thinking, targeted experimentation, adaptation strategies, continuous capacity building and monitoring and recording the farming operation are interconnected. For instance, capacity building can foster complex systems thinking, while targeted experimentation can support the development of adaptation strategies. Despite the various ways in which these indicators interconnect, they provide a means to examine the resilience intelligence dimension in more detail.

The resilience conditions dimension moves from the imaginary to the tangible where the features of the farm can be ascertained to determine if farming systems are resilient. Ascertaining whether a farming system's features are adequate to face known and unknown disturbances is challenging as it is greatly context specific. For instance, a farm that produces a diversity of agricultural products could be deemed more resilient but the additional resources required to maintain this diversity could also negatively affect farming resilience (Ashkenazy et al., 2018). The indicators for the resilience conditions dimension are related in one way or another to managing the diversification of farming systems due to its relevance for addressing known and unknown disturbances. Managing the diversification of agricultural products, economic activities and ecosystem services are oriented directly towards ensuring that the right level of diversity is established to maintain farming resilience. Maintaining the growing environments provides farmers with the option to continue farming by ensuring that the resource base needed to maintain agricultural production is maintained in perpetuity. Broadening the participation of people involved in managing the farm and establishing internal governance structures are also linked to diversification as they are oriented towards diversifying the people and governance structures involved in the participation and management of the activities supported by the farm.

The resilience collaborations dimension focuses on the farm's relationships with its surroundings, which needs to be adequately managed to support farming resilience but also to build the collective resilience of the socio-ecological systems in which they are located. This dimension acknowledges the importance of adequately managing the relationships between the farming operation and its surroundings as it can support and impede resilience. For instance, increased social connectivity can lead to the faster spread of communicable diseases and misinformation but also the spread of knowledge and innovation to adapt to and recover from disturbances. For this reason, three indicators, developed for this dimension, focus on managing the connectivity of the farming operation to its surrounding ecosystems, communities and markets. The other three indicators, engaging with external stakeholders and governance entities, complying with all relevant laws and regulations and enabling socio-economic regime shifts focus on relationships beyond the farm's immediate surroundings that need to be nurtured to continue operating and to enable change in support of farming resilience.

The three resilience dimensions are interconnected and influence each other. Resilience intelligence can greatly affect the resilience conditions and collaborations of the farming operation by guiding its diversification and connectivity with its surrounding environment which can then influence resilience intelligence by shaping experiential knowledge gains and external information accessed. For instance, a farmer's resilience mindset (resilience intelligence), shaped by various factors affecting their farming resilience faculties, such as complex systems thinking and experiential learning, influences the way in which the farming operation is managed to withstand, adapt and transform when faced with disturbances (resilience conditions), which can include diversifying the agricultural production and economic activities supported by the farm which in turn could require the farmer to manage its ecological, community and market connectivity (resilience collaborations) to support these diversified activities but also acquire the skills and knowledge needed to maintain them (resilience intelligence).

7.3 How AVSS affect farming resilience

To address the research sub-questions, a benchmarking effort and case study were undertaken. The benchmarking effort consisted of examining AVSS production criteria and if they could potentially fulfill the eighteen indicators of the AVSS resilience analytical framework to better understand how AVSS designs could potentially affect the general resilience of farming systems. The case study consisted of conducting farmer focus group discussions, a farming survey and a relational survey to gather quantitative and qualitative information needed to better understand how the implementation of the BCI program is affecting the general resilience of cotton farmers in the Adoni Mandal of India.

To examine how AVSS designs affect the general resilience of farming systems, the production criteria and indicators of eleven AVSS from seven standard setting bodies[64] were benchmarked against the 18 indicators of the AVSS resilience analytical framework. The benchmarking effort allowed for identifying gaps that need to be addressed for the AVSS examined to be designed for building farming resilience. The main gaps identified were a lack of requirements for targeted experimentation, development of adaptation strategies and managing the diversification of agricultural production and economic activities supported by the farm. Incorporating AVSS production criteria that support these farming resilience aspects could significantly contribute towards building the general resilience of farming systems. For instance, managing the diversification of agricultural production and economic activities supported by the

[64] The AVSS examined include the Better Cotton Initiative, Bonsucro – general and smallholder standards, Fairtrade International – smallholder producer organization and hired labour standards, Linking Environment and Farming, Rainforest Alliance, Roundtable for Sustainable Biomaterials – general and smallholder standards and Roundtable for Sustainable Palm Oil – general and independent smallholder producer standards.

farm is especially important for dealing with known and unknown disturbances. Meuwissen et al. (2021) found that high levels of diversity within farming systems contributed significantly to coping with the COVID-19 pandemic. The AVSS examined also support farming resilience in terms of requiring the conservation of ecosystems within and surrounding farms, the preservation of the growing environment and the continuous capacity building of people involved in the farming operation via training as well as monitoring and recording various aspects of the farming operation.

The case study allowed for examining in depth how the implementation of an AVSS affects farming resilience by conducting farmer focus group discussions, a farming survey and a relational survey. A single case design is justified on the basis that it is a critical and revelatory case to provide theoretical as opposed to generalizable findings for applying the framework (Yin, 2018). Farmer focus group discussions were undertaken to better understand the context being studied and to provide insights for conducting farming and relational surveys.

The farming survey provided quantitative and qualitative information on the effectiveness of the BCI training as well as the cotton farming practices being implemented in the study area. The information collected was examined using descriptive statistics and propensity score matching to identify farming practice differences between farmers that are and are not participating in the BCI program. The farming survey revealed that the BCI training was largely ineffective. Only 13% of the farmers who attended BCI training expressed a willingness to implement the lessons learned. In terms of differences in farming practices, there were only three agricultural practices (cover crops, fertilization based on experts and potassium application) that were implemented by a greater average of farmers who attended BCI training compared to farmers who did not (with a difference in means having a statistical significant difference of at least 90%) with a level of adoption of 50% or more. These findings convey that the effects of the BCI program on the farming resilience of cotton farmers in the study area were mostly insignificant.

The relational survey provided information required to examine how the BCI program is enabling engagement with external stakeholder and governance structures by constructing organizational networks and sub-networks collaborating on water and food security in the Adoni Mandal. The network analysis focussed on determining the network function and positioning of the PRDIS, the BCI program's implementing partner in the Adoni Mandal, and identifying network function and positioning differences between the leadership of villages that are and are not participating in the BCI program. The PRDIS was found to have no reciprocal relationships with the village leadership where the BCI program was being implemented, have no relationships with the KVK and RF, two NGOs with similar mandates working in the same villages and lack the potential to enable multi-jurisdictional collaborations based on its direct organizational relationships. The betweenness centralities calculated for the water and food security networks and sub-networks indicated that the PRDIS is not as well positioned as the KVK but better positioned than the RF to enable coordinated responses to disturbances and facilitate collective resilience. No major betweenness centrality differences were observed between the leadership of villages participating in the BCI program and those that were not within the water and food security networks examined with and without the PRDIS. Based on the network analysis results obtained, the PRDIS had very little effect in terms of enabling farming resilience via the engagement of external stakeholders and governance structures.

The limitations of the BCI program identified in enabling farming resilience provide guidance to propose how AVSS can be better implemented to enable farming resilience. AVSS capacity building efforts need to be effective, relevant and should contribute to building farming resilience. This can be achieved by involving farmers in the development and delivery of AVSS training which should meet pressing farming needs, including addressing resilience threats (Kansanga et al., 2021; Mancini et al., 2008; Nakano et al., 2018). AVSS need to require farming operations to be engaged in and to provide capacity building efforts that build farming resilience. To enable farming resilience, AVSS need to link relevant stakeholders into polycentric governance systems by integrating vertical and horizontal polycentric governance structures for sustainable and resilient agricultural production (Biggs et al., 2015; Bitzer & Steijn, 2018; Carlisle & Gruby, 2017; Galaz et al., 2012; Verburg et al., 2019a). They must also empower farmers to be engaged in governance processes to build their resilience and contribute to building collective resilience (Abid et al., 2017; Rockenbauch & Sakdapolrak, 2017).

7.4 Research Contributions

This research dissertation provides an important stepping stone to orient AVSS towards enabling farming resilience. To this day, there has not been any substantive research focussed on AVSS and their potential for enabling the general resilience of farming systems. The majority of the research undertaken to date has narrowly focussed on AVSS and climate resilience. The reason for this oversight may be due in large part to the orientation of AVSS on enabling sustainable agriculture, which is closely linked and compatible with farming resilience. Nevertheless, with the looming prospect of having to face more frequent, precipitous and unpredictable disturbances, enabling more resilient forms of agriculture is becoming increasingly unavoidable (Masson-Delmotte et al., 2021; Nyström et al., 2019). The COVID-19 pandemic and it impacts on the agricultural sector has brought this need squarely into focus (Auld & Renckens, 2021; S. Elder, 2021; Henry, 2020; Masson-Delmotte et al., 2021; Meuwissen et al., 2021; Stephens et al., 2020). Therefore, AVSS need to engage more deeply with resilience both in terms of its conceptual underpinnings and how to operationalize it to achieve their sustainability goals. To this end, this research dissertation makes analytical, empirical, methodological and policy contributions towards much needed and overdue research on AVSS and farming resilience.

The analytical contribution of this thesis dissertation consists of providing a structured and spatially bound way to think about resilience. The AVSS resilience analytical framework developed as part of this thesis is comprised of the resilience intelligence, conditions and collaborations dimensions that are interconnected but also embedded into each other. Blending insights from the resilience literature in psychology (resilience intelligence), agriculture (resilience conditions) and ecology (resilience collaborations) allowed for developing the AVSS resilience analytical framework. These dimensions reduce resilience into a manageable and feasible concept that can be implemented within the farming context but also in other domains where resilience needs to be operationalized. The resilience intelligence dimension, which is located in the centre of the framework, as it shapes the other two dimensions, conveys that resilience is a mindset which is central to its conceptualization and manifestation. The resilience conditions dimension is focused on the enabling conditions for resilience which is concerned with the tangible features in place for a given system to deal with disturbances. The resilience collaborations dimension conveys that resilience cannot be achieved in isolation and must be sought after in concert with the surrounding context or systems in which the entity of interest is embedded. This research dissertation demonstrates that the intelligence, conditions and collaborations way of thinking about resilience provides an accessible and pragmatic way of thinking about the concept with potential for it to be applied within a wide range of contexts. None of the farming resilience frameworks reviewed as part of this research offer a spatial orientation to thinking about resilience, indicating that the AVSS resilience analytical framework could be complementary to other existing frameworks (Cabell & Oelofse, 2012; Meuwissen et al., 2019; Serfilippi & Ramnath, 2018). Much like the panarchy model provides a useful temporally bounded way of thinking about resilience, the AVSS resilience analytical framework attempts to achieve a similar objective by providing a spatially bounded way of thinking about resilience (Allen et al., 2014; Holling, 1973).

This research dissertation makes an empirical contribution by providing a multi-level assessment of the BCI program's general resilience effects on cotton farming in the Adoni Mandal. The multi-level assessment consisted of conducting farmer focus group discussions, a farming survey and a relational survey which allowed for collecting quantitative and qualitative information. The farmer focus groups provided qualitative information to provide valuable contextual information ranging from the main challenges that cotton farmers face such as climatic variability in precipitation to more nuanced information such as the reticence toward establishing farmer cooperatives for fear that they turn political. The farming survey provided valuable information to establish the main resilience threats faced by cotton farmers in the study area and their main coping strategies. The farming survey also allowed for examining the training effectiveness of the BCI program and the farming practices being implemented, which overlapped with a sustainability impact assessment of the BCI program in the study area conducted by the University of Greenwich Natural Resources Institute and hence cannot be considered a contribution. The relational survey allowed for examining the network function and positioning of the BCI program in the organizational water and food security networks of the Adoni Mandal which has never been done in the study area. Examining these networks were of significant relevance to this dissertation since water and food security are important for the resilience of cotton farmers in the Adoni Mandal. The case study undertaken as part of this research dissertation constitutes the first attempt at assessing the effects of an AVSS on the general resilience of farming systems within a particular context.

Relational data and network analysis have yet to be used for assessing the resilience effects of AVSS in particular contexts, providing a potentially rich area of research to better understand the potential for AVSS to enable sustainable and resilient farming at multiple spatial and social scales (i.e. farming community, landscape scale, governance structures,) (Fransen et al., 2018). Therefore, the research dissertation provides a methodological contribution by applying network analysis to assess the potential impacts of AVSS via their contribution to enabling engagement and connectivity with governance structures. Furthermore, the relational surveying approach adopted for the research dissertation allowed for breaking down the networks of interest into sub-networks comprised of organizations collaborating on specific resources and activities relevant to farming resilience. This provided another window of analysis to better understand how AVSS may be having a role in enabling farming resilience (Bodin & Prell, 2011; Bodin & Tengö, 2012; Nyström et al., 2019; Rockenbauch & Sakdapolrak, 2017).

The policy contribution of this thesis dissertations consists of benchmarking AVSS production criteria and indicators against the AVSS analytical resilience framework. The benchmarking effort allowed for identifying where AVSS are contributing to supporting farming resilience such as requiring farmers to be engaged in continuous capacity building, monitoring and recording their farming operations but also identifying where there are clear gaps in their standards for enabling farming resilience which included requiring targeted experimentation, development of adaptation strategies and managing the diversification of agricultural production and economic activities. AVSS production criteria are regularly benchmarked to determine if they can support various sustainability objectives which range broadly from preventing deforestation to enabling gender equity (Potts et al., 2014, 2016, 2017; World Wildlife Fund, 2020). Nevertheless, AVSS have yet to be benchmarked to determine how their designs potentially affect the general resilience of farming systems. This dissertation provides a first attempt at doing so allowing for undertaking future voluntary sustainability standard benchmarking efforts in other sectors and resilience aspects.

7.5 Future Research

As there is currently very little substantive and systematic research on AVSS and farming resilience, the need for further research is vast and can fall into three broad categories which build on each other. The first category consists of engaging with supply chain stakeholders along the vertical and horizontal planes of agricultural production governance to define and establish understands of what are sustainable and resilient farming systems so that AVSS can be designed and implemented to support this prospect. The second category consists of rigorously assessing the impacts of AVSS on the general resilience of farming systems and the agricultural landscapes in which they are embedded. The third category consists of developing AVSS that can enable the collective resilience of supply chains along the vertical (from agricultural producer to end consumer) and horizontal planes (from agricultural producer to national governments) of agricultural production governance.

Continued research is required to further examine the similarities and differences between the sustainability and resilience concepts and what they mean for agriculture and specific agricultural supply chains but also to improve supply chain stakeholder engagement processes, which include farmers, for enabling constructive exchanges. Establishing AVSS that can enable farming resilience will require developing shared understandings of what is sustainable and resilient farming, which will necessitate a committed and deep engagement with all supply chains stakeholders including farmers where trade-offs between standardization and resilience will need to be explored (E. A. Bennett, 2017; Bitzer & Steijn, 2018). Furthermore, co-creating AVSS for sustainable and resilient farming sets a foundation for shaping a culture oriented towards dealing with uncertainties and conducive to farming resilience.[65] Soliciting input from women producers will be particularly important and insightful as they have more sustainability and resilience potential than men despite having less resources (Jones et al., 2017; Perez et al., 2015). Farming resilience models and heuristics, such as the AVSS resilience analytical framework, can assist with exploring the interconnections between the concepts (Ashkenazy et al., 2018; Cabell & Oelofse, 2012; Meuwissen et al., 2019; Serfilippi & Ramnath, 2018). For instance, examining how sustainable farms can support all three farming resilience capacities, comprised of withstanding, adapting and transforming, to face disturbances will be important. Establishing understandings of sustainable and resilient farming for particular agricultural supply chains will need to be dynamic to maintain relevance for changing contexts.

Measuring resilience remains elusive and an important as well as untapped area of research (Biggs et al., 2015; Cabell & Oelofse, 2012; Meuwissen et al., 2019). Establishing robust measurement and assessment approaches to efficiently measure the farming resilience impacts of

[65] A culture conducive to farming resilience and dealing with uncertainties within the supply chains, could require implementing more flexible standards that allow for production variance within farming systems and product variance within consumption systems.

AVSS agricultural production requirements in specific supply chains in various parts of the world is imperative if AVSS are to enable sustainable and resilient farming systems. To do so, research is required on a broad range of topics such as developing insightful and context relevant resilience indicators, identifying and establishing thresholds and managing regime shifts and implementing new monitoring and measurement tools to assess resilience impacts. For instance, this research dissertation used network analysis to examine how an AVSS is affecting organizational connectivity for farming resilience, which could be extended to examine how AVSS are affecting connectivity along vertical and horizontal planes of agricultural supply chain governance for farming resilience. There is clearly a broad research agenda that needs to be developed around measuring the farming resilience impacts associated with AVSS, which will be fundamentally important for them to support farming resilience.

AVSS need to expand from being focused on enabling farm-level sustainability to enabling farming community and landscape level sustainability and resilience. Ongoing discussions and recommendations in the literature have called for AVSS to adopt a landscape approach, jurisdictional approach or areas based approach to yield more sustainable outcomes (Bitzer & Steijn, 2018; Essen & Lambin, 2021; Kumar et al., 2019b; Verburg et al., 2019a). All these approaches point towards a need for AVSS to broaden its scope towards enabling more sustainable landscapes, jurisdictions and areas which could be facilitated by integrating resilience measures. Nevertheless, determining what governance structures and enabling conditions need to be in place to establish sustainable and resilient farming communities and landscapes will require significant research (Biggs et al., 2015). AVSS are uniquely positioned in agricultural supply chains to be a catalyst for enabling vertical and horizontal supply chain governance systems that are needed for supporting more sustainable and resilient farming operations, communities and landscapes. Significant research will be needed to transition AVSS from being focused on enabling farm-level sustainability to enabling sustainable and resilient farming communities and landscapes.

There is clearly an important need for research on various fronts for AVSS to evolve towards enabling sustainable as well as a resilient farming systems. This doctoral thesis provides a stepping stone towards achieving this evolution by developing the AVSS resilience analytical framework and demonstrating its potential for assessing the effects of AVSS on farming resilience so they can be re-imagined for building the general resilience of farming systems.

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Appendix 1 – Benchmarking Agricultural Voluntary Sustainability Standards

This Appendix generally describes the eleven AVSS from the seven standard setting bodies examined for the benchmarking effort and their standard revision processes. Information provided on the standard revision processes allowed for identifying opportunities for the findings from this thesis dissertation to orient standard setting bodies to revise AVSS for enabling farming resilience. General descriptions of the each AVSS examined is presented to further support the information provided in Section 3.2.1 of the dissertation.

AVSS Description

<u>Better Cotton Initiative</u>

The Better Cotton Initiative (BCI) has been in existence since 2005. The standard aims to shift the entire cotton sector towards sustainability by catering to mainstream markets and has developed a flexible production standard that allows cotton farmers to participate in their program by meeting basic requirements but committing to continuous improvement over time. The BCI's mission is "to make global cotton production better for the people who produce it, better for the environment it grows in, and better for the sector's future. BCI's Theory of Change calls for transformation of the cotton production sector, catalyzing movement toward sustainability in two spheres: Farm and Market, with changes amplified and sustained by supportive production and consumption policies and viability of improved sustainable cotton farming" (Better Cotton Initiative, 2018, p. 4 and p. 6). The standard distinguishes itself primarily from other AVSS in the cotton sector by allowing farmers to cultivate GMO cotton. This flexible approach has allowed BCI to rapidly expand in the marketplace compared to other AVSS operating in the cotton sector. BCI's focus on leveraging sustainability efforts in markets and supportive consumption policies could provide the right types of feedbacks loops and incentives for BCI farmers to continue practicing more sustainable cotton farming practices.

The BCI production standard is comprised of 7 principles and 45 criteria out of which 70 core indicators need to be met to become a BCI licensed farmer while 94 improvement indicators are proposed to promote and monitor continuous improvement. BCI is focused on enabling farmers to adopt more sustainable farming practices which can assist them with withstanding potential shocks and stresses faced by cotton farmers such as pest outbreaks and climate variability such as a lack of precipitation. The BCI's accommodation of GM cotton as well as non-GM cotton is an interesting conundrum due to the unknown long-term effects that GM organisms could have on agriculture and the dependencies on biotech corporations that this may create amongst cotton farmers (Deshpande, 2016; Gutierrez et al., 2015; Louis, 2015; Lu et al., 2012; The Guardian, 2014; Witjaksono et al., 2014; Zhang et al., 2018).

Bonsucro

Bonsucro was established in 2008 to enable the sugarcane sector to become more sustainable. Sugarcane is one of the most effective crops at converting sunlight to energy and its main derivatives are cane sugar commonly used as a sweetener in the food and beverage sector and ethanol which is used a biofuel either blended with gasoline or used in ethanol compatible vehicles. Bonscuro's mission is to "ensure that responsible sugarcane production creates lasting value for the people, communities, businesses, economies and eco-systems in all cane-growing origins." Bonsucro focusses on not only on the farmers involved in sugarcane production but also broader communities and ecosystems where the sugarcane is grown.

Their production standard first targeted sugar mills and associated sugar plantations. Bonsucro has since devised a specific standard for smallholders working in the sugarcane sector. The Bonsucro standard is comprised of 6 principles, 20 criteria and 55 indicators out of which 16 are core indicators which must be met. To become Bonscuro certified 80% of all the indicators provided in the standard must be met. The standard specifies the indicators that apply to the mill and the farm that must be satisfied to become certified. All Bonsucro certified entities must also comply with their chain of custody standard. Since sugarcane is used in the production of food and biofuels the standard tries to address indirect land use change issues which is an important sustainability challenge faced by the biofuels sector. Overall, the Bonsucro standard aims to improve the sustainability of sugarcane mills and their feedstock providers.

Fairtrade International

Fairtrade International was established in 1997 as a result of a movement towards establishing more equitable trading and working conditions for smallholder farmers and hired labour in farming operations. Fairtrade is a multisector standard working in over 10 agricultural crops. The standard provides guaranteed minimum returns for their participating farmers as well as a premium on their products which go towards supporting sustainable development projects to directly benefit farmers and workers as well as their communities. Their mission is to "Connect disadvantaged producers and consumers, promote fairer trading conditions and empower producers to combat poverty, strengthen their position and take more control over their lives" (Fairtrade International, n.d.). To this end, Fairtrade developed two standards; one focused on smallholder producer organizations and the other on hired labour working on plantations.

The Fairtrade Smallholder Producer Organization (FSPO) standard is focused on producer organizations made up of individual small producers and is comprised of core and development indicators which need to be met either immediately or over the span of 1, 3 or 6 years. The standard, which is divided up into four main sections (General Requirements, Trade, Production and Business & Development), is focused on enabling smallholders adopt more sustainable farming practices and provide them with fairer returns for their efforts. The FSPO standard is focused on addressed the sustainability challenges faced by small agricultural producers, such as market vagaries, predatory business behavior, child and forced labour, health and safety in perpetuity.

The Fairtrade Hired Labor (FHL) standard focusses on enabling more sustainable production practices within agricultural operations where laborers are hired and often reside on site seasonally or year-round. The standard is similar to the FSPO but has an important emphasis on Social Development and Labor Conditions and is divided into five main parts (General Requirements, Social Development, Labor Conditions, Environmental Development and Trade). It is comprised of core and development indicators which need to be met either immediately or over the span of 1, 3 or 6 years. Hired labor can often be vulnerable and subject to forced and child labor, prevented the right to associate and collective bargaining as well as unfair remuneration and payment arrangements, etc. For this reason, the focus of the FHL standard is on preventing unsustainable and unethical working and living environments in agricultural operations for hired labour/workers working and often living on agrulcutltural plantation premises.

Fairtrade focusses on providing a more level playing field for disadvantaged agricultural producers so they can get a fair price for their efforts. Guaranteeing a minimum price for agricultural products provides certainty and a buffer against the vagaries of markets for disadvantaged farmers to adequately plan and sustain their farming operations. Price premiums used to enable sustainable development for agricultural workers and their communities allows them to invest in their future and build resilience in their farming operations.

<u>Linking Environment and Farming</u>

The Linking Environment and Farm standard (LEAF) was established in 1991. The standard is based on an integrated farm approach comprised of 9 focus areas: organization and planning, soil management and fertility, crop health and protection, pollution control and by-product management, animal husbandry, energy efficiency, water management, landscape and nature conservation and community engagement. LEAF's mission is "to inspire and enable sustainable farming that is prosperous, enriches the environment and engages local communities. It does so via three core pillars: 1) Facilitating sustainable farming knowledge generation and exchange, 2) Developing market opportunities, 3) Engaging the public in sustainable food and farming" (Linking Farming and Environment, 2019, p. 7).

The LEAF standard is based on an integrated farming approach comprised to 9 principles supported by essential and recommended control points. By approaching agricultural production in a holistic manner the LEAF standard enables more sustainable production practices which are rewarded by giving participating farmers a way to distinguish themselves in the marketplace by using the LEAF marque. One of the key features of the LEAF program is the community outreach efforts which enables connectivity between the farm and its surrounding community.

Rainforest Alliance

The Rainforest Alliance (RA) was established in 1987 and has grown substantially working in 6 agricultural sectors. The RA is primarily a label supported by the Sustainable Agricultural Network (SAN) who sets their agricultural production standard. RA is undergoing significant changes as it announced a merger with the UTZ Certified AVSS in 2018. The Rainforest Alliance vision and mission is the following: "We envision a world where people and nature thrive in harmony. The Rainforest Alliance is creating a more sustainable world by using social and market forces to protect nature and improve the lives of farmers and forest communities" (Rainforest Alliance, 2021a).

The RA works in tropical regions of the world within seven agricultural sectors (Bananas, Cocoa, Coffee, Cattle, Ferns and Flowers, Palm Oil, Tea). The standard is comprised of production requirements applicable to crop farms that critical continuous improvement criteria. To become RA certified the critical criteria must be met right away while continuous improvement criteria must be met over a 1 to 6-year period. To maintain certification all farming operations must show that they are continuously improving towards becoming more sustainable. Additional criteria have been devised for producer group administrators and accommodations for smallholders have been devised by lowering the number of critical criteria they are required to meet. The RA focusses on agriculture associated with the loss of tropical rainforests and biodiversity. For this reason, they have an emphasis enabling farmers to enhance the natural environments that their farms may be affecting.

Roundtable for Sustainable Biomaterials

The Roundtable for Sustainable Biomaterials was established in 2011. Initially focused on enabling the production of sustainable biofuels, the RSB evolved to include all materials that can support a sustainable bioeconomy. The standard has been consistently referenced as one of the most rigorous AVSS by benchmarking efforts (Potts et al., 2014). This rigor my be due to the food versus fuel debate which criticized the biofuel sector for taking agricultural land away from growing food crops. The RSB focusses on enabling the sustainable production of biomaterials by offering "trusted, credible tools and solutions for sustainability & biomaterials certification that mitigate business risk, fuel the bioeconomy and contribute to the UN Sustainable Development Goals in order to enable the protection of ecosystems and the promotion of food security" (Roundtable for Sustainable Biomaterials, 2021).

The RSB standard comprised of 12 principles is supported by 39 criteria and 155 indicators with 143 that must be minimally met to become RSB certified (Roundtable for Sustainable Biomaterials, 2016b). Overall the RSB standard focusses on enabling sustainability among biomass producers and industrial facilities involved in the production biofuels and biomaterials. Due to the breadth and depth of the RSB standard, it could provide insights for developing AVSS production criteria oriented towards farming resilience.

Roundtable for Sustainable Palm Oil

The RSPO was established in 2004 to try and move the palm oil sector towards more sustainable production practices. The rapid increase of palm oil as the main source of global vegetable oil has led to the rapid deforestation of tropical forests for oil palm plantations. The RSPO aims to "transform markets to make sustainable palm oil the norm by undertaking the following: 1) Advance the production, procurement, finance and use of sustainable palm oil products, 2) Develop, implement, verify, assure and periodically review credible global standards for the entire supply chain of sustainable palm oil, 3) Monitor and evaluate the economic, environmental and social impacts of the uptake of sustainable palm oil in the market, 4) Engage and commit all stakeholders throughout the supply chain, including governments and consumers" .

The RSPO standard is comprised of 7 principles and 40 criteria focusing on palm oil mills and oil palm growers not considered independent smallholders (Roundtable on Sustainable Palm Oil, 2018). Certified entities are required to certifie their outgrowers within a period of 3 years after receiving certification. Several critical indicators within each criterion must be met to achieve to become RSPO certified. As the standard is meant to be outcomes based, the criteria and indicators are formulated to enable impact measurement and assessment. The RSPO also developed a standard for independent smallholder oil palm growers which provides them with a roadmap to become RSPO certified.

AVSS Revision Process

The AVSS described above all have revision processes which must be undertaken at least every 5 years to remain ISEAL members (ISEAL Alliance, 2014). The "Setting Social and Environmental Standards" as part of ISEAL's Code of Good Practice was published in 2014 to provide guidance for ISEAL members to regularly review their standards so they can remain current in addressing the most pressing sustainability challenges in the various sectors that they work in.

Table 33 describes some of the revision processes included in each of the AVSS examined, which offer opportunities for the research findings from this dissertation to influence the orientation of the AVSS under revision. All the AVSS examined have stakeholder and public consultation efforts providing direct possibilities to offer feedback on standard modifications and revisions under consideration. Direct contact with entities responsible for the standard revision efforts within standard setting bodies can also be established to have a more direct influence. Field testing may offer opportunities to measure potential farming resilience effects associated AVSS revisions. Lastly, most of the AVSS examined have ongoing feedback systems which allow stakeholders to provide comment and share grievances related to the standards outside of their revision process.

Table 33 – Standard setting processes of AVSS examined and opportunities for integrating farming resilience considerations.

Standard Setting Process	**Responsible Standard Setting Entity**	**Stakeholder Consultations**	**Field Testing**	**Ongoing Feedback System**
Better Cotton Initative	Standard Setting and Revision Committee	Up to two rounds of stakeholder consultations are organized.	Pilot Projects for local relevancy and feasibility	Yes
Bonsucro	Standard Revision Working Group	60 day public consultation	Pilot Audits	Yes
Fairtrade International	Standards and Pricing	Public and Stakeholders consultation through on-line surveys and workshops	Field testing for new standards to assess relevance for producers	Yes
Linking Environment and Farming	LEAF Marque Technical Advisory Committee	Public and stakeholder consultation and standard revision process	May test requirements feasibility and auditability	Yes
Rainforest Alliance	Standards Team	60-day initial public consultation & 30-day final public consultation	Early implementer pilots for standard implementability	Yes
Rountable for Sustainable Biomaterials	RSB Secretariat, General Standards Working Group & Specific Standards Working Group	At least 60-day initial public consultation & at least 30-day final public consultation	Optional field testing pending sufficient resources.	No
Roundtable for Sustainable Palm Oil	The standard & certification standing committee, Principles & Criteria Review Task Force	60-day public consultation	Pilot test to generate recommendations	Yes

Benchmarking Replicability Asssesment

A subset of the AVSS production criteria and indicators (approximately 11%) were benchmarked by a qualified individual with knowledge on VSS to assess for replicability. The results obtained indicate that varying levels of replicability were obtained depending on the AVSS resilience analytical framework indicator examined.

Table 34 – Replicability assessment of benchmarking the AVSS production criteria and indicators against the AVSS resilience analytical framework

AVSS Resilince Analytical Framework Indicators	Replicability Percentage
Resilience Intelligence Dimension	
Complex Systems Thinking	88%
Targeted Experimentation	97%
Adaptation Strategies	94%
Continuous Capacity Building	72%
Monitor Agricultural Operation	85%
Record Agricultural Operation	68%
Resilience Conditions Dimension	
Manage Agricultural Product Diversification	99%
Manage Economic Activity Diversification	99%
Manage Ecosystem Services Diversification	78%
Preserve Growing Environment	74%
Broaden Participation in Farming Activities	84%
Promote Internal Governance	90%
Resilience Collaborations Dimension	
Manage Ecological Connectivity	32%
Manage Community Connectivity	25%
Manage Market Connectivity	70%
Comply with Laws and Regulations	80%
Engage with Stakeholders and Governance Structures	95%
Influence Socio-Economic Regime Shifts	81%

Appendix 2 – Farming Survey and Propensity Score Matching

The survey tool used to collect farming data for the descriptive and propensity score matching analysis are presented in this appendix. The survey tool consisted of questions on household and farm characteristics, information sources accessed and training obtained, farming practices implemented and resilience threats and coping strategies. The propensity score matching method was used to examine farming practice differences between farmers that are (treatment) and are not (control) participating in the BCI program.

Farming Survey Tool

Surveyor, by writing your names below, you promise that you have obtained the permission from the farmer to be interviewed and that you will keep his or her responses confidential

Village Name: ______________________________
Surveyor's name: ______________________________
Farmer's name: ______________________________
Father's name: ______________________________
Farmer ID number (from the sampling plan): ______________________________
Age: _________
Gender Male/Female

Mobile Number:										

Household Characteristics

How is the financial situation of the household compared to three years ago? *Check one option*
O Better O About the same O Worse

How many people are part of your household? ______ Adults of working age, ______ Children under age 16, ______ Elders over age 65.
How many males and females are part of your household? ______ Females, ______ Males
How many people of your household are literate? _________
How many children in the household are enrolled in school? ________ Enrolled
Total time contributed by the household to cotton cultivation? ________ days

Farm Characteristics

What is the total area of your farm, including all crops grown, and land used for pasture? __________ acres
What is the total area you use to produce cotton? __________ acres

What soil type(s) do you cultivate your cotton in? *Check all that apply* ☐ Dense Black ☐ Black ☐ Mixed ☐ Red ☐ Other – Please specify: ____________________

How did the area for cotton production change in the last production year (June 2016 to May 2017) compared to the previous production year (June 2015 to May 2016)? *Check one option*
○ Increase ○ Decrease ○ No change
If Decrease is selected ask

What was the land converted to?
☐ Temporary set-aside/fallow ☐ Cultivated land for other crops or pasture ☐ Sold
☐ Other ____________________
If Increase is selected ask

How was the land added?
☐ Purchased land already planted with cotton ☐ Converted land that had been used for other crops or pasture ☐ Cleared natural area ☐ Other ____________________

What cotton seed(s) did you use? ____
How many packets of each type of cotton seed did you use? ___________________________
How much did each type of packet of seeds cost (in INR)? ______________________________

Productivity in the last production year (June 2016 to June 2017)	Kharif	Rabi	Total
How much cotton did you harvest this past production year (June 2016 to June 2017) (in kg or quintales)?			
How did you store the cotton seed harvested (i.e. jute, polyester, cotton or plastic bags)?			
Where did you store the cotton seed harvested (i.e. home, in the field, sold right away)?			
How much did you sell the cotton for?	INR	INR	INR
How much did you spend to produce it?	INR	INR	INR
How much was the transport cost to the market?	INR	INR	INR

Did you harvest all the cotton cultivated or only a portion, in the last production year (June 2016 to June 2017)? *Check one option* ○ Almost all or all ○ Most ○ Half or less

If Almost or all is Not Selected ask "Why did you lose part of your harvest?"

Did you hire anyone to work in your cotton fields (including planting, cultivation, harvesting, and processing)? *Check one option* Yes/No

If No is selected, then skip the next question

Hired Labor during the last production year (June 2016 to June 2017)	Producing the focus crop	Harvesting	Other
How many person days did you hire for the following tasks?			
How much did you pay IN TOTAL to all the workers you hired for the following tasks?	INR	INR	INR

What proportion of your total household income (including sales of other crops, livestock, rental income, off-farm employment, gifts & remittances, etc.) in the last production year (June 2016 to May 2017) comes from cotton sales? *Check one option* O All or almost all (90%+) O Most (75%) O About half (50%) O Some (25%) O Little (10% or less) O Don't know O Other ___________________

Could you or someone in your household get an affordable loan for cotton production from any of these sources? *Check all that apply*

☐ Buyer or supply chain (processor, input provider, exporter) ☐ Informal local lender Formal (bank, government lending agency) ☐ Other – Please specify: ___________________________

Did you keep any farm records in the last production year? Yes/No

If No is selected, skip the questions below

In the last production year, which of the following did you keep records of? *Check all that apply*

☐ Fertilizer and pesticide use ☐ Diseases or damage ☐ Payments for labor ☐ Production and sales of cotton ☐ Other – Please specify: ____

Have you used these records to help you make decisions? Yes/No

Check the equipment and vehicles you use (items in this section should last around 10 years with normal repair and maintenance). *Check all that apply*

☐ Irrigation equipment (pumps, pipes) ☐ Tractors ☐ Plowing Equipment ☐ Motorized water pump. Please encircle which ones you owned.

Which of the following describes the land tenure? *Check all that apply?*

☐ Producer owns land ☐ Producer pays money to rent all the farm's land ☐ Producer owns some of the land and rents some of the land ☐ Other – Please specify: ___________________

What is the average value (in INR) of land owned/rented per acre? __________ INR

Did you raise livestock, poultry during the last production year (June 2016 to May 2017)? Yes/No *if* ***yes*** *then ask* how many livestock did you raise - Cows: ______, Buffalos ______, Bullocks ______, Chickens, ______, Goats ______, Sheep ______.

Information and Training

What market information for cotton did you access during the last production year (June 2016 to May 2017)? *Check all that apply.* ☐ The prices paid by your producer organization

☐ The sale price obtained by your cotton buyer ☐ Other(s) Please Specify: ________________

Did you receive weather-related information (such as precipitation, temperature, etc.) in the last production year (June 2016 to May 2017)? Yes/No if Yes from whom? ______________

Are you part of a Participatory Rural Development Initiatives Society (PRDIS)/Better Cotton Initiative (BCI) Learning Group? Yes/No

If you attended training session(s) on cotton cultivation which ones did you attend? Are you implementing the lessons you learned? Were the training sessions offered by PRDIS?

Training	Attended	Implementing Lessons Learned	Provided By PRDIS
Integrated Pest Management	❑	❑	❑
Soil Conservation/Fertility	❑	❑	❑
Water Use Efficiency	❑	❑	❑
Natural Conservation	❑	❑	❑
Decent Work-Related Issues	❑	❑	❑
Health and Safety	❑	❑	❑
Fibre Quality	❑	❑	❑
Record Keeping for the Farm	❑	❑	❑
Marketing Support (prices, contracts, etc.)	❑	❑	❑
Financial Management	❑	❑	❑
Literacy	❑	❑	❑

Cultivation Practices

Check all the following that are on the farm. *Read each one and explain as needed. (see illustrations on Surveyor Notes)* ☐ Bund ☐ Drainage channels or diversion ditches for water runoff ☐ Live fences ☐ Hedgerows ☐ None of these

Check all of the following that are on the farm. *Read each one and explain as needed.*
☐ Crops interplanted with cotton ☐ Nitrogen fixing annual or perennial plants (i.e. chick peas, green gram, Bengal gram, lentils) ☐ Buffer zones between areas with crops or livestock and natural water bodies ☐ None of these ☐ Other(s): Please specify___________________________

Do you irrigate your cotton field? Yes/No *If* ***yes*** *ask* What kind of irrigation system do you use? *Check all that apply.* ☐ Canal River ☐ Pond ☐ Water retention and catchment systems (e.g. rainwater cisterns, 10 by 10 feet water retention) ☐ Groundwater ☐ Other - Please Specify: ______________________

During what growing periods do you irrigate your cotton fields? *Check all the apply.*
❑ Approximately 0 to 30 days after planting (Emergence to First Square)
❑ Approximately 30 to 50 days after planting (First Square to First Flower)
❑ Approximately 50 to 70 days after planting (First Flower to Peak Bloom)
❑ Approximately 70 to 90 days after planting (Peak Bloom to Open Bolls)

Check the tillage and soil treatment practices you followed on the farm in the last production year. *(See illustrations in Surveyors Notes if required).*
☐ Conservation tillage ☐ Mulching ☐ Cover crops planted for soil fertility and/or erosion control
☐ Crop rotation for improving/maintaining soil health ☐ None of these

How do you determine the plant spacing between your cotton plants? *Check all that applies*
☐ Cotton variety or seed type ☐ Soil conditions ☐ Seasonal weather conditions ☐ Number of seeds planted per area ☐ Other – Please specify: ______________________

Ask whether each the following were used to fertilize cotton in the last production year (June 2016 to May 2017). Check all that apply

- ❑ Natural materials from the farm, e.g., composted animal manure, crop residue, prunings, etc.
- ❑ Natural materials brought in from OFF the farm, e.g., compost or animal manure
- ❑ Nitrogen fixing plants grown in the same area as the cotton
- ❑ Chemical fertilizer
- ❑ None - specify why:

If None is Not Selected

How do you determine the correct amount of fertilizer you used to grow your cotton?

- ❑ We don't apply enough, but we apply as much fertilizer as we can afford or obtain.
- ❑ We apply fertilizer if required based on our knowledge of the nutrients in the soil and what the cotton plant requires.
- ❑ We apply fertilizer based on general advice for this region or for cotton in general.
- ❑ We apply fertilizer based on a professional assessment of our soil and the cotton plant.
- ❑ We apply potassium (or potash) to our cotton fields to improve quality.
- ❑ Other ____________________

How much did you spend (in total for the last production year – June 2016 to May 2017) on fertilizers for the cultivation of your cotton? *Repeat this questions for the fertilizers selected.*

Natural materials brought in from OFF the farm (e.g., compost or animal manure): ______INR
Chemical fertilizer: ______INR

Did you have pest outbreaks in this production year (June 2016 to May 2017): Yes/No
Did you use natural pest management approaches (i.e. integrated pest management) in the last production year (June 2016 to May 2017)? Yes/No *If **No** skip to next question if **Yes** then* ask which ones? *Check all that apply*

☐ Use of natural pesticides (bio-control agents, pheromones and hormones)

☐ Use of biological control methods (e.g. parasitoids, ladybugs)

☐ Regular monitoring of the crop for pests, crop damage and beneficial insects

☐ Use of pest trap crops, border crops, or intercrops that act a physical barrier to pests and support beneficial insects (i.e. castor, sunflower, bendi or okra, maize, sorghum, pearl millet)

☐ Crop rotation to reduce weeds

☐ Mechanical means to control pests (i.e. destroying pupae by tilling)

☐ Manually catching pests on crops

Did you use synthetic pesticides in the last production year (June 2016 to June 2017)? Yes/No *If **No** skip to next question if **Yes** then ask which ones? Check all that apply*

☐ Limit the number of applications of one class of insecticide

☐ Rotation of insecticide groups

☐ Use insecticides that are least disruptive to beneficial insects (e.g. neem based products)

☐ Use correct and registered pesticides for the cotton pest targeted

☐ Correct amount of pesticide application

☐ Correct time of application with a withholding period (period between applying and harvesting).

☐ The following 12 pesticides are not used: Aldrin, chlordane, chloredecone, dieldrin, DDT, endrin, heptachlor, hexachlorobenzene, hexachlorocyclohexane, lindane, mirex and toxaphene.

☐ Workers using synthetic pesticides are trained

☐ Workers using synthetic pesticides are healthy and are 18 years and older

☐ Workers using synthetic pesticides are not pregnant or with a small baby (in lactating period)

☐ Synthetic pesticide containers are not used for the household or other purposes

☐ Synthetic pesticide containers are disposed of safely

How much did you spend for all pesticides used for the Cotton in the last production year? *Enter 0 if the farmer did not purchase any pesticides for the Cotton.* _______ INR

Resilience

1. *Identify the major difficult events and their significance to the farming households experiencing them.*

Negative Events that lead to significant reductions in households' income, assets or consumption.	A. Select and Rank the top 3 negative events that are most likely to happen as 1) most severe, 2) moderately severe and 3) least severe	B. Their Frequency in the last 5 years are 0, 1, 2, 3, 4, 5 or >5?	C. Select and Rank the **top 3** negative events that greatly reduced the household's income, assets, or consumption in the last production year as 1) most severe, 2) moderately severe and 3) least severe. If there were no negative events simply check 'None'
Drought			
Excessive rain			
Extremely scarce rain			
Heat waves that affected agricultural production			
Theft of property or crops			
Increase in price of agricultural or livestock inputs			
Sharp decline in cotton prices			
Cotton pest outbreaks			
Livestock diseases			
Death or serious illness or injury of family member			
Major policy changes such as ending of subsidies			
Other – Please specify:			
None			

2. *Identify and rank the household's main coping strategies to negative events.*

Coping Strategies	The ***3 main ways*** your household coped with the most severe negative events in C. If answered '***None'*** in C - The ***3 main ways*** your household would have coped with the most severe negative event in A? Rank the coping strategies from most (1), moderate (2) to least (3) DIFFICULT for your family.
Reduce FOOD consumption	
Reduce consumption of other non-essential goods	
Postpone debt payment	
Sell household items (durable goods; stored grains; jewelry)	
Sell productive assets (livestock; farmland, business)	
The entire household migrated OR some household members migrated	
Start new wage labor	
Take children out of school for them to work	
Switch to other crop cultivation	
Change agricultural practices	
External support (food; cash; other help)	
Other – Please specify:	

3. Did you foresee about that the most severe event that happened to your household in the last production year *(Ranked 1 in Column C - Table 1)* before it happened? Yes/No

4. *Ask this question for the most severe event, ranked 1 in column C of Table 1*. To what extent were you and your household able to recover from this shock? *Check one option* O Recovered and better off than before O Recovered at the same level as before O Recovered and worse off than before O Have yet to recover

5. Please select from who you could receive support in case of necessity. *Check all that apply.*
☐ Civil, community groups (women, youth, etc.) ☐ Farmers' groups ☐ Family/ Relatives/Friends ☐ Religious organizations ☐ Government ☐ Other - Please specify: ______________________

Consent Confirmation

The information collected for this survey will be used to assess the sustainability of cotton farming in the Adoni Mandal. It will also be used to improve assessment tools being developed by the Committee of Sustainability Assessment for assessing the sustainability of cotton production globally. Specifically, it will be used by Vivek Anand Voora, a PhD Candidate enrolled at Central European University in Budapest, Hungary who is examining the intersection between agricultural sustainability standards and water, energy and food security. To do so, he is examining the effects of the Better Cotton Initiative programme, for cotton cultivation, on the water, energy and food security in the Adoni Mandal, Andhra Pradesh, India.

If you agree to participate in this study by way of an interview, *the information you provide will be used and presented anonymously*. Please note that you can revoke your consent with respect to the use of the information you provide for this study within three months of the interview. Participation remains completely voluntary and you can choose not to answer certain questions or continue participating. Participants will not receive payment for ethical reasons to ensure that the information remains unbiased.

Please contact Vivek Anand Voora or Dr. Laszlo Pinter for more information:

Email: Voora_Vivek@phd.ceu.edu Cell: +46-72-382-3100

Email: pinterl@ceu.edu Cell: +36-30-390-3354

I confirm that I understand how the information I have provided by way of this survey will be used. I was able to understand the information provided, ask questions and get satisfactory answers. I understand that my participation is voluntary and will not result in advantages or disadvantages. I understand that I am free to withdraw my consent without having to give an explanation and without detriment.

I consent to participate in the research by providing information that will be recorded and transcribed for the compilation of a PhD thesis and other publications such as peer-reviewed scientific journal articles.

____

Signature Date

Picture taken: Yes/No

GPS Coordinates Taken: Yes/No - ____________________________________

Covariate Selection and Propensity Score Matching

The covariate selection process is briefly described an example of the STATA psmatch2 execution and output files are provided for replicability. One of the most crticial steps in conducting the PSM analysis consists selecting covariates. The STATA psmatch2 log file generated by kernel matching farmers who did and did not attend BCI natural conservation training as well as its balancing statistics are provided below.

Covariate Selection Process

According to Stuart (2010), all covariates related to the treatment and outcome variables should be included in the propensity score calculation. Excluding important covariates related to the outcome variables of interest can significantly increase bias and therefore should be prioritized in the covariate selection process. Furthermore, covariates affected by the treatment should be excluded from the propensity score model and assessed as an outcome variable as it can lead to significant bias (Stuart, 2010). This is especially important when information on the covariates, treatment and outcome variables were collected at the same time which was the case for this study. For this study, the treatment consists of attending BCI training on at least one of eleven cotton farming topics.[66] The outcome variables of interest consisted of the cultivation practices, resilience threats and coping strategies.

Potential covariates were first qualitatively examined to determine if they would be if they would be affected by the treatment and if they are related to the treatment effect and the outcome variables of interest (see Table 35). The final covariates selection was primarily based on field experiences and observations and by trying to optimize the balance between matched treatment and control group propensity scores across the various combination of covariates examined. Out of a possible 28 suitable covariates 14 were selected for the PSM.

[66] The BCI program offered training to its participating farmers on the following 11 topics: Integrated Pest Management, Soil Conservation/Fertility, Water Use Efficiency, Natural Conservation, Decent Work-Related Issues, Health and Safety, Fibre Quality, Farm Record Keeping, Marketing Support (prices, contracts, etc.), Financial Management and Literacy.

Table 35 - Covariate selection assessment for propensity score matching.

Covariate	Variable Type	Affected by Treatment	Related to the Treatment/ Outcome	Rational
Household Demographics				
Respondent Age	Numerical Continuous	No	No/No	The age of the respondent will not be affected by participating in the BCI program and is not related to the treatment effect or the outcomes of interest. Although it can be argued that age can influence a willingness to adopt new farming practices.
Respondent Gender	Single Option Categorical	No	No/No	The gender of the respondent will not be affected by participating in the BCI program and is not related to the treatment effect or the outcomes of interest. Although it could affect participation in the BCI program since household decision-makers tend to be males in rural India.
Household Members	Numerical Continuous	No	No/No	The number of household members will not be affected by participating in the BCI progamme and is not related to the treatment effect or the outcomes of interest.
Household Literacy	Numerical Continuous	Yes/No	Yes/Yes	The number of literate people in the household could potentially be affected by the BCI program as they provide literacy training. It is related to the treatment effect and outcomes of interest since literacy allows for accessing more information.
Household School Enrollment	Numerical Continuous	Yes/No	Yes/Yes	The number of household children attending school could potentially be affected by participating in the BCI program. It is related to the treatment effect since child labour and school attendance is promoted by the BCI standard but is not related to the outcomes of interest.
Household Labour Provided	Numerical Continuous	Yes/No	Yes/Yes	The labour provided by the household for cotton cultivation could potentially be affected by participating in the BCI program since the BCI standard has provisions for discouraging child labour. Household labour is related to the treatment effect and outcomes of interest.
Farming Assets				
Total Farm Area	Numerical Continuous	No	No/Yes	The total farm area of the respondent will not change by participating in the BCI program. It is related to the treatment effect and the outcomes of interest since the total farm land can influence total cotton area cultivated.
Total Cotton Area	Numerical Continuous	No	Yes/Yes	The total cotton area of the respondent will not change by participating in the BCI program. It is directly related to the treatment effect and the outcomes of interest.
Soil Type Cultivated	Multiple Options Categorical	No	No/Yes	The soil types cultivated will not change by participating in the BCI program. It is not related to the treatment effect since cotton can be grown in various soil types but is related to the outcomes of interest since certain soil types are conducive for specific cultivation practices.
Livestock Raised	Single Option Binary	No	Yes/Yes	The livestock raised will not change by participating in the BCI program. It is related to the treatment effect and the outcomes of interest

Covariate	Variable Type	Affected by Treatment	Related to the Treatment/ Outcome	Rational
				since the BCI program does promote the use of natural fertilizers.
Farming Equipment Used	Single Option Binary	Yes/No	Yes/Yes	The farm equipment could potentially be affected by participating in the BCI program. It is related to the treatment effect and the outcome of interest since farming equipment could impact the cultivation practices adopted.
Land Tenure	Single Option Categorical	No	No/Yes	The land tenure of the respondent will not change by participating in the BCI program. It is related to the treatment effect and outcomes of interest since land ownership could result a tendency to learn and adopt land preservation farming practices.
Irrigation Source (Canal Water)	Multiple Option Binary	Yes/No	Yes/Yes	Access to canal water for irrigation will not change by participating in the BCI program. It is related to the treatment effect and the outcome of interest since irrigation can affect agricultural practices, resilience threats and cop.
Cotton Cultivation Season				
Cotton Area Cultivation Change	Single Option Categorical	Yes/No	Yes/Yes	A change in the area dedicated to cotton cultivation could be affected by participating in the BCI program and is related to treatment effect and outcomes of interest.
Hired Labour	Single Option Binary	Yes/No	No/Yes	Hired labour is not affected by participating in the BCI program and is not related to treatment effect but could be related to the outcomes of interest.
Types of Seeds Used	String	Yes	Yes/Yes	The types of cotton seeds used in the Adoni Mandal are overwhelmingly BT-Cotton seeds.
Total Cotton Harvested	Numerical Continuous	Yes	Yes/Yes	The total cotton harvested could have been impacted by the BCI program and is clearly an outcome of interest.
Total Cotton Revenues	Numerical Continuous	Yes	Yes/Yes	The total cotton harvested could have been impacted by the BCI program and is clearly an outcome of interest.
Total Cotton Costs	Numerical Continuous	Yes	Yes/Yes	The total cotton harvested could have been impacted by the BCI program and is clearly an outcome of interest.
Portion of Cotton Harvested	Multiple Options Categorical	Yes/No	Yes/Yes	The total portion of cotton harvested could have been affected by participating in the BCI program. It is related to the treatment effect and the outcomes of interest.
Household Income Dependent on Cotton	Multiple Options Categorical	Yes/No	Yes/Yes	The total household income dependent on cotton could have been affected by participating in the BCI program. It could be related to the treatment effect and potentially the outcomes of interest.
Irrigation	Single Option Binary	Yes/No	Yes/Yes	Could be affected by participation in the BCI program. Is related to the treatment effect and the outcomes since access to loans can influence cultivation practices and coping strategies.
Weather Related Information Received	Single Option Binary	Yes/No	Yes/Yes	Could be affected by participation in the BCI program. Is related to the treatment effect and the outcomes since access to loans can influence cultivation practices and coping strategies.

Covariate	Variable Type	Affected by Treatment	Related to the Treatment/ Outcome	Rational
Access to Affordable Loans	Multiple Options Binary	Yes/No	Yes/Yes	Could be affected by participation in the BCI program. Is related to the treatment effect and the outcomes since access to loans can influence cultivation practices and coping strategies.
Business Aspects				
Farm Record Keeping	Single Option Binary	Yes	Yes/Yes	Clear connection to the BCI program outcomes and should be considered an outcome variable.
Types of Farm Records Kept	Multiple Options Binary	Yes	Yes/Yes	Clear connection to the BCI program outcomes and should be considered an outcome variable.
Decision-Making based on Records	Single Option Binary	Yes	Yes/Yes	Clear connection to the BCI program outcomes and should be considered an outcome variable.
Market Information Accessed	Multiple Options Binary	Yes	Yes/Yes	Connection to the BCI program outcomes and should be considered an outcome variable.

STATA psmatch2 Log File and Balancing Statistics

The log file and balancing statistics provided below were generated from kernel matching farmers who did and did not attend BCI natural conservation training.

STATA psmatch2 Log File

```
Single-user
       Stata
       perpetual
       license:
       Serial
       number:
       301606311
       754
         Licensed to:  Vivek Voora
                       Central European University

Notes:
      1.  Unicode is supported; see help unicode_advice.
```

1 . db psmatch2

2 . import excel "C:\Users\Vivek\Desktop\PhD Thesis\Household Survey Tool\Data Analysis\Data_Analysis Both with Mods T(274 vars, 837 obs)

3 . db psmatch2

4 . psmatch2 Statistical_Group Q3_5_Age Q8687_Household_Members Q9_1_Total_Area Q10_1_Cotton_Area Q11_2_Black Q11_3_Mixed Q11_4_Red Q105_1_1_Irrigation_Used Q105_2_1_Tractors_Used Q105_3_1_Plowing_Used Q105_4_1_Pump_Used Q106_Land_Tenure Q108_Livestock Q82_1_Canal, outcome(Q14_1_Set_Aside Q15_3_Cleared Q69_3_Live_Fences Q69_4_Hedgerows Q70_3_Buffer_Zones Q80_4_Crop_Rotation Q73_Nat_Pest_Control) logit kernel kerneltype(epan) common

```
Logistic regression                             Number of obs     =        837
                                                LR chi2(14)       =      52.95
                                                Prob > chi2       =     0.0000
Log likelihood = -254.94872                     Pseudo R2         =     0.0941
```

Statistical_Group	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Q3_5_Age	.0139443	.0085459	1.63	0.103	-.0028053	.0306939
Q8687_Household_Members	-.0598014	.0405171	-1.48	0.140	-.1392135	.0196108
Q9_1_Total_Area	.0757249	.0302774	2.50	0.012	.0163823	.1350675
Q10_1_Cotton_Area	-.1494666	.0517887	-2.89	0.004	-.2509707	-.0479626
Q11_2_Black	.4868616	.5364331	0.91	0.364	-.5645281	1.538251
Q11_3_Mixed	.6481552	.5707634	1.14	0.256	-.4705205	1.766831
Q11_4_Red	.3012223	.4794286	0.63	0.530	-.6384405	1.240885
Q105_1_1_Irrigation_Used	.1387274	.3662469	0.38	0.705	-.5791034	.8565582
Q105_2_1_Tractors_Used	1.090039	.2601364	4.19	0.000	.5801812	1.599897
Q105_3_1_Plowing_Used	-.0135969	.2467234	-0.06	0.956	-.497166	.4699721
Q105_4_1_Pump_Used	1.051967	.6927608	1.52	0.129	-.3058192	2.409753
Q106_Land_Tenure	-.1159418	.2610203	-0.44	0.657	-.6275322	.3956486
Q108_Livestock	-.9710392	.2498515	-3.89	0.000	-1.460739	-.4813392
Q82_1_Canal	.8219723	.5303273	1.55	0.121	-.2174501	1.861395
_cons	-1.484918	.8545453	-1.74	0.082	-3.159796	.1899597

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Q14_1_Set_Aside	Unmatched	.011363636	.012016021	-.000652385	.012258195	-0.05
	ATT	.011494253	.010932971	.000561282	.012912739	0.04
Q15_3_Cleared	Unmatched	0	.132176235	-.132176235	.036146863	-3.66
	ATT	0	.126115062	-.126115062	.018289714	-6.90
Q69_3_Live_Fen~s	Unmatched	.022727273	.010680908	.012046365	.012251125	0.98
	ATT	.022988506	.010408907	.012579599	.017087393	0.74
Q69_4_Hedgerows	Unmatched	0	.002670227	-.002670227	.005507717	-0.48
	ATT	0	.005939515	-.005939515	.002786814	-2.13
Q70_3_Buffer_Z~s	Unmatched	.022727273	.013351135	.009376138	.01340803	0.70
	ATT	.022988506	.012860155	.010128351	.01730835	0.59
Q80_4_Crop_Rot~n	Unmatched	.147727273	.32576769	-.178040418	.051676119	-3.45
	ATT	.149425287	.285185911	-.135760623	.046026261	-2.95
Q73_Nat_Pest_C~l	Unmatched	1.79545455	1.68090788	.114546668	.052473823	2.18
	ATT	1.79310345	1.71507244	.078031012	.050569045	1.54

Note: S.E. does not take into account that the propensity score is estimated.

psmatch2: Treatment assignment	psmatch2: Common support Off suppo	On suppor	Total
Untreated	0	749	749
Treated	1	87	88
Total	1	836	837

5 . pstest, both dist

Variable	Unmatched Matched	Mean Treated	Control	%bias	%reduct |bias|	t-test t	p>|t|	V(T)/ V(C)
Q3_5_Age	U	43.523	42.168	9.5		0.86	0.388	1.12
	M	43.517	43.38	1.0	89.9	0.06	0.950	1.09
Q8687_Household_Members	U	6.25	6.7891	-15.8		-1.32	0.188	0.70
	M	6.2759	6.4065	-3.8	75.8	-0.27	0.789	0.88
Q9_1_Total_Area	U	7.7955	7.9661	-2.4		-0.19	0.846	0.58*
	M	7.7701	8.7927	-14.5	-499.2	-0.78	0.435	0.33*

Q10_1_Cotton_Area	U	5.4318	6.3293	-17.4		-1.36	0.175	0.45*
	M	5.4598	5.8725	-8.0	54.0	-0.60	0.547	0.69
Q11_2_Black	U	.85227	.85047	0.5		0.04	0.964	.
	M	.85057	.85515	-1.3	-153.2	-0.08	0.933	.
Q11_3_Mixed	U	.09091	.06275	10.5		1.01	0.314	.
	M	.09195	.09318	-0.5	95.6	-0.03	0.978	.
Q11_4_Red	U	.125	.13485	-2.9		-0.26	0.798	.
	M	.12644	.1249	0.5	84.3	0.03	0.976	.
Q105_1_1_Irrigation_Used	U	.18182	.08011	30.4		3.16	0.002	.
	M	.17241	.14383	8.5	71.9	0.51	0.608	.
Q105_2_1_Tractors_Used	U	.52273	.30307	45.6		4.20	0.000	.
	M	.51724	.50413	2.7	94.0	0.17	0.864	.
Q105_3_1_Plowing_Used	U	.42045	.41522	1.1		0.09	0.925	.
	M	.41379	.40705	1.4	-28.9	0.09	0.928	.
Q105_4_1_Pump_Used	U	.04545	.01068	21.1		2.60	0.009	.
	M	.03448	.03156	1.8	91.6	0.11	0.915	.
Q106_Land_Tenure	U	1.125	1.1575	-6.7		-0.58	0.562	0.90
	M	1.1264	1.1341	-1.6	76.4	-0.11	0.914	1.06
Q108_Livestock	U	1.4318	1.6088	-35.9		-3.21	0.001	1.04
	M	1.4368	1.4618	-5.1	85.9	-0.33	0.742	0.99
Q82_1_Canal	U	.06818	.0267	19.5		2.12	0.034	.
	M	.06897	.05907	4.7	76.1	0.27	0.791	.

* if variance ratio outside [0.66; 1.53] for U and [0.65; 1.53] for M

Summary of the distribution of the abs (bias)

BEFORE MATCHING

	Percentiles	Smallest		
1%	.5059275	.5059275		
5%	.5059275	1.057899		
10%	1.057899	2.412387	Obs	14
25%	2.919787	2.919787	Sum of Wgt.	14
50%	13.19376		Mean	15.66691
		Largest	Std. Dev.	13.85456
75%	21.07143	21.07143		
90%	35.88097	30.37457	Variance	191.9488
95%	45.61096	35.88097	Skewness	.7928079
99%	45.61096	45.61096	Kurtosis	2.660159

AFTER MATCHING

	Percentiles	Smallest		
1%	.4569544	.4569544		
5%	.4569544	.4593389		
10%	.4593389	.960996	Obs	14
25%	1.280884	1.280884	Sum of Wgt.	14
50%	2.245583		Mean	3.939744
		Largest	Std. Dev.	4.006621
75%	5.069807	5.069807		
90%	8.535485	8.010704	Variance	16.05302
95%	14.45595	8.535485	Skewness	1.436434
99%	14.45595	14.45595	Kurtosis	4.33174

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.092	51.56	0.000	15.7	13.2	79.7*	1.34	33
Matched	0.005	1.14	1.000	3.9	2.2	15.9	0.42*	17

* if B>25%, R outside [0.5; 2]

6 . export excel using "C:\Users\Vivek\Desktop\PhD Thesis\Household Survey Tool\Data Analysis\STATA\Final Investigatiofile C:\Users\Vivek\Desktop\PhD Thesis\Household Survey Tool\Data Analysis\STATA\Final Investigation\T4\T4_Kernel.xls

Balancing Statistics

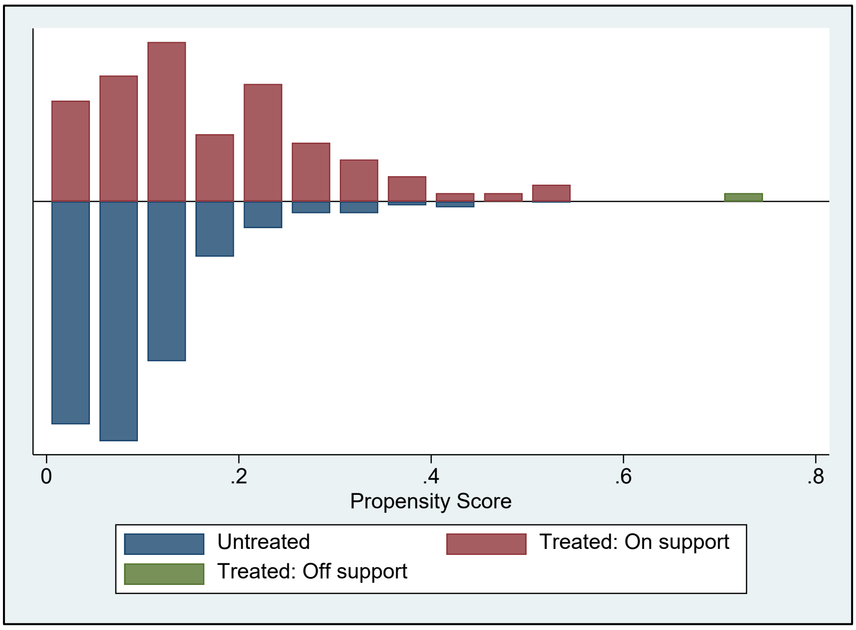


Figure 26 – Kernel matched farmers on and off support

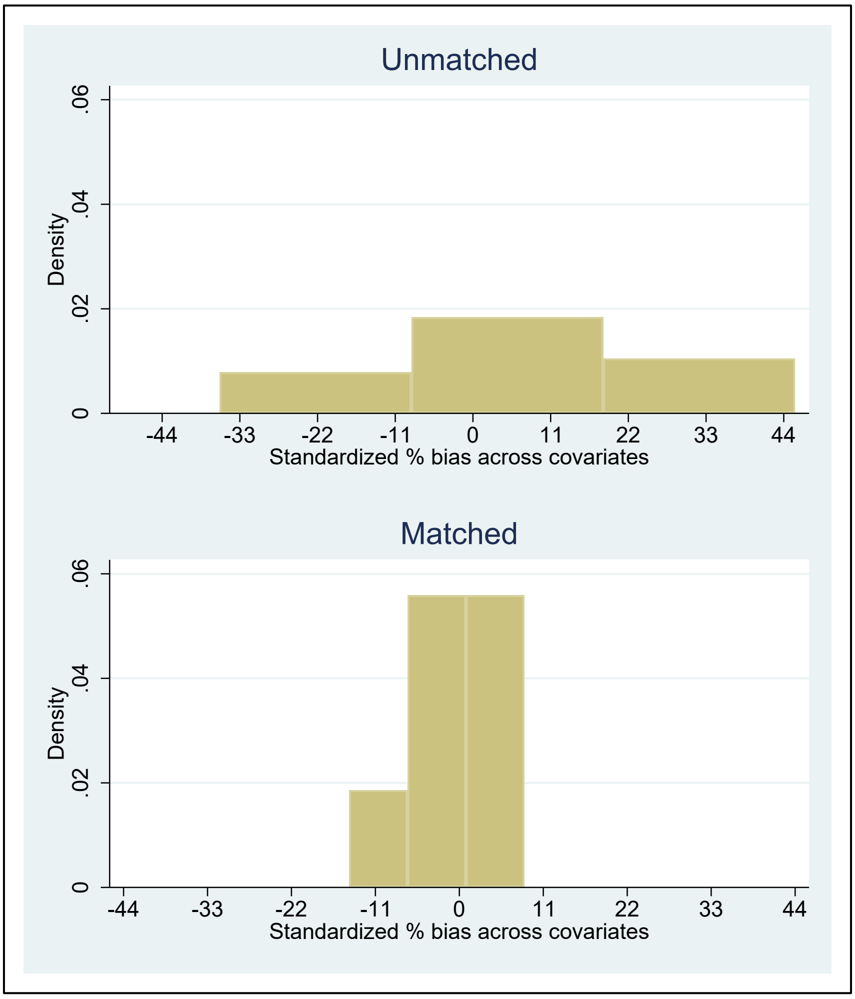


Figure 27 – Histogram of standardized % bias across covariates

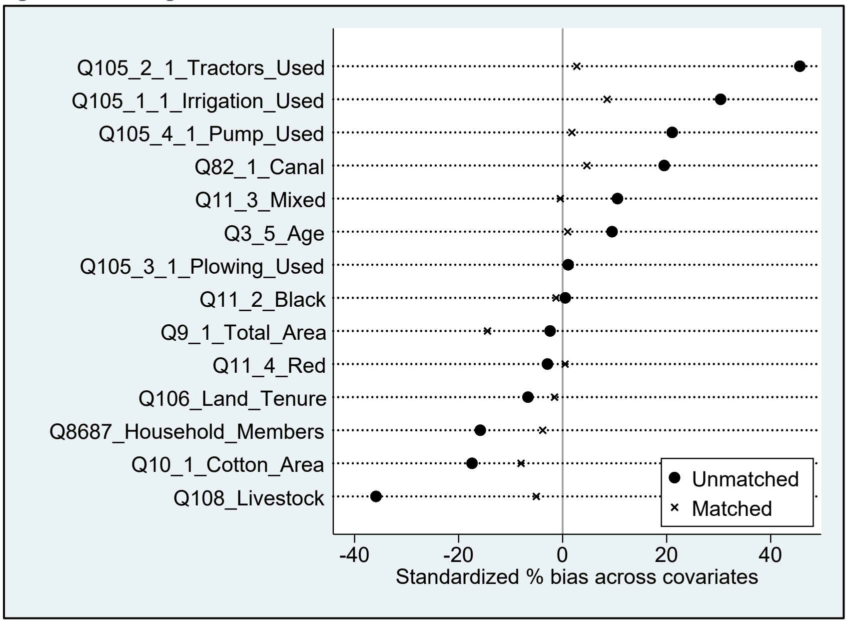


Figure 28 – Dot plot of kernel matching effect on the standardized % bias accross covariates

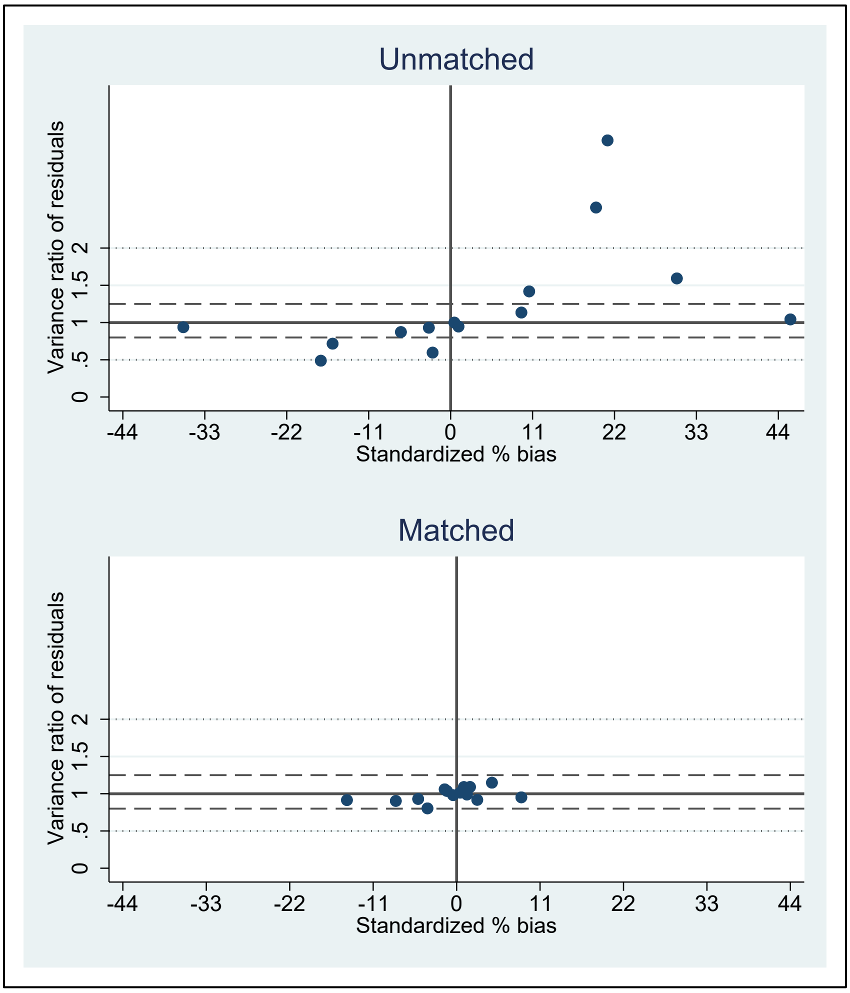


Figure 29 – Scatter plot of kernel matching effect on the variance and standardized % bias accross covariates.

Appendix 3 – Relational Survey and Network Analysis

The survey tool used to collect relational data for the network analysis and the water and food security network and sub-network graphs that were compiled are presented in this appendix. The survey tool consisted of two name generating questions to identify the organizations collaborating on water and food security in the Adoni Mandal. The organizational networks generated from the relational survey information collected where further disagragated into sub-networks based on the water and food security aspects that organizations collaborate on.

Relational Survey Tool

Relational data – how do Organizations interact within the context of water, energy and food security dynamics in the Adoni Mandal?

Name:
Organization:
Contact Information:
Date:

This survey attempts to establish the socio-ecological network in the Adoni Mandal as it pertains to the water, energy and food security dynamics in the area. It aims to understand who your Organization is interacting with and the nature of these interactions. ***Please read the instruction below carefully before you start filling the questionnaire.***

Water Security (Q1) - Indicate the Organizations that your Organization cooperates with on water security which means working towards providing access to sufficient water of adequate quality for household needs and agricultural activities, the main form of livelihood in the villages of the Adoni Mandal. Mark this interaction as "Regular" (3 or more times/year), "Occasional" (less than 3 times/year), "None" (no interaction), "In the past" (previous interaction no longer operational), or chose to decline to answer the question, by checking "Decline".

Food Security (Q2) - Indicate the Organizations that your Organization cooperates with around food security which means working towards providing access to sufficient food for household needs in the villages of the Adoni Mandal. Mark this interaction as "Regular" (3 or more times/year), "Occasional" (less than 3 times/year), "None" (no interaction), "In the past" (previous interaction no longer operational), or chose to decline to answer the question, by checking "Decline".

Q1 What Organizations do you cooperate with on Water Security?

	Frequency of Cooperation? (Choose one option)					Water Elements Worked On? (Check all that apply)							
Name of Organization	Reg.	Occ	None	In the Past	Decline	Irrigation	Gound water	Surface water	Retention	Water Quality	Water Treatment	Other
(1)												
(2)												
(3)												
(4)												
(5)												
Please describe the other water elements that were worked on below.												

Q2 What are the Organizations that you cooperate with on Food Security?

	Frequency of Cooperation? (Choose one option)					Food Elements Worked On? (Check all that apply)								
Name of Organization	Reg.	Occ.	None	In the Past	Decline	Soils	Food Crops	Cash Crops	Wild Food	Livestock	Food Pres.	Food Proc.	Pest Man.	Other
(1)														
(2)														
(3)														
(4)														
(5)														
Please describe the other food elements that were worked on below														

Water and Food Security Network and Sub-Networks

The largest nodes shown in Figure 30 to Figure 33 are the District Water Management Agency (DWMA), the Mandal Engineering Department (MED) the District Irrigation Department (DI), which had the highest betweenness centralities in the water security network and sub-networks compiled. The KVK also stood out as an organization that is strategically positioned to enable water security and farming resilience across the water security network and sub-networks compiled. The PRDIS had no relationships with these organizations, all of which are important entities that could enhance water security and farming resilience for cotton farmers. The DWMA is involved in managing natural resources on a watershed basis and is responsible for administering the NREGS (Kurnool District, 2019). The MED is well connected with the villages of the Adoni Mandal as they maintain their drinking water supplies. The DI department provides water via the lower level canal to some of the villages for irrigation. The KVK provides agricultural extension services to all the villages in the Mandal. Although all these organizations have direct relationships with most of the village leadership in the Adoni Mandal, the PRDIS could further facilitate the connectivity of farmers being trained to become BCI verified cotton producers by developing direct relationships with these key water security organizations.

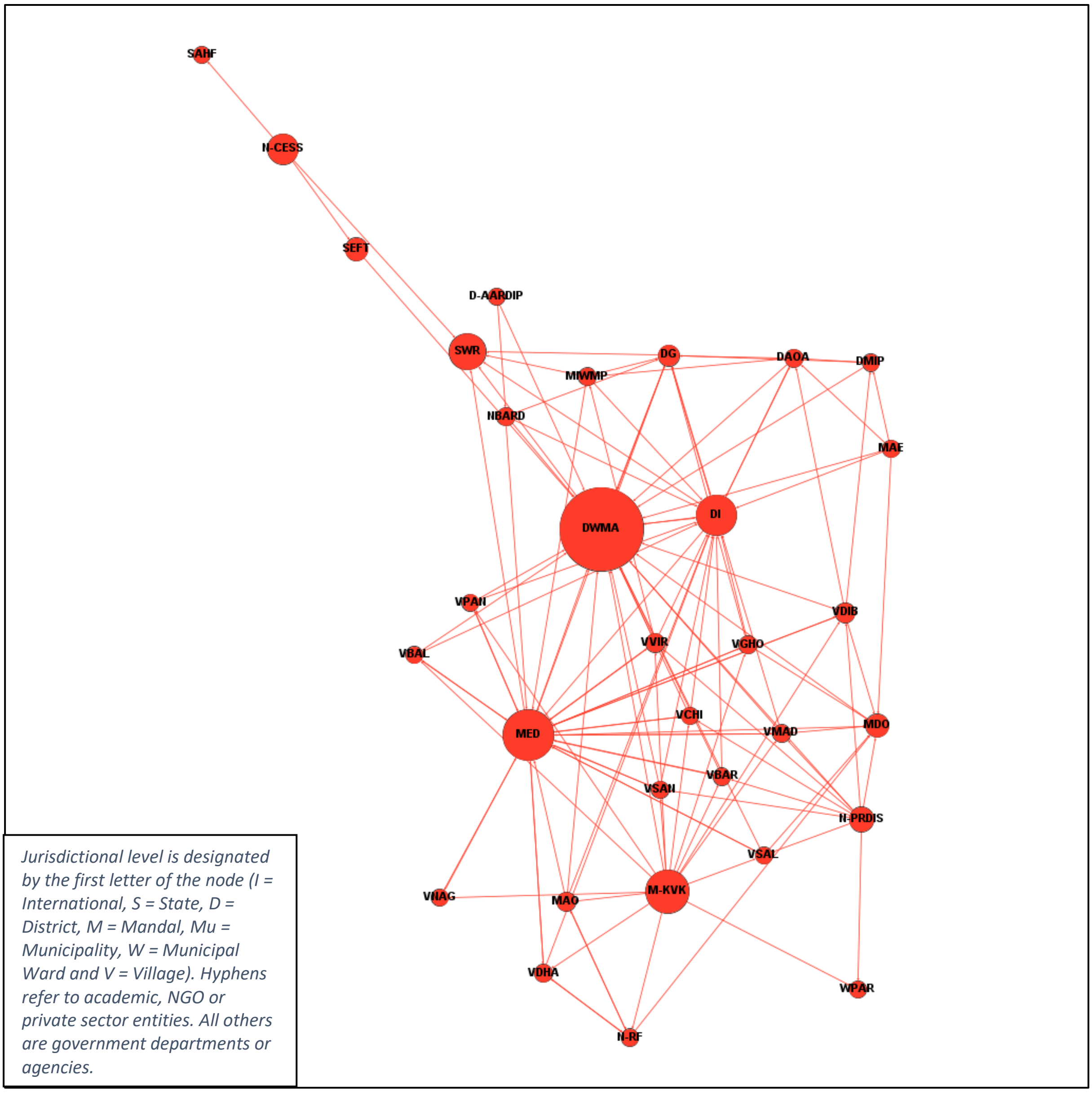
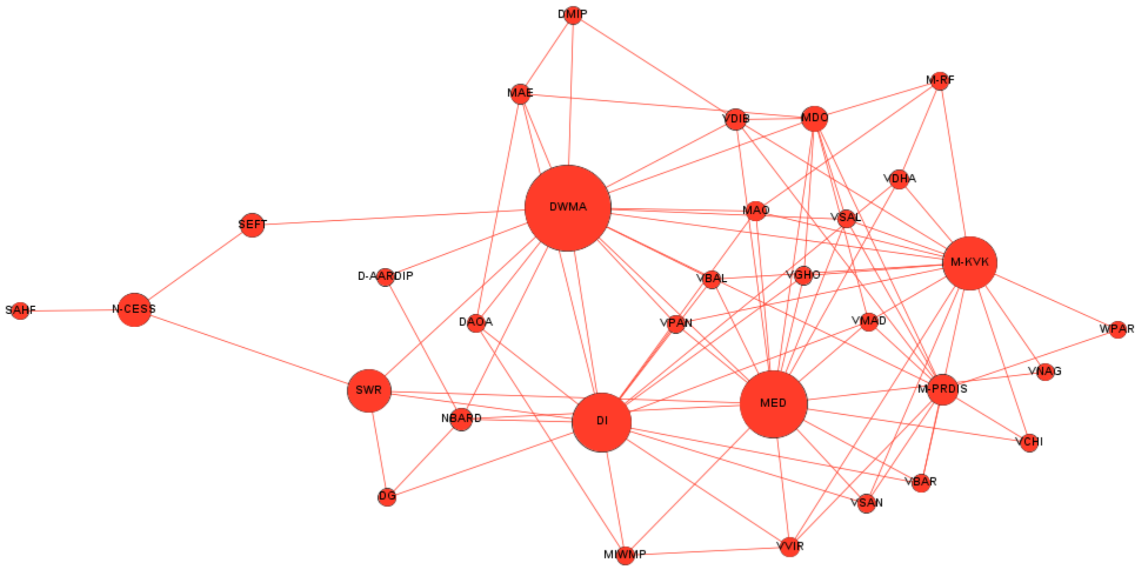


Figure 30 – The water security network of the Adoni Mandal



Jurisdictional level is designated by the first letter of the node (I = International, S = State, D = District, M = Mandal, Mu = Municipality, W = Municipal Ward and V = Village). Hyphens refer to academic, NGO or private sector entities. All others are government departments or agencies.

Figure 31 – The water conservation sub-network of the Adoni Mandal

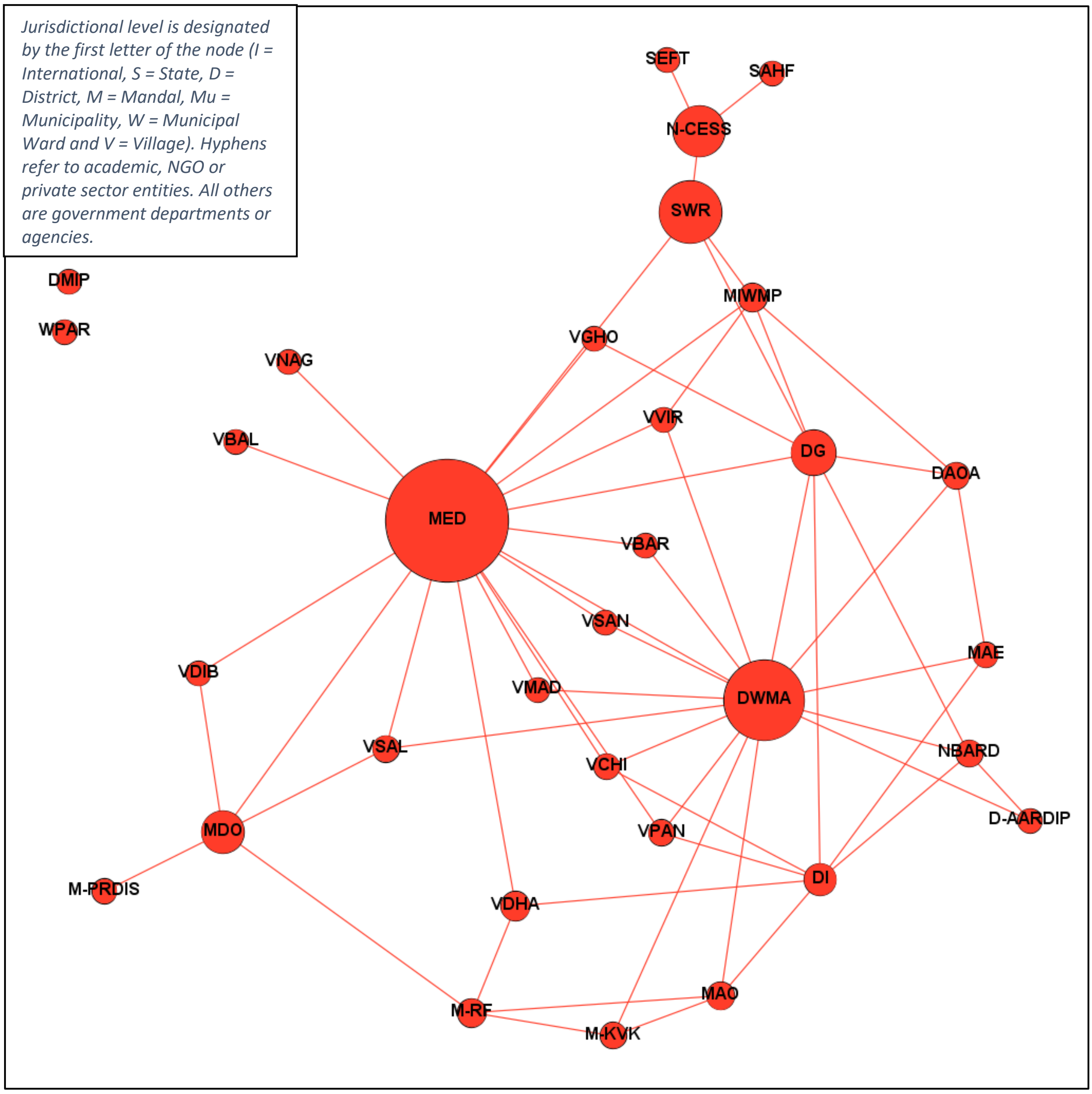
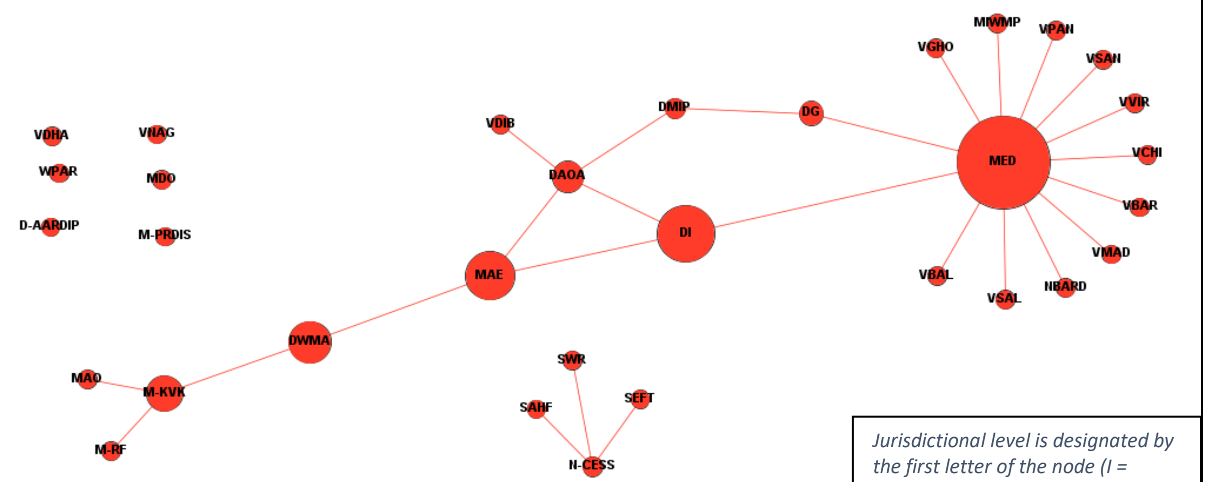


Figure 32 – The water resources sub-network of the Adoni Mandal



Jurisdictional level is designated by the first letter of the node (I = International, S = State, D = District, M = Mandal, Mu = Municipality, W = Municipal Ward and V = Village). Hyphens refer to academic, NGO or private sector entities. All others are government departments or agencies.

Figure 33 – The water quality sub-network of the Adoni Mandal

The largest nodes in Figure 34 to Figure 37 are the KVK and the District Agriculture Agency (DAOA), which had the highest betweenness centralities in the food security network and sub-networks compiled. The Mandal Agricultural Office and Extension services (MAO and MAE) also stood out as an organization that is strategically positioned to enable water security and farming resilience across the water security network and sub-networks compiled. The KVK and DAOA, MAO and MAE have similar roles in the Adoni Mandal delivering agricultural extension services to improve agricultural productivity. These KVK, MAO and MAE have direct relationships with most of the village leadership in the Adoni Mandal. The PRDIS also had a fairly high betweenness centrality reflecting its focus on enabling more sustainable cotton production provision via its training efforts and encouraging food security via the cultivation of cover crops and intercropping in the form of legumes and lentils (Better Cotton Initiative, 2018). It has organizational relationships with the MAO and MAE but not with the KVK and DAOA, important entities for enhancing food security and farming resilience for cotton farmers. The network and sub-networks compiled indicate that the PRDIS is well positioned to enable food security. Establishing additional ties with key organizations such as the KVK and DAOA could enhance this potential.

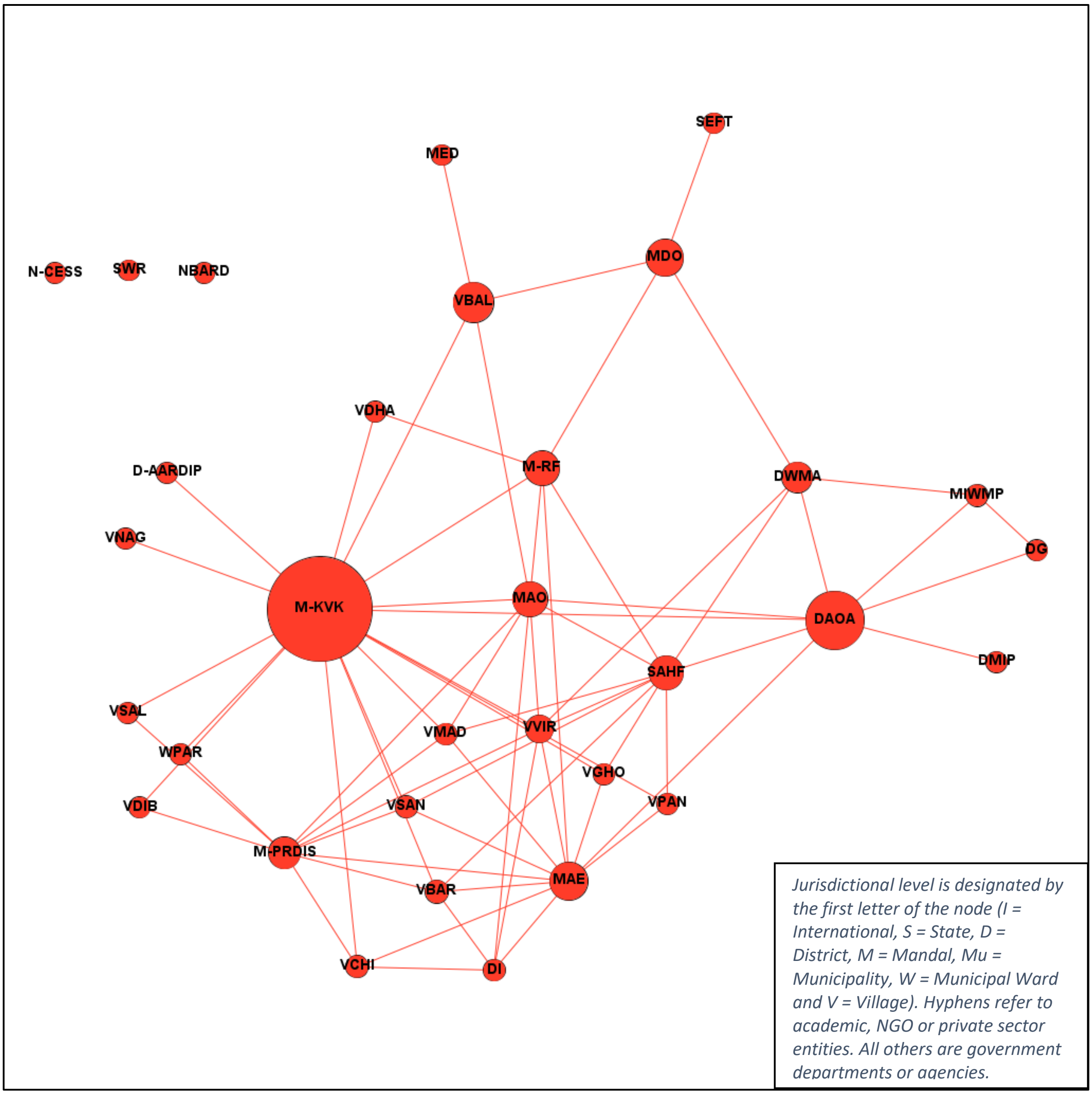


Figure 34 – The food security network of the Adoni Mandal

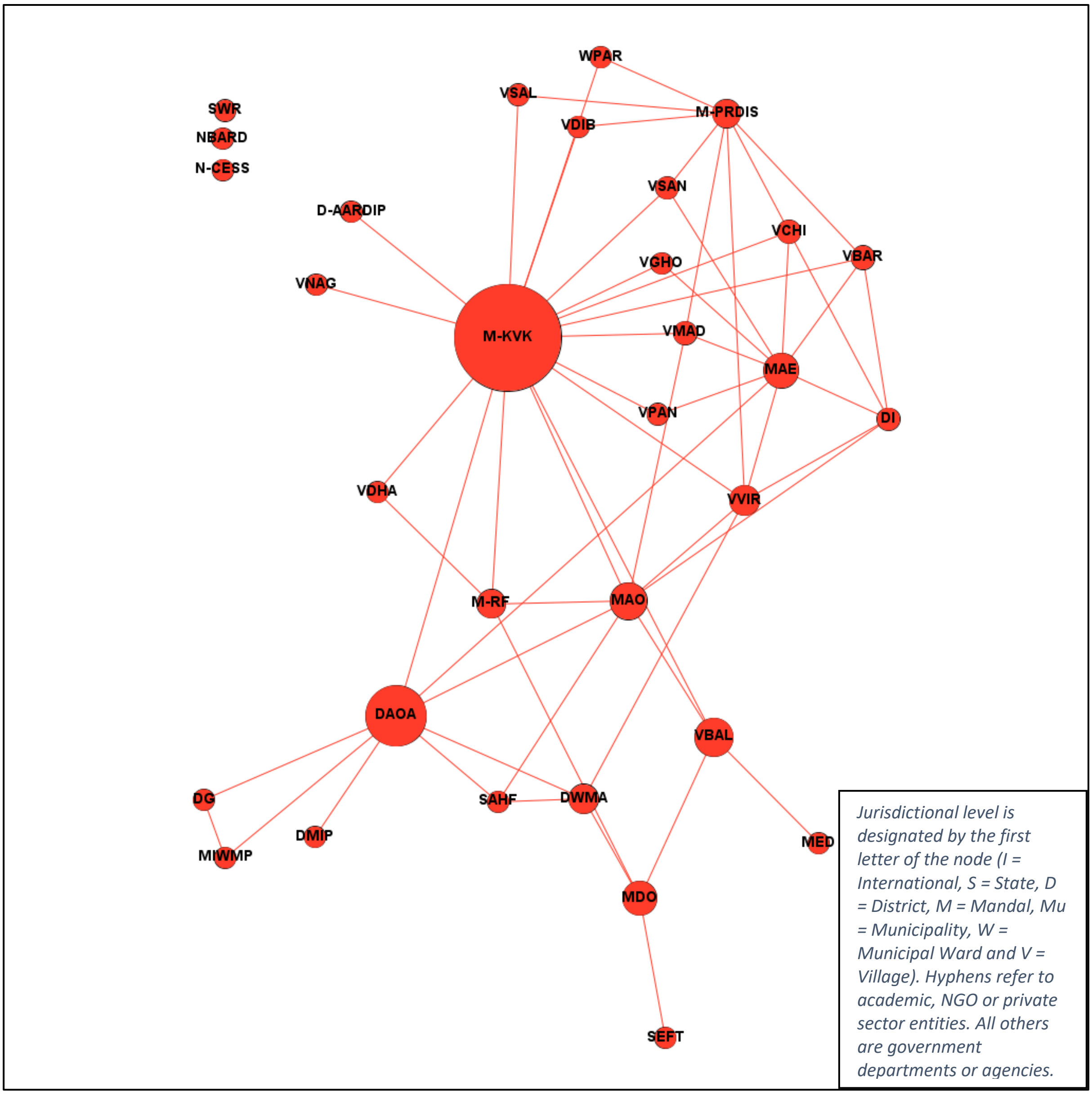
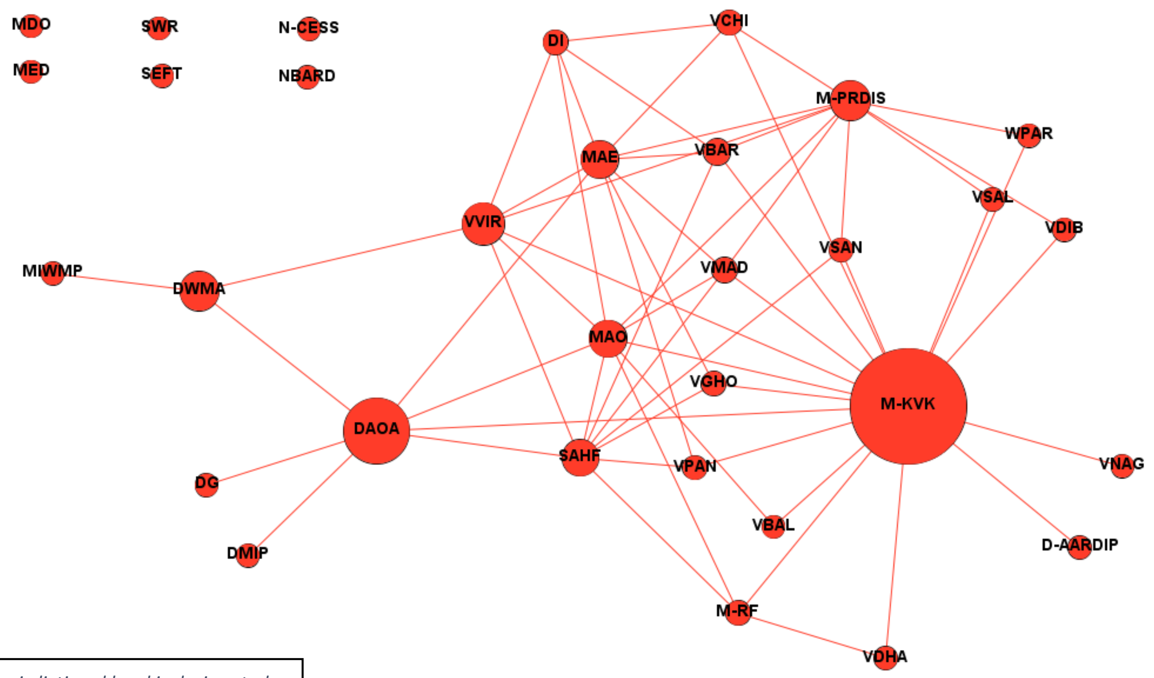
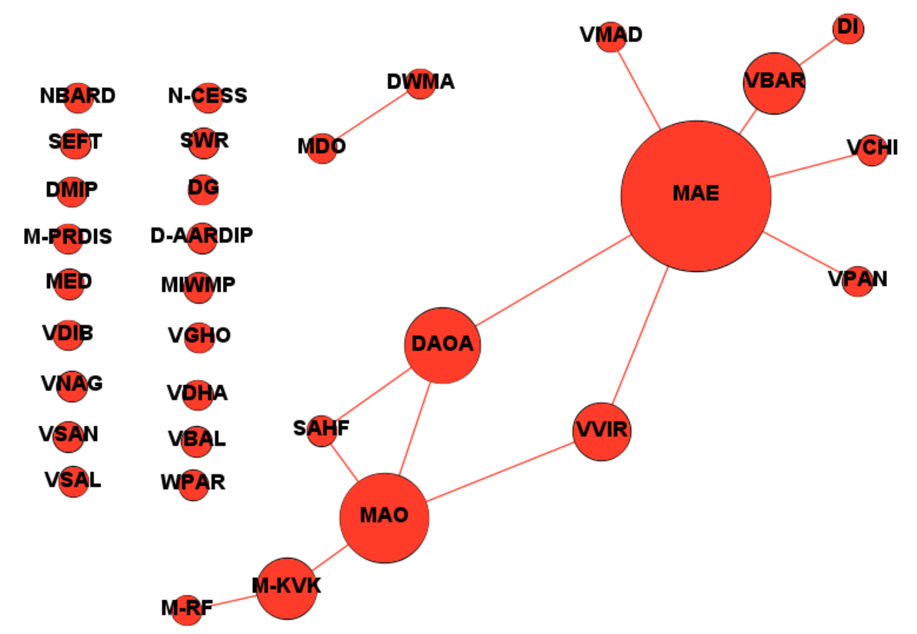


Figure 35 – The agricultural practices sub-network of the Adoni Mandal



Jurisdictional level is designated by the first letter of the node (I = International, S = State, D = District, M = Mandal, Mu = Municipality, W = Municipal Ward and V = Village). Hyphens refer to academic, NGO or private sector entities. All others are government departments or agencies.

Figure 36 – The agricultural practices sub-network of the Adoni Mandal



Jurisdictional level is designated by the first letter of the node (I = International, S = State, D = District, M = Mandal, Mu = Municipality, W = Municipal Ward and V = Village). Hyphens refer to academic, NGO or private sector entities. All others are government departments or agencies.

Figure 37 – Post-harvest practices sub-network of the Adoni Mandal

A hybrid water and food security network was constructed to bring together the organizations that are focused on water conservation and agricultural practices, where the PRDIS is likely most active based on the orientation of the training it provides. The largest nodes in shades of orange to red in Figure 38 are the DWMA, KVK, MED and DI, which had the highest betweenness centralities in the network. The PRDIS also had a fairly high betweenness centrality. The hybrid network compiled indicate that the PRDIS is well positioned to enable connectivity for farming resilience. Establishing direct relationships with the DWMA, KVK, MED and DI could significantly enhance this potential.

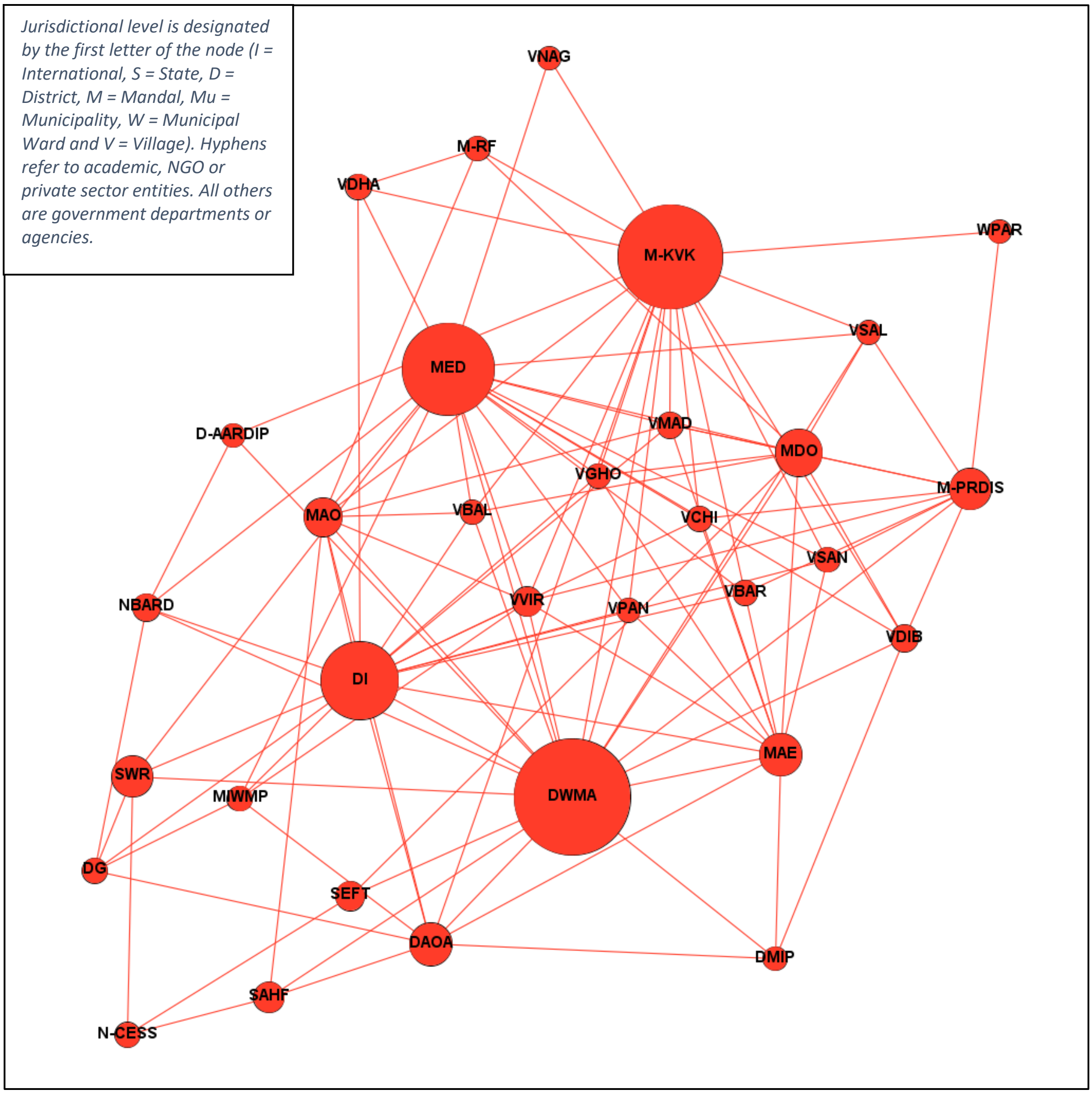


Figure 38 – Hybrid water and food security network of the Adoni Mandal