Linking agroecology and community seed bank

A case study from Araku region, India

Avinash Valluri

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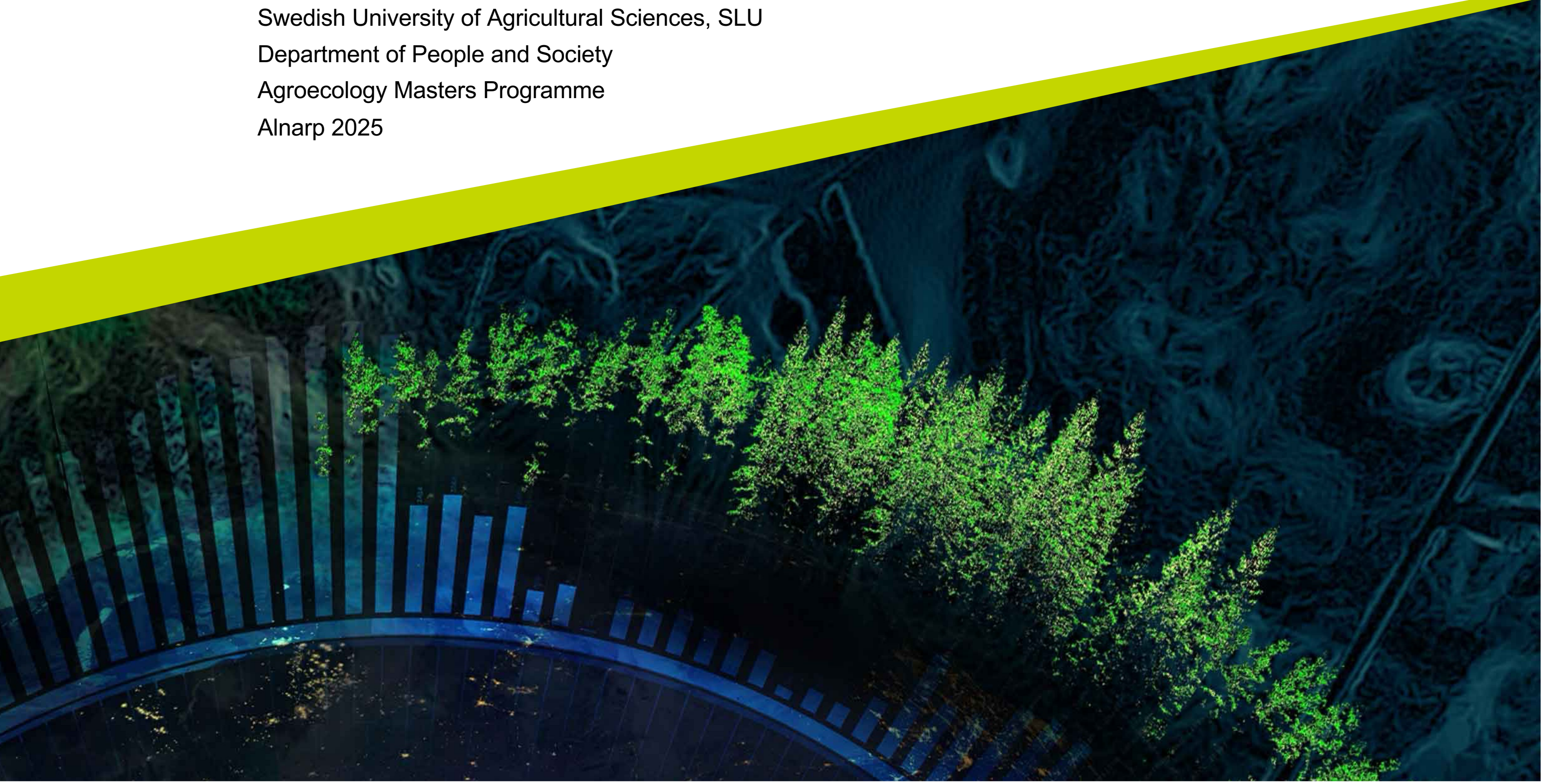

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Avinash Valluri

Supervisor:	**Mats Gyllin, Swedish University of Agricultural Sciences, Department of People and Society**
Examiner:	Iman Raj Chongtham, Swedish University of Agricultural Sciences, Department of Biosystems and Technology

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Swedish University of Agricultural Sciences

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Foreword

First, I thank the Swedish University of Agricultural Sciences (SLU), and Sweden for providing me with the SLU Scholarship to study Agroecology master's program. Without the support, it would have been impossible for me to start this journey of studying abroad. I came from a family that is close with farming, and that shaped me in pursuing a career in agriculture. I always wanted to explore the research that makes our food systems align with the nature. This led me to explore the Agroecology master's programme.

The Agroecology programme is a balance, where I found a mid-ground between the natural sciences and social sciences. It offered me a global perspective, through the expert lectures in the field and through the peers offering a wide perspective. This program gave me a platform to learn and express my thoughts with open-minded people. During the mid of my programme, I had a chance to do internship at NordGen. That internship, shaped my views on the genetic conservation, seeds and importance of open scientific community.

I remember the courses on agroecology, social science research and scientific methods. Those courses gave me the knowledge, and formed a basic groundwork required for the scientific questioning. I would say they curated me to the present thesis work.

Finally, this thesis is a reflection of my learning from the programme and beyond it. This journey at SLU had broadened my scientific view and offered me a chance to explore the academia. The lectures that I had in the programme built me a curiosity to question and try to find answers to them. What else do I need to find!

Abstract

Seeds are an essential part of our lives and food systems. People saved, shared, and exchanged seeds over centuries, but this changed in the last century after the green revolution. To protect the seed diversity and seed rights decentralised community seed banks are established, which functioned to conserve seeds, promote seed sovereignty and protect farmers rights. However, they are not well bridged to the agroecology and climate studies. This study wants to fill the gap by studying a CSB as an institution and by using agroecology as a framework. This study used both qualitative and quantitative data collection methods. A CSB from Araku region is used as a case study. The analysis showed that the collective action of the farming community led to a successful agroecological transition in the Araku region. The collaboration mechanisms used by the CSB helped in better transition of farmers to the natural farming. However, there are certain areas where the study region needs improvements, those are youth migration and agriculture labour, value addition, extension activities, and wild diversity conservation. The climate data analysis showed that the Araku region is warming and by 2100 the annual mean temperatures are increasing by (1.8 °C to 4.8 °C) compared to the 1950-80 average. This can disrupt the locals' livelihoods, and biodiversity. Hence, the study recommends an immediate attention to the issues by addressing the gaps, implementing policies and targeted frameworks.

Keywords: Seed sovereignty, agroecology, climate change, community seed bank.

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Abbreviations

Abbreviation	Description
APCNF	Andhra Pradesh Community Managed Natural Farming
CMIP	Coupled Model Intercomparison Project
CSB	Community Seed Bank
FAO	Food and Agriculture Organization
FES	Foundation for Ecological Security
FOSS	Free and Open Source Software
FSI	Forest Survey of India
FSN	Food Security and Nutrition
GMO	Genetically Modified Organism
GOAP	Government of Andhra Pradesh
GOI	Government of India
ha	Hectare (10000 m^2)
ICAR	Indian Council for Agriculture Research
IPCC	Intergovernmental Panel on Climate Change
IPES-FOOD	International Panel of Experts on Sustainable Food Systems
ISFR	India State of Forest Report
ITDA	Integrated Tribal Development Agency
MOEFCC	Ministry of Environment, Forest, & Climate change
NASA	National Aeronautics and Space Administration
PPVFR	The Protection of Plant Varieties and Farmers' Rights Act
RCPs	Representative Concentration Pathways
RySS	Rythu Sadhikara Samstha
SLU	Swedish University of Agricultural Sciences
WASSAN	Watershed Support Services and Activities Network

1. Introduction

The seeds, the basic need for the human civilisation are going under the corporate control, preventing farmers to save their seeds. The seed diversity is vanishing away from our farming baskets. Along with all the factors, the human induced climate change is accelerating the bio-diversity loss, and agriculture biodiversity is no exception in the climate change era (Howard 2009; Gliessman 2014; IPCC 2023).

Seeds played a central role in our agriculture and food systems, but the seed systems changed a lot in the past century. As the industrial agriculture started to spread across the world, private seed companies emerged as primary seed suppliers for farmers. Industrial farming relied mostly on the private seed varieties, Howard (2009), described this phenomenon as an agricultural treadmill, where farmers lost their knowledge of seed saving and depended on companies for seeds and inputs on year-to-year basis. Initially, many private seed companies were family-owned business entities, but this shifted in last five decades where seed industry transformed from family-owned entities to multi-national corporations (Jorge Fernandez-Cornejo et al. 2007). This transformation in the seed industry involved conglomeration of small businesses, competitors and family-owned entities into huge corporations (ibid.) In 2025, ETC Group reported that around 56 percent of the global commercial seed market is controlled by just 4 companies (ETC Group 2025). This concentration of power of the seed giants had been questioned by peasant groups.

The 1990's peasant movements shaped the way in which the present international treaties function and paved ways for decentralised agroecological initiatives. When the WTO agreements seemed to favour the corporate giants, peasant groups from several countries resisted the unilateral regulations. This resistance evolved into a social movement (La Via Campesina) fuelling the food sovereignty and agroecology. While among this chaos around the world, informal institutions promoted by the non-profit organisations raised as a hidden treasure. These decentralised institutions, are the Community Seed Banks (CSBs) (Wezel et al. 2009; Gliessman 2014; Vernooy et al. 2015; La Via Campesina 2025).

Community seed banks (CSBs) are decentralised seed banks run and manged by farmers. They preserve local seed diversity and distribute those seeds to farmers. In addition, CSB's facilitate seed access, and promote seed sovereignty (Vernooy et al. 2015). Studies from various regions of the world identified other important roles of CSBs beyond their main functions, where they helped in enhancing food security, improving food products quality, and promoted farmers rights (Okori et al. 2022; Tione et al. 2025).

Along with the internal problems of agriculture sector, there is a looming problem of climate change. This is altering the long-term weather patterns in many parts of the world, affecting the agriculture and food systems. The changes are well pronounced in the developing economies. The 2023 IPCC report, recommended implementation of agriculture diversification and community-based solutions to prevent severe droughts and food insecurity in this climate change era. Diversification and adaptation in agriculture requires broadly adapted cultivars for the changing climate (IPCC 2023) . The 2025, EAT-Lancet report described agriculture as the forerunning factor that is breaching the planetary boundaries (Rockström et al. 2025). This highlights the need for sustainable food systems transformation and having a wide genetic diversity for future adaptation.

The agroecological transition is viewed as a sustainable alternative to industrial farming practices, while also helping adapt to climate change. Agroecological practices reduce dependence on external inputs and promote transitions at multiple levels of the food system (Gliessman 2014). Several, agroecological transition programs started in the last three decades around the globe, one such initiative is natural farming program in India. The large-scale natural farming program was started in the state of Andhra Pradesh in 2017. The programme evolved over the years and now about 0.8 million farmers participate in the programme in (Khadse & Rosset 2019). The natural farming encourages the input reduction, which means reduced dependence of external seeds. This aligns with the main mottos of CSBs and agroecology. However, the connection between the CSBs and agroecology is not well studied, and there are few studies addressing this bridge.

Previous studies on community seed banks from India have focussed on evaluating seeds as commons, intellectual property rights, breeding rights, and marginalisation of the seed saving communities (Patnaik 2016; Patnaik et al. 2017; Duthie-Kannikkatt et al. 2019; Ramanna & Andersen 2022). Over the past decade, these studies mostly focussed on examining social issues around the seeds and the seed rights. The natural farming movement was introduced in 2017, focussed on agroecological transition (Khadse & Rosset 2019). Although there are studies assessing the natural farming movement, they have not focused on the CSBs and its farmers. While the IPCC (2023), emphasises that isolated rural communities in global south are highly vulnerable to the climate change, but such a generalisation at global level cannot be applied uniformly to all the communities in isolated regions such as the present case study region Araku.

As previous researchers have identified sensitive nature of the seed saving communities in India (Patnaik 2016; Patnaik et al. 2017), it is important to include them for future policies on agroecological transition and climate change. This highlights the need for and importance of having hyper local evaluation of agroecological practices used by the farmers and studying such regions for climate change and understanding local perceptions. This thesis wants to link such seed saving community in Araku region with agroecology using a transdisciplinary approach.

The rest of thesis is organised as follows, Section 2 describes the existing literature on seed sovereignty, community seed banks, agroecology, and climate change. Section 3 describes the research methods, theoretical framework, and data analysis. Section 4 presents the findings from the qualitative and quantitative data. Section 5 discusses the findings with relevant literature and presents brief recommendations for the study regions future. Finally, Section 6 concludes with a broad agroecological view of the study.

1.1 Research aim and research questions

Research Aim

This project aims to study the seed sovereignty movement through the institution called community seed bank (CSB) that promotes seed sovereignty and food sovereignty. This study uses a CSB from Araku region, India as case study to provide a holistic perspective of the CSB farmers and stakeholders on agroecological practices, indigenous knowledge, climate change, seed policies and seed systems. In overall, this study wants to provide a transdisciplinary view around a CSB in the Araku region by linking community seed bank and agroecology.

Research questions (RQs)

1. Which are the seed systems and agroecological practices are associated with the community seed bank and its member farmers?
2. What are the perceptions of people engaged with CSB regarding seed policies, indigenous knowledge, and influence of climate change on their livelihood?
3. How did the CSB study region's (Araku) climate change in the past, and what are the plausible future climate change pathways based on the present climate models?

This project uses agroecology principles as a theoretical framework. The central core of this thesis derives from the perceptions of CSB farmers, stakeholders captured using qualitative data methods. To understand the complexity of changing climate, the case study regions climate data is analysed using the climate models output.

2. Literature review

This section provides an overview of relevant literature to the present study. The section is organised into sub-sections based on the topics. Following topics are covered in this section: seed sovereignty, community seed banks, climate change, context of the study area, and agroecology.

2.1 Seed sovereignty and Community seed banks

Community seed banks play multiple functions, and they are tightly knit with complex agriculture systems. The functions and roles of the community seed bank, align with the food sovereignty, seed sovereignty and agroecology movements. In the times of biodiversity loss and climate change, it is important to understand the community seed banks and its diverse roles to safeguard the agriculture systems.

2.1.1 Seed sovereignty

Seed sovereignty is a dynamic word which is used to describe an independent seed system for farmers. Literature says, *"Seed sovereignty ensures people's right to save their own seeds, grow the seeds, share exchange with people of choice, and finally gives the people right to frame the seed policies"* (Kloppenburg 2014; Wattnem 2016). The seed sovereignty became an important issue with restrictions imparted on seed saving and free exchange.

The concentration of power in commercial seed industry is well evident, and the seed industry is an oligopolistic market. The big four companies Bayer, Corteva, Syngenta, and BASF owns about 56 percent of global commercial seed market share. Top 9 companies, controls 69 percent of worlds commercial seed market (ETC Group 2025:7). While the large control of seed industry by few companies is not a surprise, as the pharmaceutical giants started the concentration of major agrochemical industries since 1990's. The corporate concentration didn't stop even in the present decade, where agri giants bought other major companies in the field especially the small entities and competitors (Howard 2009; Peschard & Randeria 2020). Overall, this indicates a huge corporate consolidation in the commercial seed industry.

Corporate consolidation is a threat to the seed sovereignty as the seed industry influences the seed systems in multiple ways. The seed industry giants, control the catalogue of the seeds available to the farmers. This corporate cataloguing removes farmers choice to plant their own seeds and leading to decline in traditional varieties, seed saving, and traditional knowledge. As the seed giants have huge lobbying power, the agriculture policies and regulations are influenced to favour the agrobusiness companies rather than farmers (Howard 2009; Peschard & Randeria 2020; Gliessman 2023).

Few nations are building their local seed regulations in favour of the private companies, and their Intellectual property rights. These corporate favouritism laws exclude the ability of the farmers to save seeds. Those seed regulations are also making the seed saving, seed exchange, and informal seed systems illegal (Wattnem 2016). Here the informal seed systems define the farmer-to-farmer seed exchange out of formal system.

Globally several food sovereignty movements focussed on moving seed systems away from the corporate control. The strategies used vary according to the region, seed activism is seen across many countries. The seed activism is described as a *"Constellation of movements"*, where the activism combines with peasant movements like La Via Campesina. Seed activism pushes for informal seed exchanges, seed saving, and agroecological practices. Along, with sovereignty the seed activists are also focussing on the lobbying the laws and international seed regulations to benefit farmers (Peschard & Randeria 2020; Gliessman 2023).

The large social movements pushed the concept of seed sovereignty at the top-level of governance systems and international treaties. To promote the seed sovereignty at grass root level in global south independent NGOs established informal institutions called community seed banks (CSBs).

2.1.2 Community seed banks

The origins of the community seed banks can be traced to the 1980s, when the ETC group established CSBs in Ethiopia to revive the local seed systems after a severe drought (Vernooy et al. 2015). Subsequently, the independent community seed banks are established in different countries of global south.

Functions of Community seed banks

Community seed banks performed wide area of functions based on the requirements of the community members. Vernooy et al. (2015) classified community seed banks into three core areas. The core areas include, i) Seed conservation, ii) Seed access and availability, iii) Food and seed sovereignty. Based on CSB's are classified into one or multiple core areas.

Seed conservation: Seed conservation can be described as the primary function of the CSBs. The basis of the CSB, is primarily to conserve the local agro biodiversity, and prevent local seed varietal loss. They rely on the in-situ or on-farm conservation of the seeds, where seeds are stored in local storage facility. The seed in the storage facility are stored for few seasons, years and are not intended for long-term storage (Vernooy et al. 2015).

Seed access and availability: Seeds conserved in the CSB are made available to the farmers in some seed banks through sales, loans, and exchanges. Seeds are sold to the farmers directly, and the sales are done as a service with minimal profit. Seeds are loaned to farmers, and by the end of crop season farmers should deposit seeds along with interest percentage to the CSB. Few CSBs also promote seeds exchange between the farmers or organisations, and through the seed fairs (Vernooy et al. 2015).

Food and seed sovereignty: Apart from the seed conservation and seed access, some community seed banks and its members focus on the food sovereignty. Food sovereignty movement is broad and can be aligned with the agroecology principles. Activities like promoting agro-ecological practices, striving for farmers rights, participatory breeding can be categorised into the core of food sovereignty. In overall the community seed banks perform one core function, or dual, multiple functions. From around the world there are case studies of CSBs which fall into individual function and others performing multiple functions (Vernooy et al. 2015).

Community seed banks began as a place of seed conservation and slowly diversified their roles. These diverse roles include protecting farmers rights, encouraging extension activities, forming seed bank networks and encouraging research activities. The regional conditions, local and international organisations (NGO's, Research institutes) played a crucial role in the transformation of CSB's roles and functions (Vernooy et al. 2015:13–19).

India and CSBs

In India, NGOs and farmers organisations played a crucial role in establishment of CSB across the country. The establishment of CSBs are favoured by, The Protection of Plant Varieties and Farmers' Rights Act (PPVFR) enacted in 2001, allows individual farmers and the communities to register a variety on their name. In principle this section of the Act promotes the community seed saving, and conservation. Communities registering a variety enjoys equals rights as an individual (PPVFR Act 2001; Vernooy et al. 2020). So, in a case of commercial usage of the registered variety, the community can demand the royalty or restrict the usage of the variety for sale.

The previous studies on Community seed banks (CSBs) in India examined the Intellectual Property Rights (IPRs), social resilience, disputes between farmers' rights and breeders' rights (Patnaik 2016; Patnaik et al. 2017; Duthie-Kannikkatt et al. 2019; Ramanna & Andersen 2022). Local regulations such as PPVFR Act and its implications for the seed saving initiatives and their non-alignment with international treaties for IPRs on seeds were crucial in protecting the interests of the CSBs and their farmers (PPVFR Act 2001; Ramanna & Andersen 2022). In South India (Andhra Pradesh and Telangana), seed saving initiatives (CSBs) in the marginalised communities have helped build a network of farmers creating a seed sharing community and the view of seeds as social commons (Patnaik 2016; Patnaik et al. 2017; Duthie-Kannikkatt et al. 2019).

Why community seed banks are important?

CSBs are involved in various important roles, such as ensuring food security, advocating for farmer rights, creating alternative seed networks, knowledge sharing platforms, and collaborations. A long term research study from Okori et al. (2022) in Malawi found, farmers participating in the CSB activities improved the food security of the farmers household. Similarly, Tione et al. (2025) study in Malawi showed, CSB farmers have better food security than the non CSB participating peer farmers in the region.

The CSB's also helped in enhancing the locals' livelihoods by increasing the farm produce sale and promoting local food processing industries. The training activities focussing on farmer-to-farmer knowledge sharing helped improve quality and quantity of farm produce. The quantity of farm output increased by following agronomic changes, while the quality improved by reduce aflatoxins in the crops. For all the success the peer to peer knowledge networks enabled by the CSB played a vital role (Okori et al. 2022). Along with that the farmers exposed to climate extremes (Drought, floods, erratic rainfall, and high temperatures), participate well in the CSB activities. The better food security of CSB farmers shows the active participation of the farmers in the extension and education events (Tione et al. 2025).

Similarly Westengen et al. (2018), emphasized the importance of creating subsidiaries to the formal gene banks using CSBs. Formal gene banks can only supply small quantities of the seeds to the farmers, and there is a need for seed multiplication before supplying seed to farmers. This role of seed multiplication can be filled by the CSBs, creating a direct link with formal seed banks (Westengen et al. 2018). The benefits of using alternative seed systems, to supply the ex-situ seed material directly to farmers, also helps in increasing the trust on the formal seed banks (ibid.). This integration between formal seed banks and CSBs require a scaled and well-planned training to the community seed banks members.

Seed legislation in India

In India seeds and agro biodiversity used to be under shared public commons, and now they are under the IPR framework laws. Until 1990's, seed in India are seen as public commons, and patents cannot be obtained on these common goods. The seed laws brought in 1988, changed the regulations around the seeds subsequently the WTO agreements and the TRIPS, forced India to bind for the IPR on the seeds (Dadlani 2025).

The present legislation that covers the seeds and rights is introduced in 2001. The protection of plant varieties and farmers rights (PPVFR) Act 2001 governs the regulations around seeds and protects rights of both farmers and breeders in India. PPVFR act gives the farmers, rights to save, grow, sow, sale or exchange the seeds. However, the farmers cannot sell the seeds registered under the act, using a brand name or in similar packaging. This implies that informal sales of seeds can be done by the farmers, but not the under a branded packaging (PPVFR Act 2001). The PPVFR Act covers all the propagating materials, that can be used to generate a plant

Farmers can register their own varieties under "farmers varieties", which they bred or conserved. Farmers varieties have similar rights to the breeders' rights. For registration of a variety under the PPVFR Act, seed material should meet the DUS (Distinctive, Uniform, and Stable) characteristics (PPVFR Act 2001).The Act established a national gene fund to encourage farmers preserving the local farmers varieties, and also the wild cultivars or wild relatives (PPVFR Act 2001; Ramanna & Andersen 2022).

2.2 Context of study area

The present case study region is in Araku region of Andhra Pradesh, India. The below sub-sections provide context about India, and the local area.

2.2.1 India

A country with 1.45 billion people and 3.2 million km^2 of area. About 25 percent of the land covered with forests, from tropics to the Himalayas. The per capita income stands at 2330 Euros and about 44 percentage of population depends on the agriculture sector (World Bank Open Data 2024).The nutritional profile of India is at extreme ends, on one end about 25 percent of population is obese and on the other side India faces a significant lack in protein-based diet and is in the verge of hunger (Global Hunger Index 2024). The recent Global Hunger Index (GHI) report ranked India at 105th position, the hunger level is classified as serious with a score of 27.3. Despite being an agriculture economy, about 35.5 percent of children below five years old are stunted, 18.7 % of children are wasted, and 13.7 % of the population are undernourished in 2024 (ibid.). This implies there is a significant gap in the production and consumption of the nutritious food among the population.

Seed industry in India

A formal seed enterprise began with the establishment of National Seed Corporation (NSC). The NSC is owned and run by the central government and overlooked all the seed industry in India. NSC started its role as a seed producer, distributor and subsequently moved to spreading of seed technology. Though there are few other public owned seed companies they didn’t succeed much during the green revolution. The sale of private seeds started by the Indo-American seeds, they sold vegetable and flower seeds. After the enactment of Seeds Act in 1966, the seed regulation authorities were created, the NSC acted as a regulatory authority (Dadlani 2025).

In 1980’s National Seed Program (NSP) was introduced to enhance the seed supply chain. As a part of this program, state seed corporations (SSC) and State Seed Certification Agencies (SSCA) were established. The SSC looked into the production of seeds while the certification agencies worked for the quality assurance of the seeds. The seed production in the stated was linked with the State Agriculture Universities (SAUs) to enhance the production of breeder and foundation seeds. The NSP was run in three phases, during these phases the private seed industry was also promoted to enter into seed industry in India. By the end of

1980's the seed companies with foreign shareholders were allowed to establish in the India (Dadlani 2025).

GMOs and their controversies in India

India still has a conservative approach towards Genetically Modified Organisms (GMOs), to protects its farmers voices. The first GMOs were allowed for the cultivation in 2002, in the cotton crop (Dadlani 2025:1). The GMO cotton seeds or Bt cotton seeds are released by Monsanto in India, through its subsidiary Mahyco. Seed industries and private seed players argue that the GMO cotton alone increased the cotton production in India. However, a study from Kranthi & Stone (2020), showed that GMO cotton adoption alone did not contribute to the increased cotton yield in India. The high yields are attributed to multiple factors like development of irrigation facilities, usage of external inputs, fertilisers, and pest controlling chemicals (ibid.). The crop production cost of GMO cotton increased over the years, and thus the failure of the crops had led to bankruptcy and many farmer suicides in cotton growing regions such as Andhra Pradesh (Gutierrez et al. 2015). While governments and the private companies praise the GMOs as a futuristic solution, a balance of inputs usage and failure of monitoring policy implementation seems to be evident in the case of GMOs in India (Gutierrez et al. 2015; Kranthi & Stone 2020). Even in 2025, only the cotton GMOs are legally allowed for the sale and cultivation in India. Despite this conservative approach there are many reports showing illegal usage of GMOs in Brinjal and other vegetable crops (PIB n.d.). Many instances were reported where the illegal GMOs seeds are seized

Minimum support price

Minium Support Price (MSP) is introduced in India to support farmers in adapting to new technologies. Subsequently, it included cost of cultivation in the MSP to assure a fair price for farmer. This financial inclusion helped the production of incentivised crops (wheat and rice). MSP is also believed to favour few crops and neglect the diversification of crops such as oil seeds, pulses and millets (Aditya et al. 2017). The findings from Aditya et al., showed only about a quarter of farmers are aware of the MSP, and farmers below the poverty line are less aware of MSP. The paper also highlighted the lack of knowledge with farmers about procurement agencies in many states across India and conversely farmers from the states with good procurement mechanism from the government had high awareness. However, the MSP is limited to few crops and primarily focussed on the cereal crops. As per recent update from the MOAgri the MSP is announced for the 22 crops (GOI 2025). The MSP is not provided to all the crops, such as millet varieties and tuber crops grown by the seed saving communities.

2.2.2 Andhra Pradesh

Andhra Pradesh (AP) a “sunrise state”, located in East coast of India, AP is known for its agriculture exports, and fisheries. The total area of the state is 162 975 sq. km out of which 40 % is under agriculture, forests and other uses. Rice is one of the major crops sown in the state, with 32 percentage of annual land coverage. Around 60 percent of population in the state are dependent on agriculture for their livelihood (GOI 2025). The state is divided to administrative blocks called as districts, at present the A.P state has 26 districts. Out of 26 districts five districts are classified into tribal districts (*India State of Forest Report* 2023). AP state leads in production of Banana, Chilli, Oil palm, Cocoa, paddy, maize, pulses and oil seeds among other Indian states (GOAP 2025).

Forests

A 2023 report from Forest Survey of India (FSI) estimated the total forest cover of Andhra Pradesh as 3688220 hectares, which is 22.63 percent of the state area. Tropical dry deciduous forests are the major type of forests in the state followed by dry deciduous scrub type, the both major forest types occupy around 71.36 percentage of forest cover in the state (India State of Forest Report 2023:11).

Economy

The Gross state domestic product (GSDP) is 169.2 billion EUR, the major contributors to the GSDP are the service sector, industries, and agriculture sector. The growth rate of agriculture and allied sectors is 10.70%, for the year 2024-25. States average per capita income is Rs 268653 (2600 Euros) in 2024-25 (GOAP 2025).

Araku region

The present case study CSB is in the Killoguda village, which is near Araku of Alluri Sitarama Raju (ASR) District. The ASR district consists of hilly regions (Eastern ghats), with a highest peak of 1690 m. Araku region is well known as a local tourist place, because of its relatively low temperatures and scenic views. Soils commonly found in the region are red soils, sand clay and loamy soils. The total area of the district is 1.2 million acres of which 0.77 million acres is forest area. A common type of forest in this area is moist and dry deciduous. Average rainfall of the case study region is around 1200 mm-1300 mm per year (GOAP 2022:2; CGWB 2025:6). The region is rich with its biodiversity in flora and fauna. The forests consists of tree species *Anogiessus spp., Mangifera indica, Xylia, Lanneas spp.* (Naidu & Kumar 2016).

The population of tribes makes up about 82.67 percent of the district's population. Agriculture employs about 70 percent of the district's population. Literacy rate of the population is at 48.3 percent in 2011 census (GOAP 2022:2; CGWB 2025:6)

Natural farming movement in Andhra Pradesh

The natural farming movement began in the Andhra Pradesh around 2006, when a public servant introduced the alternative farming methods through agroecology. Initially the alternative farming methods were named as Community Managed Sustainable Agriculture (CMSA). The CMSA was aimed to reduce the pesticide use by alternative sustainable methods. CMSA was implemented from 2004-2014, The CMSA model focussed on empowering the women farmers through SHGs (Khadse & Rosset 2019; *APCNF* n.d.)

In 2016, the Andhra Pradesh government launched an initiative to shift the farming to sustainable practices, and the initiative is named as APZBNF (Zero Budget Natural Farming). The Zero budget in ZBNF implies low input cost but not zero costs. The ZBNF farming promotes the crop growing with natures harmony, its toolkit is introduced by Subhash Palekar in India. The core principles of ZBNF, are aimed to reduce the reliance on external inputs in farming. APZBNF used a similar formal organisation as CMSA model but aimed to introduce natural farming and other agroecological principles.

Initially the APZBNF programme aimed to cover about 0.5 million farmers in 5 years (2016-19) from chemical farming practices to natural farming practices. The initiative is renamed into (Andhra Pradesh Community Natural Farming) APCNF in 2019. (*APCNF* n.d.). APCNF initiative is promoted by NGOs and the organisation Rythu Sadhikara Samstha (RySS). RySS is a not for profit organisation established by the Government of Andhra Pradesh as the sole primary shareholder (GOAP 2014). At present about 0.95 million farmers are adapting natural farming (APCNF) in 0.35 million ha .The state government under the mission "Swarna Andhra 2047" is aiming to enrol 4.1 million farmers, and to bring 19 lakh Ha under APCNF by 2029 (GOAP 2025). The present land under natural farming is about 7 percent, and govt targets to bring 15 percent by 2029, and 40 percent by 2047 (Swarna Andhra 2024:94).

The success of APCMNF adoption is led by the policy implementation, participatory extension activities, and farmer friendly knowledge exchange. The RySS and other NGOs played a crucial role in natural farming adoption in the state. (Bharucha et al. 2020).

Though the natural farming adoption is increasing the large parts of the food and agriculture system remains unsustainable in Andhra Pradesh. The natural farming movement also has its downsides where it does not include all the principles of agroecology (Berger et al. 2025a).

2.3 Climate change and agriculture

The changes in the earth's climate have been a common phenomenon through millions of years, but now human induced changes are rapidly changing the climate beyond the natural equilibrium. Climate change is defined by IPCC as: *"A change in climate that can be quantified using means or statistical tests, and this change should last for a decade or more"* (IPCC 2023*)*. The changes in climate can happen by internal process or through the external process. The externals process can be natural, such as volcanoes, change in solar cycles, or the human induced changes. The recent IPCC report clearly pointed influence of humans on the climate change, and it is projected to be adversely affecting the basic humans needs like food and daily lives like economy and society (IPCC 2023:49). Overall, it is undeniable that humans altered and accelerated the climate change in the last two centuries.

The first scientific literature on climate change can be traced back to the description of Arrhenius. In 1890's, Arrhenius published in his paper "*Influence of the temperature on the carbon acid* ", Arrhenius (1897). His finding began as the pioneering research in the field of Climate change. The next most influential publications were from the 1970s when Manabe & Wetherald (1967), described the radiative equilibrium state. They made an important observation, when the carbon concentration is doubled the temperature is raised by about 2 °C, later the climate change had been a central debate in many scientific fields.

The communities or the places that had done the least damage in the form of emissions are affected disproportionately, this is an ongoing debate between the global nations. The global rich or the 10 percent population contributes the 40 percent of emissions across the globe and people with lowest per capita income, the 50 percent population contributed only abut 15 percent of emissions, (IPCC 2023:44). When the world is divided into the geographical regions, the most GHG emissions for per capita is highest in the North America and the lowest is Africa and the Southern Asia (IPCC 2023:49). The present case study region is in the region will historically less emissions.

2.3.1 Climate change and plants

As every other organism the plants are also influenced by the climate change. A recent study by Anderson et al. (2025), showed the influence of climate change on the plants ability to adapt. The lack of adaptation ability in local plants can lead to extinction. The paper also highlights the bias of climate change and species prediction models, where the locally adapted plant species are neglected in the models. Finally reduction of green-house gases (GHGs) is suggested as a good strategy for genetic conservation (Anderson et al. 2025).

Climate change and agriculture

The climate change will affect agriculture in major regions of the world. The effects can be reducing yields, increase in pest incidence, drought stress, erratic rainfall. A recent study by Hultgren et al. (2025) projected the global crop yields for six major crops till the 2100. The models predicted that the yields of major crops might fall from about 10-40 % by the end of the century. These major crops make up about two-third of the global crop calories. The influence of climate change exists on agriculture, livestock, aquaculture and fisheries, so the impact is clearly on all the food producing communities. Along with those effects, the people health is impacted in the form of diseases, malnutrition, and mental health (IPCC 2023:49).

Climate change had already reduced the yield of major agriculture crops, and with present conditions this might continue to the future. An analysis from Lobell & Di Tommaso (2025), concluded that in last 50 years the yield of major crops reduced by 10 percent due to climate change. Similarly, the future scenarios are looking similar for example the models from Hultgren et al. (2025) estimated for every 1°C rise in mean surface temperature (MST), global calories of 5.5 x 10^{14} kcal are reduced from the output, which is about 120 kcal per person/day. Such a deficit is very huge, when looked at the global level.

2.3.2 Reducing emissions from the agriculture

The present food systems are dependent on the fossil fuel and it is important to reduce the non-renewables usage in food system (Burney 2025). The fossil fuels are used in the food systems at most stages of industrial agriculture. For example, 99% of synthetic Nitrogen fertiliser in the world is produced from the fossil fuels. Similarly, the transportation/logistics consume a lot of fossil fuel. The dependence of the food system on the fossil fuels makes the systems susceptible to price shocks. A little change in fossil fuel price is reflected in the prices of the food prices around the world (IPES 2025). The price shocks in the food systems can bring hunger in many parts of the world. The influence of climate change will lead to change in the food prices. Wealthy nations, have the capacity adapt for price changes whereas the poor nations will suffer from the food prices and shortages (Hultgren et al. 2025). The food systems need to move away from the fossil fuels to reduce part of emissions.

From 1750-2023, the CO_2 concentration in the atmosphere increased by 47 percent and methane by 156 percent, the nitrous oxide however remained similar to the natural patterns. The greenhouse gases emissions from the usage of fossil fuels and industrial purpose is the leading one, followed by the CO_2 released by the changes in the land use and forests (IPCC 2023:43). This highlights the importance of reducing emissions from the agriculture sector.

A zero-emission food system transition cannot be achieved in the coming decades, unless the transition movements start now. Locally adapted strategies across the globe are required to achieve a sustainable food system. The transition of the food systems should not happen overnight and requires a safety net policy. These include decentralised food reserves to avoid the food shortages and shifting to the crops with less impact from the climate change, or the crops which are well adapted to the climate change (Lobell et al. 2008; IPCC 2023:49).

Droughts in India

The historical data from 1880-2020's from Mishra et al. (2019), shows India experienced severe droughts and famines. The droughts are primarily caused by the low soil moisture content. The paper highlights that all the famines during the period 1888-2015, are not caused by the drought, but some are due to the policy negligence. The prime example of this can be The Bengal famine in 1941, that caused 1-3 million deaths by starvation (ibid.). This highlights it is very important for a country with large population to have a strategic plan for droughts. In the era of climate change droughts might become frequent and prolonged.

Mishra et al. (2019) research shows, droughts caused by the soil moisture are linked with the wind patterns in the Pacific Ocean (*The El Niño*). In the last decades the famines are prevented in India, by having public distribution system (PDS), irrigation, and grain storage. If in future, the rainfall pattern is disturbed the irrigation is effected, which directly effects the crops and the agriculture output (Mishra et al. 2019). In a country with a large population and agriculture economy it is important to address the climate change in the forefront of the policies.

2.3.3 Climate models

Climate models are simulations used to quantify changes in energy of the Earth systems. These simulations use complex mathematical equations and evaluate them using supercomputers (NOAA 2025). The climate models divide the Earth's land surface into grids and cells, to carry out modelling for each cell. Models predict the past data, and their output is compared with the observed data, and then models are tuned based on the differences. These fine-tuned models are used for forecasting future climate by using various scenarios (NOAA 2025). Several groups of scientists and institutions form a common future possible outcome; these are called scenarios.

There are many labs and institutes that work to create climate models; this created isolated models. To tackle this problem, in the 1990s, an initiative called the Coupled Model Intercomparison Project (CMIP) began to coordinate the climate models from different countries and help them compare. This initiative helped in standardising the models and running them in phases. The latest phase is CMIP6 which was used in the 2023 IPCC report (Eyring et al. 2016; IPCC 2023).

The scenarios

To evaluate changing climate the global climate models, uses different scenarios or pathways (Moss et al. 2010; van Vuuren et al. 2011; O'Neill et al. 2014) which are described below. This thesis used these pathways in the quantitative data analysis to understand the climate change in Araku region and hence they are described in detail.

Representative concentration pathways (RCPs)

The Representative Concentration Pathways (RCPs) are designed by the scientific community for better climate modelling. These pathways are an output of collaboration between several climate experts and climate research institutes, enabling them for modelling experiments (Moss et al. 2010; van Vuuren et al. 2011). The RCPs used existing literature on land use, greenhouse emissions, and air pollutants to form the pathways. Climate researchers used the plausible radiative forcing values until the end of 2100. There are 4 main RCPs based on the radiative forcing values; RCP2.6, RCP 4.5, RCP6 and RCP8.5. The number in the RCPs indicate the radiative forcing value in W/m^2 by 2100. They also include the CO_2 concentration that could be reached by 2100. These RCPs are used in the Global Climate Models (GCMs) such as CMIP6 (Moss et al. 2010; van Vuuren et al. 2011).

Shared socioeconomic pathways (SSPs)

The Shared socioeconomic pathways (SSPs) are a plausible outcome in the process of human development and evolution of the nature. The SSPs scenarios are designed by using different levels of socioeconomic challenges for adaptation, and mitigation of climate change (O'Neill et al. 2014). A brief overview of SSPs adapted from Riahi et al. (2017) is provided in the Table 1. SSPs use wide range of indicators of economic development, global population growth, urbanisation, policies, energy usage, land usage, human and technology development. For an in-depth information on the key indicators refer (O'Neill et al. 2014; Riahi et al. 2017; *IIASA* 2025). The SSPs and RCPs are used in the climate modelling and sometimes they are used as a combined scenario.

Table 1. A table showing different Shared Socioeconomic Pathways (SSPs) (Adapted from O'Neill et al. 2014; Riahi et al. 2017).

Scenario	Narrative description
SSP1	**A green road** where the world favours to shift in a sustainable way. Investments of education, health driving human well-being. Reducing resources usage, inequality.
SSP2	**A mid road** uneven development, world pushing towards sustainable development. Moderate population growth, income inequality.
SSP3	**A regional rivalry, bumpy, rocky road** where the world has regional conflicts, reduced investments on health and education. Increased economic inequality, and resources usage. Inequal population growth.
SSP4	**Inequality a divided road,** economic divides in the world, inequal development, carbon intensive fuels usage, environmental issues remain.
SSP5	**A fossil fuelled development, The Highway** where rapid technological development, and human capital occur. Exploitation of fossil fuels, human population reaches peak.

2.4 Agroecology

The term "Agroecology" evolved over a century to form its present state. Initially, the word agroecology is used by Bensin in 1920's to describe plant morphology (Gliessman 2014). In the following decades, it was widely used in scientific literature to describe agricultural ecology. In 1980's, agroecology evolved as a farming practices and movement. By the end of 20th century, agroecology transformed into wide discipline and started to focus at food systems level. The wide discipline included dimensions of ecology, social, and economic. Overall, the agroecology started as morphological description, evolved into a discipline, and finally continued as a social movement, and science by 2000's (Wezel et al. 2009; Gliessman 2014).

Agroecology has evolved and is still evolving its nature. Though we cannot define the evolving nature, a short description of agroecology and its principles is required for a basic understanding. The Agroecology can be described with its dimensions, as social movement, a set of agricultural practices, and as a transdisciplinary science (Gliessman 2014; HLPE Report 2019). Researchers see agroecology as an answer for several current issues such in food systems such as sustainability, climate change, nutrition, and social issues.

2.4.1 Food sovereignty

Can people or consumers decide which countries fruits or grains are imported to their plate? For this we need to explore food sovereignty. The food sovereignty provides peoples' rights to choose the food, agriculture, markets, trade policies and to produce their food sustainably. Along with those rights it also deals with many other aspects of the food systems. The La Via Campesina defines food sovereignty as, *"The right of peoples to healthy and culturally appropriate food, produced through ecologically sound and sustainable methods, also their right to define their food and agriculture systems."* (Pimbert 2009; *La Via Campesina* 2025).

Agroecology supports food sovereignty, all forms of knowledge, and local culture. As a package of agricultural practices, it promotes the natural synergies between biological organisms to conserve ecosystems and its services. Agroecology as a science, promotes the studies on food systems ecology, research, education, and action of ecological practices (HLPE Report 2019; Gliessman 2018; 2014; Francis et al. 2003:2014). The further expansion of the agroecology principles was detailed in the theoretical framework of the methods section. The Venn diagram (Figure 1), shows interaction of agroecology, food sovereignty and seed sovereignty based on on the literature used in this study.

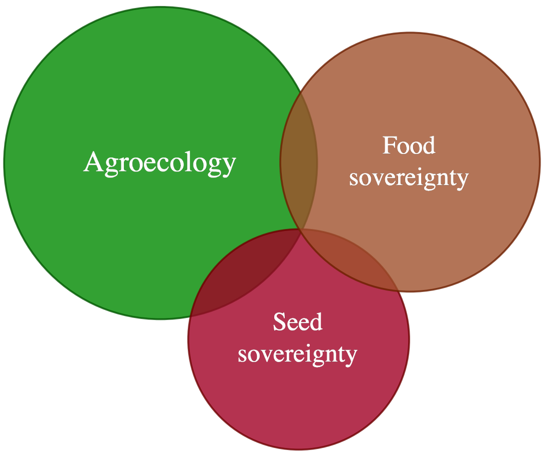

Figure 1. A Venn diagram showing convergence of agroecology, food sovereignty, and seed sovereignty (Self illustration).

2.4.2 Agroecological transition

The transformation from industrial farming practices to the agroecological practices cannot happen overnight, and hence they require a slow transition in the farming practices. Gliessman (2014), described the levels of agroecological transition from farm to the food systems level. There are five levels in the transition, Level 1 starts from improving efficiency of existing industrial inputs used in the farm, Level 2 focusses on replacing the industrial farm inputs with available local alternatives. Level 3 helps in re-designing the agroecosystem by introducing new ecological processes. Level 4 aims to build a bridge between producers and consumers. Level 5 emphasises for a transformation at a food system level that helps aligns with nature and provides an equitable and sustainable farming. For further information readers are directed to (Gliessman 2014:22).

Agroecology always encourages a transdisciplinary approach to solve the sustainability of the food systems. Which means combing the science, social movements and practice to achieve a common goal (Gliessman 2014). This aspect of integrating multiple disciplines is essential for the present thesis work. With these insights from the literature, we now move on to the next section where the research methods used in this project are described.

3. Research methods

This section of the thesis describes the research methods used in this project. The section includes qualitative, quantitative, epistemology, ontology, theoretical framework, choices made during the data collection, and finally the data analysis.

3.1 Data collection

This project used both qualitative and quantitative data collection methods. For qualitative data collection, semi-structured interviews, field visits, participatory observation, informal conversations and photographs were used. The participants of the interviews are selected by using multiple sampling methods. The qualitative data collection for the project is carried between January - April 2025. While the quantitative data is collected from the secondary datasets using the methods described in the next sub-sections.

3.1.1 Qualitative data

The qualitative data is collected through methods such as semi-structured interviews, participatory visits, field visits. The methods and their choice of usage were described in detail below.

Semi-structured interviews

As Robson & McCartan (2016), describes semi-structured interviews as a type of interviews used for qualitative data collection. The semi-structured nature helps the interviewer to be flexible based on the participants response. This nature of flexibility is crucial for this project and hence the qualitative interviews were used. Interview guides with a checklist of questions were prepared prior to the interviews (see Appendix 3). The questionnaire was designed to be flexible offering an adaptation to the participants role.

Sampling methods

Three different sampling methods are used in the study. In the initial phase purposive sampling is used to identify the participants in connection with community seed bank. As the study region is in remote place, unfamiliarity with the region and people the snowball sampling method is used to recruit the participants. This included asking the interviewees to recommend desired participants to the study objectives. Convenience sampling is used because of case study regions terrain and farmers location (Robson & McCartan 2016; Bryman & Bell 2017). Overall, the sampling methods are adapted to the local context, where required

Tables (see Table 3) provide details of the qualitative interviews, and sampling methods used in the study. During the interviews participants were given a choice of two languages Telugu and English. All the participants opted for Telugu, as it being one of the most commonly spoken language in the case study region and native language in the state of Andhra Pradesh (Language atlas of India 2011). Prior to interviews consent is obtained from all the participants, they were given a choice of either a written consent or an oral consent [SLU guideline]. There are people in the study region with Odia as their mother tongue, and to avoid difficulty in translation these people are not interviewed. Interviews were recorded using a hand-held voice recorder. The voice recordings are translated and transcribed to English, by self. Translators were not hired for this project for two reasons firstly, I being a native speaker for the Telugu and secondly due to the sensitive nature of the research.

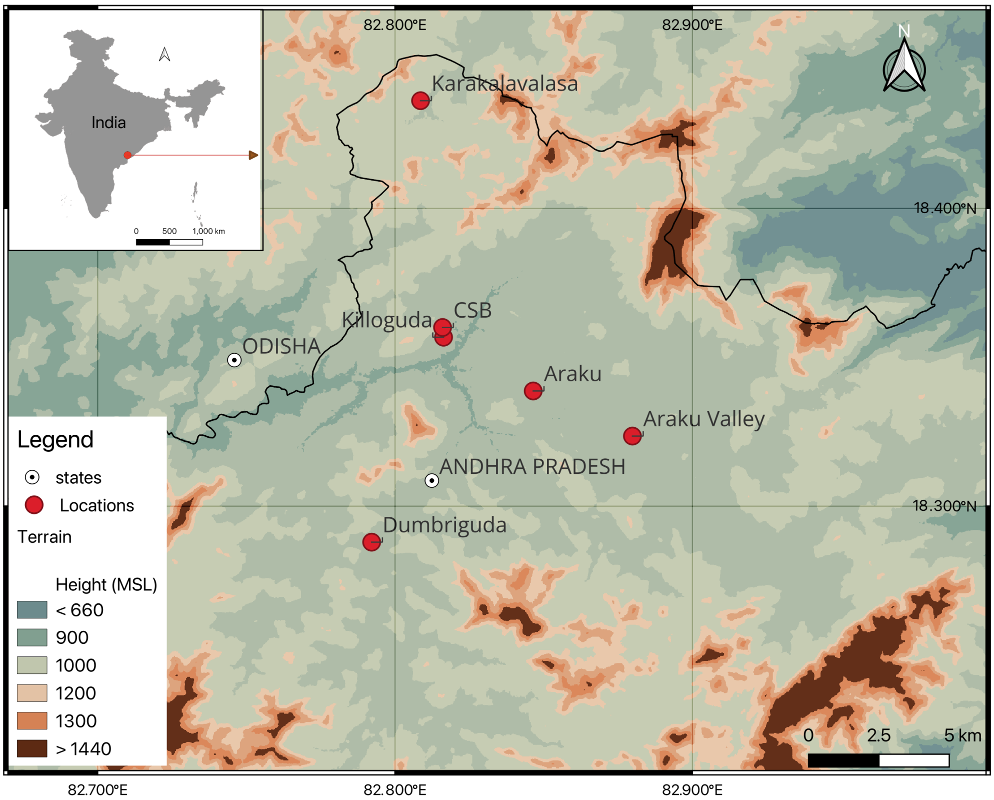

Figure 2. A terrain map of the case study region, red dots indicating key villages and places (Map prepared in QGIS using Mapzen open terrain data)

Visits

To understand the local culture and history, I visited Tribal Museum in Araku (see Table 3). The museum is known for its rich anthropological displays of local culture and traditional works. During the visit local arts were observed and photographed with permission. The Tribal Museum had a seed gallery, where the seeds from the Community seed bank are displayed and food products are sold. There was also an informal conversation with the gallery manager to understand about the seed gallery. The photographs in the seed gallery are obtained with the permission. The data collected from the visit is used for thematic analysis and triangulation of data.

During the primary data collection stage, the interviewees of the Community seed bank invited me to the Roots and Tuber festival. I participated in the Roots and Tubers festival, held in the village Killoguda to understand the local culture around the seeds, farming traditions. The tuber festival is a gathering that bridged the farmers, seed savers, researchers and public. The organisers are well informed about the study and based on their permission, I had the chance for participatory observation during the event and had formal and informal interviews. The interactions during Roots and tubers festival event included farmers, seed savers, attendees, researchers and organisers. The data collected through field notes, participatory observation, photographs, and the formal interviews is used in the thematic analysis section of this study.

Field visits

Field visit to the community seed bank farmers is organised based on the availability of the farmers. The fields which can be reached by the road are chosen, due to the difficulty in the terrain and the weather. As the visits were during the off season - there are only few farmers' fields with crops, so the fields with crops are selected for the data collection. The field visits included participatory observation, informal conversations and photographing. The farmers markets in the Araku region and one in the Visakhapatnam city were visited by me to understand the markets (see Table 3). The farmers markets visits included informal conversations, and photographing. The data collected through the field visits is used in thematic analysis and for the pictorial representation of the farms.

Consent

The participants are informed about the consent form, and their right to withdraw from the study. The SLU guidelines allow usage of both oral and written consent; the former was chosen by all the participants. Oral consent is obtained from all the participants in the study. To avoid the language barrier in the consent process, the written consent is presented and explained in two languages English and Telugu (See Appendix 1, 2). Contact details of the SLU and researcher are shared with the participants, to use their right to withdraw the consent or make any changes. Interview recordings, photography, informal conversations personal and field visits are all made only after obtaining the consent from the participants and organisers of the events. All raw files are stored in encrypted folders.

The tables (see Table 3) provides details about the interviews, participatory visits and other qualitative data collection methods. Participants' ages ranged from 34 – 60 years. All the participants are actively involved in the seed saving, or community seed bank either directly or indirectly. Participants from the organisations RySS, WASSAN, and FES representing diverse roles participated in the study (see Table 2). Details for the participants 8-12 are omitted to protect their identity; these participants are researchers, and public activists working with seeds. Their contributions are included in the analysis, but no identifiable information is disclosed.

Table 2. A table showing the details of the participants, and interviews.

Participant Id	***Role/profession***	***Organisation***	***Interview duration***	***Sampling method used***
1	Farmer	CSB	30 minutes	Purposive
2	Project coordinator	WASSAN	70 minutes	Snowball
3	Project coordinator, Farmer	RYSS	50 minutes	Snowball
4	Resource person	FES	30 minutes	Purposive
5	Farmer	CSB	65 minutes	Convenience
6	Farmer	CSB	40 minutes	Snowball
7	Seed saver, farmer.	Individual	45 minutes	Purposive
8-12	Scientists, farmers, activists.	x	20-30 minutes each	Convenience

Table 3. A table showing the details of the visits, and the data collection methods used during the visits.

S.no	***Visit/event***	***Location***	***Data collection method***
1	Farmers market	Visakhapatnam	Informal conversations & photographs.
2	CSB farmers field visit.	Araku	Participatory observation, photographs.
3	Farmers market	Araku	Informal conversations & photographs.
4	Tribal museum	Araku	Informal conversations & photographs.
5	Roots and tuber festival	Killoguda	Participatory observation, interviews, and photographs.
6	Community seed bank	Killoguda	Participatory observation, interviews, and photographs.

3.1.2 Research philosophy

The study uses a pragmatic epistemology, and a pluralist ontological view. This allows understanding knowledge and reality in different lenses based on the research goals. I believe that there are objective realities that can be measured and subjective social realities that cannot be measured. Thus, a balance between positivist and social constructivism. The dual nature of the realities helps in providing required insights for the research questions. The quantitative methods help in understanding the relationships and patterns for the data. On the other side the qualitative methods help in understanding the people's perceptions and their experiences.

3.1.3 Theoretical framework

As Denver et al. (2014) described, theoretical framework plays a crucial role in determining the direction of the study. This project used principles of Agroecology adapted from HLPE report (2019), and Wezel et al. (2020) as a theoretical framework. The principles were supported by the Socio ecological systems framework (Ostrom 2009; McGinnis & Ostrom 2014) drawing its inspirations from the Governing the Commons (Ostrom 2015).

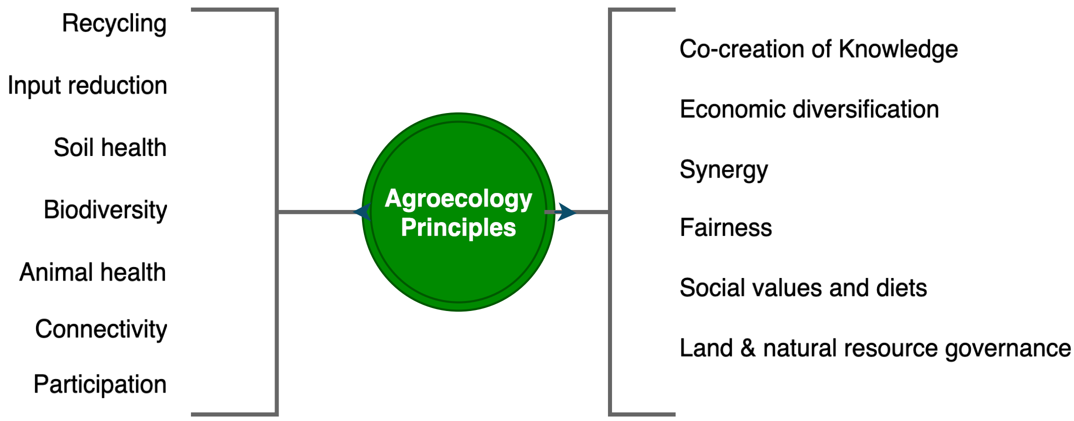

Figure 3. The 13 principles of Agroecology (Adapted from HLPE report (2019), and Wezel et al. (2020)).

The principles of agroecology

The agroecology principles evolved over time and became 13 principles at present (See Figure3). These principles are applied at different levels: field, agroecosystem, and food system level (HLPE report 2019; Wezel et al. 2020). The principles deal with a different levels of agroecological transition suggested by (Gliessman 2014).

The transition of farms from industrial agriculture to a sustainable alternative requires moving away from inputs. The transition happens in a long duration with gradual steps as described in the agroecological transition of the Literature section.

Table 4. Agroecology principles used in the theoretical framework of the study (Adapted from HLPE report 2019; Wezel et al. 2020)

S.no	***Principle***	***Description***
1.	Recycling	Usage of local renewable resources for nutrients and biomass.
2.	Input reduction	Reducing dependence on external inputs for farms
3.	Soil health	Conserving soil organic matter, enhancing biological activity and plant health.
4	Biodiversity	Maintaining diversity at agroecosystem level by enhancing species, functional and genetic diversity.
5	Economic diversification	Diversifying farmers income, focussing on value addition. Promoting financial independence for small-scale farmers.
6	Co-creation of knowledge	Knowledge sharing at horizontal and vertical level. Focussing on local and scientific knowledge.
7	Social values and diet	A healthy diet based on the local culture, and traditions. Promoting gender and social equity.
8	Land and natural resource governance	Promoting local institutions for small scale farmers. Sustainable management of genetic and natural resources.
9	Connectivity	Reducing distance between producer and consumer food chains. Supporting local economies through food systems.
10	Participation	Promoting equal participation of producers and consumers to decide their food systems. Improve local and decentralised governance for food systems.
11	Fairness	Supporting dignified livelihoods, fair trade, fair employment. Protecting intellectual property rights.
12	Synergy	Integrity between agroecosystem components.

3.1.4 Qualitative data analysis

The qualitative data is analysed using the thematic analysis by Braun & and Clarke (2006). Reflexive thematic analysis from the Braun & and Clarke (2006) is refined based on the suggestions from Robson & McCartan (2016). The transcripts are read, and open coding is done for transcripts. The coding of the transcripts is carried out using the Free and Open Source Software (FOSS) Taguette (2025). A total of 611 codes is generated by the initial open coding process. The initial codes are grouped into similar codes and recoding is done. The grouped codes are then categorised into sub-topics and then to sub-themes. The sub-themes are further reduced based on their similarity with each other. Finally, a six broad level themes are generated by the end of reflexive thematic analysis.

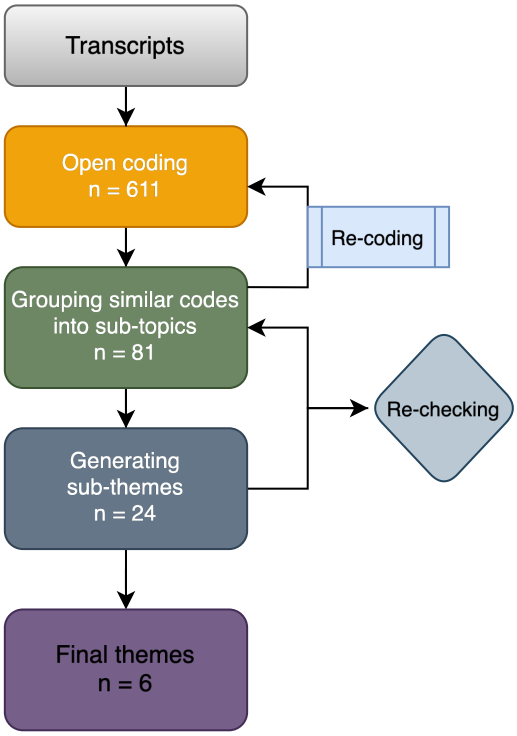

Figure 4. A flow chart showing the thematic analysis process used in the study.

3.2 Quantitative data

This thesis project used the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) data for analysis local climate change. The dataset consists of data from 1950-2100, for temperature and precipitation (Thrasher et al. 2021; 2022). The data is bias corrected by the dataset provider, and it is designed to be used by the academia and researchers, hence this provides a much more reliability. For temperature CanESM5 (Swart et al. 2019) model data is used, and for precipitation FGoalsG3 (Li et al. 2020) model data is used. The models are selected based on the recommendations from the previous studies (Rahman & Pekkat 2024; Vinod & Agilan 2024). The data consists of 5 scenarios with combined SSPs and RCPs: historical, SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5.

Data and processing

The data files (netCDF4) are downloaded by using AWS Cli in Ubuntu 24.10, using Xarray package in Python 3.14 (see Figure 5), the local data is extracted for Araku (Lat Long). The daily data is converted to annual data and statistical tests are done using R, in R studio. (Xarray 2025; VScodium 2025; RStudio 2025)

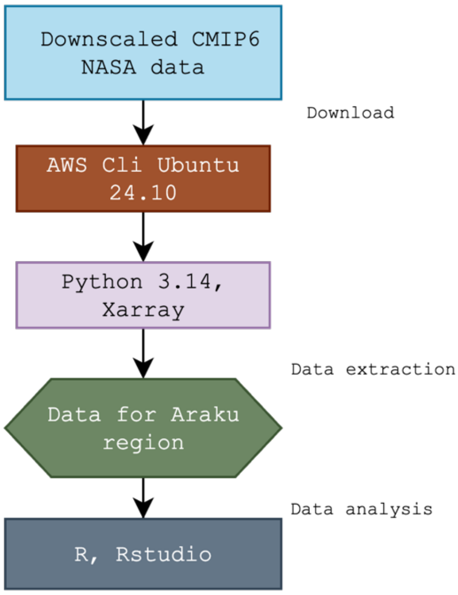

Figure 5. A flowchart describing the processing of climate data used in the study.

Quantitative data analysis

The historical data (1950-2014), and the future scenario data (2014-2100) are analysed using basic descriptive statistics in R. To determine the long-term trends in the data, non-parametric tests: Mann-Kendall, and Sens slope estimation is carried out using packages in R (Sen 1968; Lund et al. 2023; Pohlert 2023; R Core Team 2025). First the raw data is checked for autocorrelation (Lag-1), one time-period (month or year) data influencing another time periods data. This problem is avoided by checking if there is autocorrelation, and then correcting with Variance corrected trend free pre whitening method (VCTFPW) (Lund et al. 2023).

The trends of the data are estimated by the non-parametric test Sens slope, and Mann Kendall test. The scenarios are checked for statistical significance at 95 percentage (p value < 0.05 and Z value > 1.96). Here the Kendall tau (τ) positive value indicates positive trend and negative value indicates negative trend. MK-Z value shows if the trend is significant Z > 1.96, means significant increasing trend, Z < -1.96 indicates significant decreasing trend, and Z = 0, no trend. Sens slope value shows how much the variable value is changing, here it describes change in temperature or rainfall per year (Pohlert 2023; R Core Team 2025). The statistical results from the analysis tables are presented in the tables (see tables 6-9).

The next section provides the results that are an output from the methods explained in this section.

4. Results

This results section presents findings from both qualitative and quantitative data. The qualitative data are analysed through thematic analysis, while the quantitative data is analysed using statistical methods. The result from the qualitative data is presented as six main themes; each theme is further divided into clustered sub-themes. While the quantitative data is presented using charts, and statistical tables connected with text. Overall, this section provides a holistic view of thematic results around the seeds, agriculture, community seed bank, farmers voices, and finally the climate change in the case study region.

The data collected through the qualitative interviews are transcribed and analysed using the thematic analysis. A detailed explanation of the analysis is described in the methods section (see 3.1.4). The codes generated initially are further grouped, into sub-themes and then to the themes. The themes here are generated by using reflexive nature of the theoretical framework and the research questions, where there is similarity across the theme and each theme differs from one another. The table below (see Table 5) presents a brief overview of the thematic analysis and the themes of this study. Further in the results section each theme is explained by using the clustered sub-themes. Sub sections 4.1 through 4.6 address research questions 1 and 2, while sub section 4.7 addresses the research question 3.

Table 5. A table showing the details of main themes, codes and sub themes from the qualitative thematic analysis.

S.No	*Theme*	*Initial Codes*	*Sub-topics*	*Focus of the theme and related research questions (RQ)*
4.1	Seed Systems & Agrobiodiversity	119	15	Biodiversity conservation, seed access, sovereignty (RQ 1)
4.2	Agroecological Practices & Farming Systems	86	17	Natural farming, sustainable farming practises. (RQ 1)
4.3	Socioeconomic Dynamics & Food Security	146	19	Local culture, livelihoods, collective action, social changes (RQ1, 2)
4.4	Institutional Support & Governance	90	11	Collaborations, policies, power relations. (RQ 2)
4.5	Climate Adaptation & Environmental Resources	68	9	Climate change impacts, resilience, and resources management. (RQ 2)
4.6	Knowledge Systems & Capacity Building	102	10	Extension, indigenous knowledge, participatory research. (RQ 1, 2)

4.1 Seed systems and agrobiodiversity conservation.

The theme seed systems and agrobiodiversity forms ground base for the thesis. This theme is introduced in the beginning of the results section making it easy for the readers to get an idea of the seed systems in the region. The discussion of the broad theme investigates clustered categories of sub-themes such as agrobiodiversity conservation, seed access and distribution systems, seed sovereignty, and finally the community seed bank operations. The seed systems in the case study region can be broadly divided into formal and informal/traditional seed systems. The CSB farmers are mostly using the informal seed systems for their seed needs. The community seed bank plays a central role in the seed systems of the case study region farmers by bridging seed access and seed conservation. The analysis revealed that seed systems work as a socio-ecological networks where the seed conservation practices, seed access networks, community governance plays a crucial role for the seed sovereignty.

The participants described the changes in seed systems of the region in the historical context. The CSB farmers and RySS members described that green revolution made the local seed systems to be dependent on the external players, such a government institutions and private seed retailers. Now, the collective community action for seed saving, and seed access through community seed bank (CSB) ensured the agro biodiversity conservation in the region. The natural farming practices in the region are aiding for the seed conservation and sustainable agriculture transition. The below sub sections describe the biodiversity conservation, seed conservation, and seed access systems.

4.1.1 Biodiversity conservation and management

The farming communities in the study area keep the role of conservation as an important task in their agriculture work. This sub-theme investigates the process followed by the communities to save the seeds, protocols, seeds distribution and concerns on genetic erosion of traditional varieties.

Agrobiodiversity conservation

The participating CSB farmers described seed saving as a cultural practice that is ingrained in their farming practices with the practise being passed down from one generation to another. All the farmers in the study saved their own seeds and are not dependent on external seeds. The seeds are conserved both at the CSB farmers household level and centrally in the community seed bank. Conservation efforts began two decades ago when the members of the organisation decided to start a seed festival. The thoughts from the individuals became a collective action through the seed festival, laying the foundation for the community seed bank.

The community seed bank (CSB) now holds around 380 seed varieties, ranging from crops such as rice to rare wild varieties of tuber crops. It used a sophisticated seed conservation mechanisms and is trying to adapt a hybrid model that combines centralised and semi-decentralised seed saving models as seen below.

The seed conservation models

The seed conservation can be divided into two different models in the case study region: centralised and decentralised.

Centralised model:

In the centralised model, seed varieties are stored at the community seed bank headquarters and are distributed to the farmers based on their requests. Every year farmers meet during seed festivals and decide the conservation plans, in consultation with their stakeholders. The CSB brings new varieties from other seed banks/seed savers after assessing the local suitability and then stores them in the central seed bank. Endangered or the rare varieties of seeds are first distributed to a batch of farmers who specialise in conservation of seeds for initial seed lot. Seeds from the initial lots are allocated to others based on performance of the variety seed-lot avalability. (see Figure 6).

Decentralised model:

In the decentralised model, the seeds given by the CSB are stored at farmers place and the CSB facilitates seed exchange between the farmers (see Figure 6). Members of the CSB explained that this decentralised model is adapted in the recent years and being prioritised to reduce the storage workload, and logistic demands of the CSB.

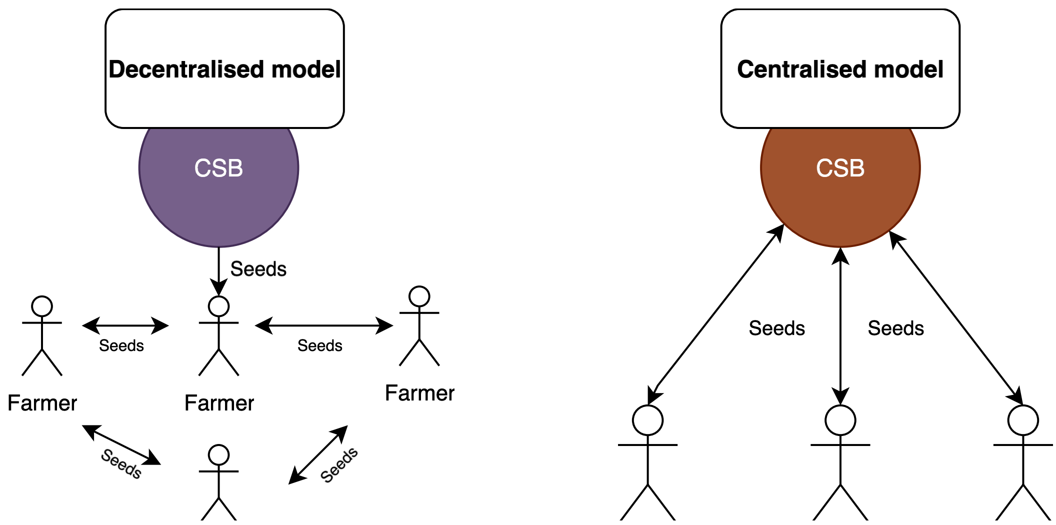

Figure 6. An illustration showing centralised and decentralised seed conservation/distribution models in the study region.

Agrobiodiversity loss

The participants linked their memories to old cultivars that were once popular in their region. Over the decades, many traditional varieties have disappeared, and the CSB farmers, seed savers and RySS staff are worried about this loss. The CSB is helping to preserve the endangered and rare varieties, despite that the CSB farmers and stakeholders in the study (WASSAN, scientists, and FES staff) expressed that there are certain seed varieties which are unique and had already been eroded from the farmers' fields. They attributed the reasons for loss of their local varieties to introduction of green revolution, and promoting varieties released by the universities. The traditional varieties could not compete with those varieties because of their lack in commercial value and having low yields. The eroded varieties include the seeds of crops such as rice and millets. Farmers recalled the lost varieties by their unique colour or morphology of the plants and seeds.

Figure 7. A photograph of Community Seed Bank in Killoguda village, on the left is outside view, on the right is the inside view of CSB.

4.1.2 Seed access and distribution systems

The accessibility of seeds is important for farmers to grow their crops. The farmers described they depend on two different seed systems, formal and informal. They expressed that the informal seed systems play a major role in the study region. Over the decades, the systems have shifted between formal and informal system, and the farming practices tend to favour informal seed systems.

Formal seed systems

Formal seed systems or the seeds systems where seeds are coming from the private companies. The CSB farmers, respondents from RySS and the WASSAN highlighted that those who rely on formal seed systems usually grow vegetable crops such as cauliflower, carrot, chilli pepper and broccoli. These farmers depend on the formal system because they are unable to produce their own seeds for the vegetable crops, they grow.

The RySS team mentioned that farmers practising industrial or chemical farming purchase seeds from private players. They form groups to buy seeds for rice, chillies/peppers, and pulses. The respondents pinned that private sector seeds are usually hybrids which must be purchased every year for good yields. This purchase cycle every year becomes costly on yearly basis.

Informal seed systems

Informal seed systems are important for the local communities and are engrained into their culture. Participants indicated that majority of farmers in the study area are practicing natural farming in which they use traditional seeds, open pollinated varieties and heirloom seeds. The informal seed systems operate on trust between people or within the community. Seeds are shared through seed exchange, and seed loans. In a seed exchange, farmers trade/exchange seeds, and there is no monetary sum involved in the exchange. Seed loans are used between farmers and the CSB, where the farmer borrows seeds from the CSB and after the growing season they deposit twice the quantity of borrowed seeds. The seed requests are submitted by the CSB farmers and other farmers before the agriculture season begins.

Seed-access systems operate similar to the de-centralised conservation model as seen in the Figure 6, in addition to that there are seed savers and farmers out-side of the CSB who can access and save the seeds. While the conservation and seed access systems look similar they differ in their objectives: one focuses exclusively on conservation, while the other focuses on distributing seeds for crops periodically. The CSB farmers are given priority for the seeds during a cropping season, followed by farmers and institutions from other regions. RySS and CSB work closely to cater the seed demand for the dry sowing agriculture, where 18 different types of seed varieties are used. This high demand of seeds in a single season requires collection of seeds from several farmers and facilitating to the required ones.

While the CSB farmers can meet their seed needs there is an exemption for vegetable crops such as carrot, onion, chilli pepper and cruciferous vegetables. CSB farmers are unable to produce seeds for those vegetable crops, and dependent on the external markets. In general, for most food crops (cereals, and millets) farmers are able to meet the seeds demand, either on their own or through the CSB, achieving seed sovereignty.

4.2 Agroecological practises and farming systems

Agroecological practises and farming systems is a vital theme for the present study. This theme encompasses the natural farming methods, adoption, agroecological practices, and farming practices in the study area. The analysis of the data revealed that the natural farming movement is intertwined with the CSB for the seeds. The collaboration between the institutions has led for better adoption of sustainable agriculture practises in the study region. Overall, the theme will be a viewed through an agroecology lens.

4.2.1 Natural farming adoption

Natural farming represents an influential agroecological approach in the region. The natural farming method aims to reduce usage of external inputs in agriculture. This sub-theme explores the natural farming history, adoption, practices and challenges of natural farming in the study region.

Natural farming in the region

The natural farming was introduced in the region in 2017. The initial project was named as community managed natural farming (CMNF), which is implemented by the NGOs such as WASSAN. Later, the agriculture department of Andhra Pradesh renamed the project into Zero Budget Natural Farming (ZBNF), and finally to APCMNF. The natural farming in the region is now encouraged by the RySS through a formal system, backed by the agriculture department.

Natural farming adoption

In the study region, RySS promotes the natural farming program through a formal system (APCMNF). Field personnel conduct awareness campaigns in the villages and educate the farmers about the shift of farming practises. Personnel from the RySS, WASSAN, and CSB mentioned that about 85-90 percentage of the farmers in the CSB region are part of the natural farming movement. The RySS staff added that they aim to achieve a saturation of natural farming in the next five years, despite the challenges they face with farmers' transition. All the participating farmers in the study practice natural farming (see Figure 8). Most of the farmers in this study and region being small scale farmers and their transitioning to to natural farming happened in the last decade. The extensive network of the RySS and mutual collaboration with CSB had encouraged to draw more farmers into the natural farming practise. The education sessions by the RySS include the practical preparation of the pest control solutions and training the farmers.

The shift of farmers from industrial farming to the natural farming was promoted by several factors. Firstly, the economic factor played a crucial role in transition, natural farming methods used fewer external inputs and relied on the farmer made solutions and traditional seeds. The reduction in reliance on external inputs saved the crop cultivation cost. Secondly, external factors such as farmer-to-farmer interaction, rising input prices (fertilisers, seeds, and pesticides). Finally, farmers realising the benefits of natural farming for soil health and human health, promoted the transition of many farmers into the natural farming.

Figure 8. A figure showing fields of CSB farmers, a) Finger millet (Guli-ragi) cultivation in natural farming method. b) A rice field in the near Killoguda village.

A successful case of finger millet cultivation adopted through natural farming became a regional role model. Farmers in the area pioneered the cultivation of the finger millet in a method called “Guli ragi method”. The guli cultivation of finger millet yielded twice (200%) compared to the chemical/industrial farming method. The Guli method uses only 3 kg of seed per acre, which is 70 percent lesser than normal cultivation method. This method is now widespread in the state of Andhra Pradesh. The CSB and the NGO’s facilitated the initial training for the farmers, leading to successful finger millet cultivation through participatory research.

4.2.2 Natural farming methods and challenges.

Natural farming methods/practices

Farmers adapted the natural farming practices to their local conditions and raw material availability. Some of the practices used in the natural farming include, seed treatments, bio fertilisers, agronomic practices. For example, before sowing the seeds are treated with biological seed treatment called Beejamrutham, which is believed to introduce beneficial microbes and protect the seeds during germination. Pest control strategies include preparation of farm made solutions called Kashyaams. For fertilising the soil, a fermented solution is used. There are two forms: Jeevamrutham, a biological solution made with fermented farm waste, and soil inoculum. Ghana Jeevamrutham, a solid version which is made from farm manure and used during the crop growth stage.

Challenges in natural farming

As every practise has its own challenges the natural farming faces several challenges. The challenges are identified from all the participants and are grouped into overall problems. These include expensive manual labour, labour intensive activities, change in social dynamics, and rise in cost of raw ingredients. The farm labours availability seems to be the most common challenge because the natural farming involves use of manual work, it is important to have labour available during farm operations, and at affordable wages. All the participants agreed that farm labour availability as a challenge for the natural farming. However, the RySS staff added that including small hand-held equipment such as sprayers, pruners, and weeders can reduce the burden of physical labour in certain areas of natural farming.

4.2.3 Traditional farming systems and transition

The CSB farmers and stakeholders mentioned that previously there are other traditional farming systems such as “Podu vyavasayam” or shifting cultivation, where the patches of land are burnt and used for the cultivation. Farmers noted that the practice used to be a common thing in the past, but after the introduction of joint community forest management began, the shifting cultivation was stopped. The efforts from the CSB in farmers education along with stakeholders helped in stopping this practice and saving the forests This also acted as a catalyst to protect the forests and reforestation planning. These protected forests now hold wild edible diversity, which now CSB, its farmers and other research institutions are trying to document and preserve.

4.3 Socio-economic dynamics and food security

Socio economic dynamics and food security constitute the second-largest theme. This theme captures the broad socio-cultural, economic and food security arrangements in the region that shape local livelihoods. The cultural and social dynamics play a crucial role for the community seed bank and the sustainable agriculture of the area. The practice of seed conservation and sustainable agriculture is closely tied with the local culture and the economic aspects of the communities.

The economic condition of the people changed over the time, once the subsistence farming was very common in the area. Now, the farmers are self-sufficient with their produce for some crops and are also cultivating commercial crops like Coffee, black pepper and other spices. Market access and the transportation facilities played a crucial role for this transformation. Similarly, food security was once a major question in the region, but the present condition of the region improved by the government initiatives and efforts by non-profit organisations. The CSB is also playing a crucial role for food security by bridging different institutions and creating a collaborative environment.

4.3.1 Seed festivals and social changes

Cultural and social dynamics

The CSB farmers and the RySS staff expressed that agricultural practices in the study region are deeply embedded in their local culture systems, that combines local rituals, and social celebrations. The traditional agriculture calendar aligns with the local seasons, and the agriculture festivals are part of their cultural celebrations. Local festivals are closely intertwined with the community's culture and seeds. Villagers named seed festival as an important celebration in their region. Each year, farmers pack their seeds in seed baskets and keep the baskets near the village deity. The seed baskets remain near the deity until it is time to sow the seeds. Once the seeds are sown, men will stay away from the farm work and will rest in forest for few days. The farmers said this tradition of treating seeds as a deity is a common practice followed from their ancestors. Another festival that is linked with agriculture is "Sankranthi", it is celebrated to mark the harvest of grains by the farmers. Sankranthi is celebrated in January, when the agriculture season ends and harvest reaches the homes of farmers.

4.3.2 Collective action and public engagement

Collective action mechanisms include the formal organisation of the local farmers through Farmers producer's organisation (FPO), green banks, CSB, as well as informal groupings that facilitate resources sharing, knowledge exchange, and other collaborative activities. The community seed bank initiative began as a collective opinion of the local people to save the local cultivars. During initial days of the CSB, people used to volunteer for social cause. Local village committees with elder people were setup to identify the varieties and display them in the seed festival. The seed festival, which began as a small initiative now attracts more than 1000 participants from various locations in India. Its audience include farmers, scientists, students, community leaders and activists. This creates a platform for knowledge sharing and displaying the seed diversity to common public.

Figure 9. A picture showing the social celebrations in the seeds festival, a) People gathering to treat seeds as deity (left), b) A traditional dhimsa dance performance (right).

Local farmers usually live with their nearby families in the villages, and these close families help each other for the agricultural tasks. Farmers recall that villagers used to work in each other's fields, creating a strong sense of community. The payments are rather a non-monetary type, where the farmers help each other instead of paying cash. However, CSB farmers have mentioned that these close relations and sense of community are fading in the recent times, and the rural families are becoming individualistic.

There are other collective initiatives along with the CSB. For example, previously there used to be green banks exclusively to supply grains for local villagers, and this initiative was managed by CSB members, eventually the initiative faded away and replaced by the public distribution of grains by local governments. Recently, in last five years farmers formed a Farmers Producer Organisation (FPO), so they could collectively sell their agriculture outputs directly to consumers or middleman. These FPOs are registered under the formal system as an organisation. Similarly, there is Joint Forest management committees, where the local people protect and govern the community forests and the resources within them. In several ways the local CSB farmers are engaging in collective action to protect and manage their shared resources.

4.3.3 Economic and Food-Security dimension

Food security and availability in the region have changed over the decades. Initiatives from the government and the NGOs have helped stabilise food availability in the study area.

Food security in the past

Participants (CSB farmers, RySS and WASSAN staff) highlighted the contrast between past and present food availability. They said that, in past there used to be lack of food during the summer season, and people are relied on wild resources such as fruits, and tubers in the forests. Those wild resources served as an important source of energy throughout the summer season. Participants pointed that it used to be difficult to obtain food during crop failures and drought seasons. The local food dishes made from the millets used to be staple for the farming community. Rice supplied by the government through public distribution system (PDS), played an important role in ensuring the villagers food security. In addition to the PDS, the green banks also ensured the food security for both farmers and villagers.

Food security in the present

Food systems in the region have transformed over decades, but still some of the old elements remained the same. The subsistence farming is an important practice in the region, where the farmers grow crops and keep the harvest for their self-consumption. This practice of storing grains is a crucial step for them ensuring food security in the farming community. Even today, the public distribution system (PDS) of rice and other essential food commodities continues to operate in the region. The natural farming method by RySS is promoting the kitchen gardens at people's homes, and the Anytime crops models (ATM), to ensure adequate food for farming family's self-consumption. The seeds needed for these models are supplied through a collaboration between RySS and CSB, helping meet food requirements at farmers household level.

Transition in diet

The participants noted that millets and millet-based dishes were once a common diet in the study region. Their wide availability and less rice cultivation had favoured the traditional millet-centric diet in the past. Today, however locals adapted to a rice-based diet as their staple, and this is much more common among the younger generation. There is an opinion from the farmers to shift back to a traditional millet-based diet by developing new value-added millet products from their traditional heirloom seeds.

Economic dimensions and challenges

Economic factors shape agriculture decisions and daily lives of people. Participants described economic challenges they face and how they could be financially supported by government or other organisations. The community seed bank does not receive direct support from the government, and such support will ensure building proper storage facilities and help up-skill CSB members. Individual seed savers expressed similar concerns: modern storage systems are expensive, and they cannot to buy new equipment without external support.

Natural farming involves a lot of individual manual labour, as previously discussed the region is already facing a labour shortage in the agriculture sector. CSB farmers seeking support in the form of subsidies to purchase small farm equipment such as mini-tillers and harvesting equipment which can be used for their natural farming practices. The CSB farmers and stakholders (RySS, WASSAN personell) noted that Minimum Support Price (MSP) is not available for all the crops they grow. This is particularly mentioned as an issue for the crops such as barnyard millet, foxtail millet, and little millet. Lack of MSP meant fluctuating prices in the market. However, the crops such as maize, finger milletand Pearl) and rice do have an MSP ensuring a stable price.

Social changes

The CSB farmers and the stakeholders expressed that employment patterns are changing in rural regions. Many people are migrating from their villages to cities to work in the service or industrial sector. As a result, farmers observe that the shared agriculture responsibilities have diminished, and there is a lack of people's interest towards agriculture work which, in turn is creating a labour shortage. Participants observed that the young generation is reluctant to enter the agriculture sector. The lack of participation threatens the traditional agriculture knowledge transfer, and many young people are unaware of the seed varieties, morphology and cultivation knowledge. In addressing this gap, farmers recommend the inclusion of teaching agriculture in formal education, which could create interest in young generation and train them for skills needed for sustainable agriculture.

These changes are particularly important for the agroecological transition and for the future of the CSB. If the youth do not participate in the future operations of CSB and migrate to other areas the seed systems will change in the study area. This might also impact the natural farming transition in the region. All the participants in the study expressed concern about the next generation not entering agriculture. This concern goes beyond knowledge systems, as the region's food security and sovereignty are dependent on the local farming practices, and a lack of youth might lead to drastic changes in the local food systems.

4.4 Institutional support and governance

During the thematic analysis, institutional support and governance emerged as a key theme that supported seed sovereignty and agroecological transition in the study area. The current success of the community seed bank can be attributed to the constructive collaboration between multiple institutions. Institutional support and governance include formal and informal institutions, policies, and governance that shaped local seed systems and their management. This theme highlights how the institutions are essential for supporting seed systems, advancing agroecological transitions and promoting seed sovereignty.

4.4.1 Multi-stake holder collaboration

Muti-stakeholder collaboration was mentioned by participants as a critical factor for the success of various missions of the CSB. These programs include natural farming transition and seed sovereignty movement in the study area. Effective collaborations helped build institutions with shared goals, bridging knowledge gaps, and empowering farmers. Much work remains to be done in the space of institutional collaborations.

Institutional collaboration

The study participants identified the institutional collaboration and related events as a solution that helped address their complex issues. For example, these issues include seed conservation and distribution, which cannot be achieved by the CSB acting as a solo institution. Thus, collaboration with the other formal institutes had mutually benefitted the farmers and vice versa. An example can be drawn from the region where the farmers are assured of their rights to register the varieties under their names, when they deposit local germplasm in formal gene banks. The gene bank is benefitted by the conservation measures and germplasm collection. Previous collaborations had helped with deposition and registration of around 40 farmers varieties in the NBPGR, New Delhi, which is a win-win situation for farmers and gene-bank.

The natural farming movement in the area is promoted by multiple stakeholders: WASSAN, RySS, Naandi, Velugu foundation, FES, and others. The participants said the mutual sharing of the knowledge between the institutes has helped in better assessment of the farmer's needs.

Events such as the seed festival, and tubers festival organised by the CSB, and the local farmers are helping in create new partnerships with formal and informal institutions. The participants said it is important to build new collaborations for conserving the local diversity, and equally important to utilise the conserved biodiversity. For example, participants from the formal institutions highlighted the importance of evaluating the local diversity to improve the wild tubers by studying cooking quality, breeding new varieties, scientific evaluation of nutritional profiles, and educating farmers about crop cultivation. Some other such collaborations are mentioned in the food security sub-theme.

Future collaborations

The community seed bank is looking to create new partnerships. These partnerships are aimed at bringing new formal research institutions to help farmers in the areas of food sovereignty and agrobiodiversity conservation. Some of the planned initiatives include involving school and college children in the farming activities as a part of their formal education.

For the IPR, patent rights or GI (Geographical Indication), the CSB is trying to create partnerships by using technical advisories from NGOs such as a WASSAN, FES. The participants in the tuber festival also welcomed the future co-operation between CSB and formal institutions for conservation of local wild-tuber diversity. The future plans include bringing wild tubers into cultivation in the region, obtaining farmers' rights, the local biodiversity register update and educating farmers about the nutrition of tubers.

4.4.2 Institutional gaps

The analysis revealed institutional gaps in the support from government agencies. The gaps identified are in the form of policy-implementation failures or the ineffectiveness of those policies.

Institutional gaps in the past

The participating farmers said that their voices were not heard by the government agencies in the past. For example, in the 1980s, the government had promoted use of fertilizers and university-released seed varieties in the region. The Integrated Tribal Development Agency (ITDA) is responsible for promoting industrial agriculture in the tribal region. Although, the region lacked basic transport facilities, government institutions expected farmers to carry the fertilizer bags for 20-30 km to their homes. Initially, farmers did not adapt to the external inputs promoted by the agencies; over time they slowly began adopting industrial farming practices and inputs. Farmers describe this change as a significant departure from their traditional agricultural practices.

Similarly, another example of neglect emerged in the conversation: the seed festival organised by the community seed bank and farmers was neglected by the Integrated Tribal Development Agency (ITDA) in the initial years. The farmers felt that the ITDA did not recognize the seed festival until it became well known through the news agencies. In contrary to the past, the ITDA is now also promoting the seed festival.

Finally, the agriculture department, which represented the formal agricultural system, had neglected the traditional seeds and seed systems. Traditional seeds were not brought into mainstream agriculture and research. There had been no training for farmers on seed conservation and preservation through the formal agriculture system.

4.4.3 Policy frameworks and regulation.

Policy frameworks and regulations shape local institutions, seed systems and the way people save seeds. Similarly, national and regional policies play an important role in determining the legality of seed systems. The analysis has shown that seed regulations should be changed to favour seed savers.

Seed rights and regulations.

The formal and informal seed systems in India are governed by seed legislation. The Seeds Act and the PPVFR Act constitute the core policies in the legislation. Participants in the study have mentioned the ineffectiveness of the PPVFR Act, where the local germplasm documentation and farmer rights recognition are neglected. There is also the opinion that PPVFR Act favours the formal seed system over the informal seed networks. Some participants expressed the policies favour the giant seed companies, creating excessive control of the private seed companies on the seed systems. The participants are not interested in speaking about the policy because they feel they are not part of decision-making process, and their ground-level opinions are not considered while designing the policies for them. This is different with the farmers roles in the CSB. The people who are working in the main roles of the CSB are aware of the regulations around the seeds, while the other farmers are not completely aware of the regulations.

4.5 Climate adaptation and environmental resources.

Climate adaptation and environmental resources represent the smallest theme based on code frequencies. However, climate concerns are an important issue for farmers and the organisations/institutions working on the ground. This theme discusses the impacts of climate change as perceived by study region farmers. Participants described climate change as a threat to agriculture and their daily lives. Their experiences are described in detail in the present section. This theme provides an overview of perceptions of the local farmers and stakeholders on climate change. These perceptions include impacts of climate change, local resource management and adaptation strategies.

4.5.1 Local climate change and its impact

Climate change and its impact emerged as a key discussion in the present theme, reflecting the shift in the study region's environment. Participants described changes in weather patterns by comparing the current weather trends with their childhood memories.

CSB farmers and stakeholders (RySS, WASSAN, and FES personnel) described that local weather patterns used to be predictable. There used to be rains before the monsoon season arrived, specifically rains in April and May. The monsoon rains began in June and continued until October. Winters were cold and lasted till the February. All the participants expressed that the weather patterns had changed in the recent decades. They observed several key patterns, including changes in monsoon arrival, erratic rainfall, forest fires and increased heatwaves. The monsoon rains, which used to arrive in the initial weeks of June, had been shifting until July. Rainfall was erratic, with excessive precipitation in a single day and followed by dry days for weeks.

The changing climate and weather patterns had been impacting locals in several ways. Erratic rainfall and dry spell in the region had reduced crop yields and made harvesting difficult. Due to changes in rainfall, irrigation projects dependent on the water streams failed. The local streams that had fed the irrigation projects and local villages changed their flow patterns, disrupting the lives of locals, who were dependent on them. Furthermore, the sudden outburst of rain had caused soil erosion and led to landslides in some villages. One local village was displaced due to the landslides and additional risk of erosion. The participants expressed the human induced factors are the primary cause for the climate change in the region, and the people's mindsets should change towards shifting trends in climate.

4.5.2 Adaptations to climate change

CSB farmers experiencing climate change started to adapt their farming practices. Adaptations such as dry sowing, shifting planting dates, and choosing resilient cultivars were used by the farmers. These practices are used in the crops such as rice, millets (finger millet, pearl millet, and barnyard millet), pulses (pigeon pea, cow pea, and lentils). The most common strategy used by the local farmers is dry sowing of crops. The dry sowing is divided into two different types: The Rabi dry sowing (RDS) and Pre-monsoon dry sowing (PMDS) based on the season following the sowing time. Participants from RySS, FES and WASSAN reported (respondents 2,3 &4) that PMDS technique was widely used by the farmers. It encourages reliance on multiple crops instead of mono-cropping, where 18 different types of seeds are used. Before sowing, seeds are treated with a farmer-made solution called "Beejamrutham". The seeds are then sown in the ploughed land before the onset of monsoon rains. This time-adapted sowing helped in higher germination rate of seeds.

The choice of seed varieties used for crops (rice, finger millet, pearl millet and other millets/cereals) has helped farmers adapt to local weather changes. Based on farmers indigenous knowledge, they are using long-duration varieties to escape rainfall during the harvest season. This ensures a safe crop harvest without any moisture problems. Similarly, the indigenous varieties with drought tolerance and adaptability are being used for cropping. Farmers explained that their indigenous seeds are better suitable for the changing weather conditions, compared to the seeds from the private players.

4.5.3 Environmental resources and management

There is a strong consensus among participants regarding the way their community managed the forests. The local forests had been heavily exploited through excessive logging and resource depletion. However, introduction of the Joint Forest Management (JFM) had promoted collective action and helped save the remaining forest patches. The JFM also promoted afforestation and environmental awareness campaigns about forests and resource conservation. These activities had helped increase forest cover slightly over the last two decades.The increase in coffee and black pepper cultivation area had helped in the increase in the forest cover as they require shade and support trees for cultivation.

4.6 Knowledge systems and capacity building

Capacity building plays an essential role for agriculture community by enhancing their crop cultivation practices and agriculture knowledge. Several institutions are working in the region for the farmers capacity building. Despite the efforts, analysis identified gaps in extension activities and farmers' expectations. This theme highlights the challenges and needs for capacity building and farmer training. This theme is particularly important in addressing agroecological practices and the support systems that help CSB farmers during the transitioning of their farming practices (research questions 1, 2).

4.6.1 Participatory learning and research.

Participatory approach of research, and learning serves as a bridge between the farmers, researchers, and research institutions. By encouraging a collaborative environment, it enables farmers share their insights directly with researchers.

Participatory research

The participatory research had already shown a successful case in the region. The Guli ragi method of finger millet cultivation, which was introduced as a collaborative approach, succeeded in the region. Though the formal research institutions did not show interest in the method, the WASSAN helped in spreading the word. This awareness led to the creation of farmers-field trails at a nearby research station. Eventually, the collaboration expanded, by establishing trail plots for other crops in the farmers' fields.

Apart from the formal research institutions, the NGOs have been closely working with the farmers to develop cultivation methods and optimising agronomic factors in natural farming. Some of the approaches include participatory area specific breeding using traditional seeds, gravity-based irrigation and micro irrigation models. The organisations are trying to adapt the well-known models to the local conditions, using the local data and farmers' feedback.

The participants in the study highlighted that there is a great need for the participatory research in multiple areas. The gaps identified for the wild tubers research include, nutritional profile, wild diversity evaluation, cooking methods The panel discussions between scientists and farmers, in the Tuber festival also pointed the need for participatory research by formal national research institutions. The formal institutes had neglected the local traditional varieties and the farmer centric research.

4.6.2 Traditional and indigenous knowledge systems

Traditional and indigenous knowledge has been accumulated over generations and forms a base for the local culture, agriculture and systems. The findings revealed the usage of many indigenous techniques for seed storage at farmer level and at the CSB level.

Indigenous knowledge and seed storage

Seed savers in the study region use different indigenous storage methods based on knowledge passed down from their ancestors. For example, seeds are stored in the mud pots and ash is mixed with seeds to keep the seeds viable for longer periods. In a similar way maize cobs are hung near the stove region so that the repels pests away. The seeds of Pigeon pea are stored in a traditional storage structure called "Daaku", similar techniques are used to preserve the seeds in the CSBs main location.

The farmers explained the seed storage techniques, crop cultivation methods, and the local varieties features are shared from one generation to another. Fathers used to share the knowledge to their next generation during the evening gatherings near bon-fires. Similarly, people used to meet in gatherings called "Rachabanda" to share knowledge among themselves. In recent days these traditional knowledge sharing meetings have become non-existent.

4.6.3 Extension and capacity building

Extension and capacity building activities include the processes through which the agriculture knowledge, technology, information are transmitted and adapted by the farmers. The extensions activities are carried by the formal system (RySS, Agriculture department), and NGOs in the study region. The awareness activities by the RySS and CSB played an important role in natural farming adoption, and seed conservation. The CSB co-ordinated the activities with other NGOs and disseminated the knowledge to farmers. People working in the CSB highlighted that there is requirement to up-skill and train both farmers and CSB member staff. The training needed in the areas of technical knowledge, seed preservation techniques. There is a need for awareness among local people about wild diversity, cooking methods and their nutritional profile. Similarly, the young generation, in the schools should be encouraged to participate in the seed bank activities.

4.7 Quantitative data

This thesis analysed two primary climate data variables: temperature and precipitation addressing the research question 3. In brief, the temperature data showed a warming trend in the past and is continuing the same for the future. Precipitation data did not show any significant trends for the past data and most of the future scenarios. Overall, this sub-section presents the findings from the quantitative climate data analysis.

4.7.1 Temperature

The extracted SSP scenarios from the CMIP6 data is analysed using the Mann-Kendall and Sen's slope analysis. The Mann Kendall test is applied to the data of all the SSPs scenarios and historical data, in all the scenarios the p-values is less the 0.05, indicating a statistically significant trend. The analysis of historical temperature data (1950-2014) exhibited a statistically significant warming trend. Historical temperature data analysed using the variance corrected trend free pre whitening method (VCTFPM). The Sens slope estimate showed a warming rate of 0.0151 °C/year, with a statistically significant (p value < 0.05, $\tau = 1$)

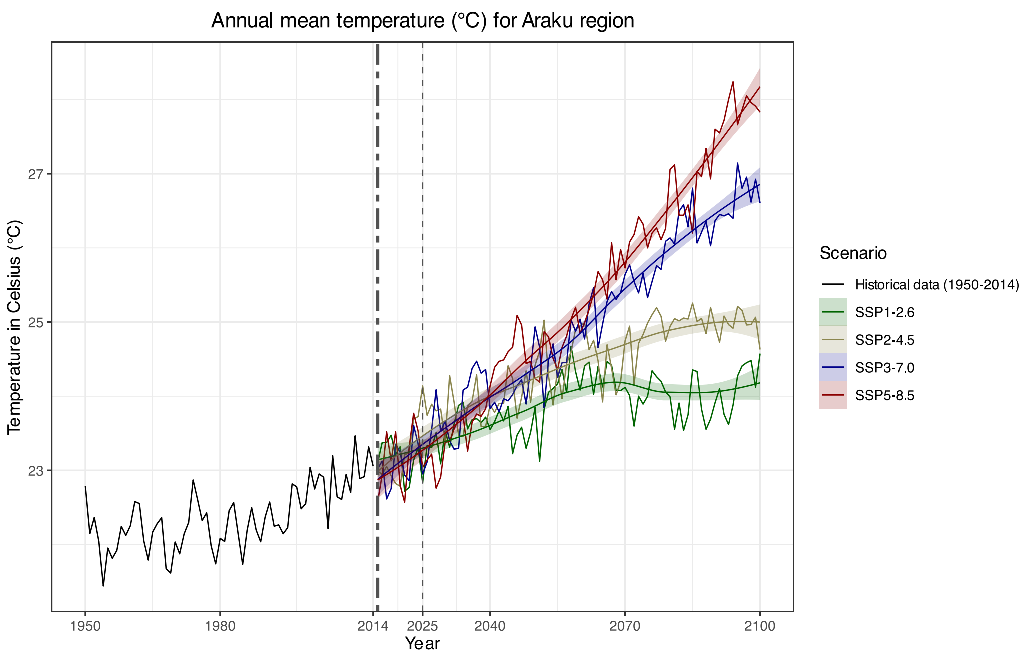

Figure 10. A graph showing the CMIP6 projections of annual mean surface air temperature for the Araku region.

The projected temperature (2015-2100) data showed a statistically significant upward trend across all emission scenarios. In the optimistic scenario SSP1-2.6, the warming rate is 0.0124 °C/ year. The SSP2-4.5 had warming rate of 0.0232 °C/ year. While the mid ground scenario SSP3-7.0 showed a 0.0483 °C/ year (See

Figure 10). The extreme emission scenario (SSP5-8.5) showed a highest warming trend of 0.0633 °C/ year. The trend values of all the SSP scenarios are statistically significant ($p < 0.05$) as seen in the Table 6. All the emissions scenarios exhibited a warming trend, and the warming trend raised with high emissions scenarios.

Table 6. A table showing results from the statistical tests of temperature data.

Data	***Scenario***	***Sens slope***	***Lag-1 autocorrelation***	***MK Z value***	***p-value (p)***	***Kendall's tau (τ)***
Historical	*Historical data*	0.0151	0.61	5.69	< 0.001	1
Projected	*SSP1-2.6*	0.0124	0.7293	8.88	< 0.001	0.64
	SSP2-4.5	0.0232	0.8499	9.21	< 0.001	1.00
	SSP3-7.0	0.0483	0.9352	16.34	< 0.001	0.47
	SSP5-8.5	0.0633	0.9455	11.99	< 0.001	0.93

The average temperatures for periods ranging from 20-30 years is provided in the Table 7. When compared with the baseline of 1950-1980, by the end of the 21^{st} century the warming is expected to cross 1.5 °C. The increase in the temperatures by 2100 are 1.87 °C, 2.81 °C, 4.09 °C, 4.86 °C with respect to the SSP scenarios (SSP1, SSP2, SSP3, SSP5) as listed in the Table 7.

Table 7. A table showing the average temperatures for different time periods in Araku region.

Time periods	***Historical data*** (°C)	***SSP1-2.6*** (°C)	***SSP2-4.5*** (°C)	***SSP3-7.0*** (°C)	***SSP5-8.5*** (°C)
1950-1980	22.15°	X	X	X	X
1961-1990	22.19	X	X	X	X
1981-2010	22.53	X	X	X	X
1995-2014 (AR6)	22.82	X	X	X	X
2011-2040	X	23.38	23.56	23.51	23.34
2041-2070	X	23.98	24.35	24.64	24.95
2071-2100	X	24.01	24.96	26.23	27.01

4.7.2 Precipitation

The analysis of historical precipitation data (1950-2014) showed no statistically significant trends in the analysis. Historical precipitation data also did not exhibit any autocorrelation. The Sens slope value indicated an increase of rainfall by over 1.65 mm/year; however, the increase is not significant (p value = 0.333). Overall, the historical precipitation data did not show a monotonic trend (see Table 8, Figure 11).

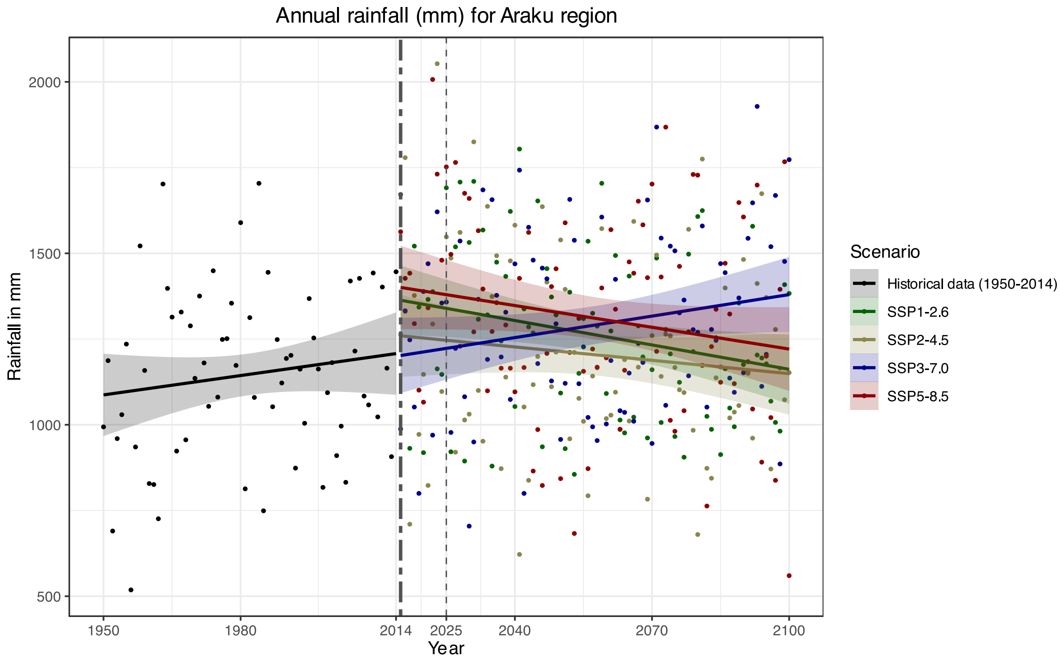

Figure 11. A graph showing the CMIP6 projections of annual precipitation for the Araku region.

The projected rainfall data (2015-2100), under various emissions scenarios showed a mixed trend, in the analysis. The SSP1-2.6 scenario exhibited a decreasing of -2.62 mm/year, with a statistically significant downward trend ($p = 0.024$, $\tau = -0.17$). The other emission scenarios SSP2-4.5, and SSP5-8.5 had decreasing trend, but the trend is statistically not significant. The SSP3-7.0 showed an increasing trend, yet the rise was not significant. Overall, the high emission scenarios did not exhibit any statistically significant trends for precipitation data.

Table 8. A table showing results from the statistical tests of precipitation data.

Data	Scenario	Sens slope	Lag-1 autocorrelation	MK Z value	p-value (p)	Kendalls tau (τ)
Historical	*Historical data*	1.65	-0.18	0.97	0.333	0.08
Projected	*SSP1-2.6*	-2.62	-0.12	-2.26	0.024	-0.17
	SSP2-4.5	-0.84	-0.13	-0.66	0.507	-0.05
	SSP3-7.0	1.93	-0.04	1.59	0.112	0.12
	SSP5-8.5	-2.03	0.11	-1.5	0.133	-0.11

The average rainfall in the region from 1995-2014 remained same when compared to the baseline of 1950-1980. The future rainfall in the study region is projected to increase in the coming decades and then fall back near to the 1950-1980 baseline. However, the scenario SSP3-7.0 shows a large difference in 2071-2100 in comparison to other scenarios from the baseline as seen in the **Error! Not a valid bookmark self-reference.**.

Table 9. A table showing the average rainfall for different time periods in Araku region.

Time periods	Historical data (mm)	SSP1-2.6 (mm)	SSP2-4.5 (mm)	SSP3-7.0 (mm)	SSP5-8.5 (mm)
1950-1980	1142.31	X	X	X	X
1961-1990	1202.44	X	X	X	X
1981-2010	1141.48	X	X	X	X
1995-2014 (AR6)	1160.12	X	X	X	X
2011-2040	X	1332.97	1289.50	1246.09	1411.85
2041-2070	X	1260.50	1156.90	1255.77	1242.37
2071-2100	X	1203.78	1194.05	1405.48	1243.35

4.7.3 Linking data and perceptions

This study aimed to investigate the changing climate in the Araku region and examine it might be changing under different climate pathways (research question 3). The climate data analysis in the previous sub-sections clearly showed that the temperature in the Araku region has been changing is projected to head in a similar way coming decades until 2100. However, precipitation does not have such trends for most scenarios (see Figure 12). During the interviews, visits, and informal interactions, all the study participants were concerned about the climate change. At the tuber's festival, climate change was one of the key discussions point among the farmers, scientists, and the stakeholders. The primary worries expressed by the CSB farmers are towards their rain dependent agriculture, and reduced availability of irrigation water from streams. This study shows that precipitation has relatively little change in long term and its different than what farmers expectations, this doesn't invalidate their perceptions.

There is a strong concern among the stakeholders (WASSAN, RySS, and FES staff participants) about wild diversity loss due to rising temperatures. Similary, most CSB farmers shared their experiences of temperature changes over decades and fear that the crop failure may occur due to rising temperatures and extreme heat. These concerns, regarding the temperature change are strongly supported by the temperature data analysis (see Figure 11) which shows that temperature change is iminent and cannot be avoided in future even in the sustainable pathways such as SSP1-2.5 .However, by heading towards a sustainable pathway the temperatures can be limited to a level below 2 °C by the end of 2100. Overall, the perceptions of the participants show a worry for the future climate change and its effect on their livelihoods. The quantitative results of the climate data support some of their fears, while remaining neutral in some of the scenarios.

5. Discussion

This section discusses the findings of the empirical study with the existing literature and provides a critical view. The section is organised as follows: first a short summary of the results, then followed by the discussion with the existing literature. The discussion part is in a similar order as the results section, with a few exemptions. Finally, the discussion moves on to the recommendations for policy makers, stakeholders and ending with the limitations of the study. Overall, this section provides a critical view of the findings and presents a future roadmap for the CSB, and the study region based on the study findings.

A short summary of the results

The present study focussed on answering the key questions related to seed sovereignty, agroecological practices, and farmers' perceptions on seed conservation, social dynamics, climate change, and agriculture. This paper used agroecology principles as a theoretical framework and used a transdisciplinary approach, with much focus on the social science part.

The community seed bank (CSB) in the case study region is playing a vital role by providing a wide range of services to the farming community. These include agro-biodiversity conservation, multi-stakeholder collaboration, cultural space, bridging science, agriculture and consumers. Seed sovereignty in the study region is not achieved as an isolated regional phenomenon; perhaps it had a multi-directional approach and support. In turn, these support mechanisms formed the pillars for seed sovereignty and agroecological transition of farmers. The collective action of the community in the past acted as a stepping stone for the CSB and continued till the present, leading the CSB as institution of their pride.

Despite the efforts of CSB and its stakeholders there are few areas which the study identified and that needs attention. Firstly, farmers' voices highlighted the great need for extension activities and scientific knowledge dissemination to their community. Similarly, there is a requirement of participatory research and conservation of wild agrobiodiversity. Secondly, the shift in social dynamics is viewed as barrier for the dissemination of indigenous knowledge on crops and seeds. This shift also creates a dilemma in the rural families about who does the farming in the future? Finally, the warming trends from the climate data analysis showed that study region had warmed and is continuing in a similar trend. However, the precipitation data did not yield significant trends compared to the temperature data.

Seed systems and agrobiodiversity

The CSB farmers are mostly using the informal seed systems for their seed needs. The seed access provided by the CSB is similar to the other case studies reported in Africa and India (Patnaik et al. 2017; Duthie-Kannikkatt et al. 2019; Tione et al. 2025). The new outcomes are the alignment of the CSB with the natural farming movement and seeds supply through the RySS.

Natural farming and agroecological practices

This study showed that training provided by multiple institutions had helped the farmers transition to natural farming and increased yield in crops such as finger millet. This highlighted the importance of the farmer trainings in the study region. A similar phenomenon is reported in a long-term study conducted by Okori et al. (2022) in Malawi, where the CSB farmer trainings had improved the crop productivity and farm produce quality. A minimum of three trainings had resulted in successful adoption of new practices in the agriculture (Okori et al. 2022). Though the present study did not quantify the yields of all the crops in the region. There is strong evidence showing that the yields of finger millet increased by two-fold in the fields of farmers following the Guli-ragi method of cultivation with agroecological practices.

Majority of the CSB farmers are part of the natural farming program. The study from Berger et al. (2025b) showed that natural farming in Andhra Pradesh had helped in increase farmers' profits by 123% compared to industrial farming by usage of fewer external inputs. Apart from economic benefits, the study also highlighted that natural farming plots had higher faunal diversity compared to the chemical farming plots (Berger et al. 2025b). The present Araku region being surrounded by a sensitive forest, natural farming in the existing cropland can offer a balance between sustainable food production and biodiversity conservation.

The local state government is aiming to scale up the natural farming in the state to include 4 million farmers in natural farming by 2047 (GOAP 2024). The present CSB case study can offer insights into the policy framework for seed systems and establishing local community seed banks in other locations of the state.

Natural farming had its own set of challenges in the study area. These challenges include farm labour shortages, increased raw ingredient costs, and social changes. The farm labour shortage is seen in many areas across India, as the workforce shift is evident in the last five years (GOI 2025). The social changes included the lack of family support and young generations in the farming, so the farms are being managed by the elder farmers. The natural farming is labour intensive during peak farming season, so it required help and was difficult to manage as a single person. The rise in raw ingredient costs, such as cane sugar and flour, is volatile and not constant through the years.

Producer-consumer bridge

Local CSB farming households are self-sufficient for some of their main diet, which includes millets, rice, vegetables and fruits. This self-sufficiency of food items aligns with the principles of agroecology. However, for some pulses and food ingredients they are dependent on the external markets.

Farmers are selling the excess produce after their self-sufficiency. Farmers' markets have been one of the main sales channels used in the region to sell the farm produce. These markets are bridging the producers directly with consumers, eliminating middlemen. This elimination is bringing down the cost for the consumers and offering a fair price for the farmers. Hence, this bridge through farmers market can be viewed at a Level 4 of agroecological transition.

The recent EAT-Lancet report highlighted the importance of affordable access to food in bringing the Planetary Health Diet (Rockström et al. 2025). The farmers' markets had been aligning with this goal of the sustainable food systems recommended by the EAT-Lancet. Similarly, Gliessman (2014) described that creating local food chains is important in agroecological transition, a Level 5 of agroecological transition aims to bring the consumers and producers together, creating sustainable food systems.

Cropping systems and shifts

The shifts in cropping systems from millets to rice and bouncing back to millets is observed in the case study. The changes in cropping systems, where rice is dominated as a main crop, left other crops such as millets and pulses aside. In the last decade the millets came back to the cultivation through the promotion of CSB stakeholders. A similar shift in cropping systems trend is observed in the national-level statistics, where the millet cultivation area showed downward trend over the last five decades (UPAG 2025). India is a leading producer in pulse production but still imports pulses every year. To avoid large imports and reduce future food prices inflation, the NITI Aayog report (2025), suggested an increase in domestic pulse production. Pulses are also encouraged in the planetary health diet suggested by the EAT-Lancet as an alternative source for protein (Rockström et al. 2025). This offers the CSB farmers an opportunity to align with the growing pulses demand and fill the production gap, by moving away from the rice cultivation.

Socioeconomic dynamics and food security

The lack of interest in the youth to enter agriculture is an important concern in the area. This phenomenon is not restricted to the study area but to several regions around the world (The Status of Youth in Agrifood Systems 2025). As the local economies are shifting from being agriculture-based to service- and industry-based, there is a shift of workforce between the sectors. The strong concern in the elder generations about the future of agriculture is evident in the present study region. This concern is valid, as the region remained agriculture-dependent for several decades. The food grown is used for their local consumption, and disruption in the crop cultivation can make the people dependent on the external markets for their food.

Another important factor in youths' disinterest is the present case study region is located remotely and has less connectivity with the nearby urban areas. A 2025, youth and food systems report from FAO (2025) emphasised the youth’s role in shaping the future of agriculture. The report showed that most of the youth in the world are living in regions with high potential for agriculture and poor connectivity. In addition to that, the traditional food systems did not offer better opportunities compared to the industrial food systems. The regions with traditional food systems are highly susceptible to climate change (The Status of Youth in Agrifood Systems 2025). This voice from the FAO report can be matched to Araku region, where the similar conditions exist.

Dietary transition

The diverse seed availability is helping CSB farmers to grow wide range of crops. The crops grown by the CSB farmers, are majorly millets. There is local production of millets, but young generations in the region are shifting away from the millet-based diet. Shift in diet, is a concern in multiple ways. First, traditional seed varieties in the region are moving towards extinction when they are not part of local diet. Second, the local traditional foods are intertwined with millet-based diet, and the dietary shift will erase the culinary history of the region. Third, recently millets are being promoted as nutrient rich food, but lack of local consumption means farmers should sell their crop to the external markets. This meant that price volatility can reduce the millets cultivation.

The United Nations (UN) had promoted millets, by celebrating 2023 as an International Year of Millets (IYM). Millets are highlighted for their nutritional value, role in food security, climate resilience and their importance in livelihoods of peasants (UN general assembly 2021). While there is a great attention to millets at global food systems, there is also a role to increase the local consumption to buffer the losses when there is shift in trades or tariffs.

Participatory research

The CSB, and its farmers hold wide diversity of seeds. With the participatory research between the public institutions and the farmers, the new open pollinated varieties can be developed in future. The participatory research showed successful examples from the case study region, one of the bright examples is the Guli-ragi cultivation. Participatory research requires a long-term investment plan from the public institutions or the stakeholders.

Similar to the present study findings participatory research had been used by various institutions around world. The Kultursaat e.V., is an of independent breeders' association, where the new seed varieties are deposited as public commons. Similarly, MASIPAG from Philippines is a network of NGOs, farmers, and scientists that worked for the food sovereignty, and promoted organic agriculture and breeding farmers varieties (Sievers-Glotzbach et al. 2020; *Kultursaat e.V.* 2025). This can be drawn as an example for the present CSB and other research organisations.

Wild seed diversity

The case study region harbours unexplored crop wild diversity in the forest patches. This uncultivated wild diversity is as important as the cultivated diversity; with the climate change on the horizon this needs much more attention. In October 2025, India announced its roadmap to prepare a National Red List by 2030. In the preliminary vision document of National Red List Assessment of Indian Flora and Fauna (2025:24), there is a plan to include the crop wild relatives and wild edible species into red data list. However, the exact roadmaps are yet to be published, and the crop wild relatives and the crop wild diversity needs to be studied and included. The CSBs can be part of the roadmaps for conserving the diversity. Along with that it is equally important to educate the locals about the species' rarity and sustainable usage of wild diversity.

Capacity building

Major part of the extension is done by the non-profit organisations and the RySS. This study identified that farmers expectations for some extension activities are not met. Primarily, the farmers expect more training in the form of seed saving practices and scientific knowledge related to the seeds. The local agriculture department or relevant authorities should focus on creating a tailored approach for the CSB farmers. This specific plan should address training on botanical knowledge, storage techniques, and storage pest identification.

Regarding the research question relating to the seed policies and farmers perceptions [2], there is a large gap in the policy awareness and farmers interests towards the policies. This is similar to the findings of Aditya et al. (2017), that highlighted the lack farmers awareness on the government policies in the farming community. There is a sense that farmers voices are not part of policy design, and so they are not concerned about the policy framework. For example, the PPVFR Act that forms the base for the seed sovereignty and CSBs legality is not well known in the farming community. Only the CSB staff and the stakeholder institutions are aware of these policies. This highlights the need for policy awareness programs for farmers and enhancing their participation in decision making.

The Indigenous Technical Knowledge (ITKs) about the seeds, their usage, history and cultivation are embedded in the local culture and the people. The ITKs offer immense value about the seeds and agriculture systems, which might be essential in future. With the changes in social dynamics of region, the ITKs might not pass on to the next generation. This knowledge erosion might accelerate the genetic erosion of seeds due to impractical use of the conserved seeds. The documentation of the ITKs require a bottom-up approach with the farmers and institutions, helping the co-creation of knowledge.

Climate data and trends

The climate data analysis showed warming temperature trends for all the analysed emission scenarios. The warming rate increased from the low-emission to the higher-emission pathways. These temperature trends are consistent with the findings of the IPCC AR-6 report (IPCC 2023). The historical data also showed a similar trend to the future projections. This answers the research question [5], where the study wanted to find the climate change trends in the study region. In converse to the temperature data, the precipitation data did not yield any significant trends in most scenarios. Only the low emission scenario, had a significant upward trend.

The study regions warming exceeds 1.5 °C by 2040-2070, in all the scenarios (low emission to high emission) compared to the 1950-80 baseline. There is no return to the 1.5 °C by the end of 2100, even under the strongest adaptation and mitigation measures. This finding is consistent with the IPCC report (2023:92). The warming levels in the study region exceed 2 °C in most scenarios in comparison to the baseline. This warming is way beyond the Paris agreement (UNFCCC 2015) to limit warming below 2 °C to the pre-industrial levels.

Rising temperatures in the study region are alarming, and need an immediate attention and adaptation strategies. They might shift the agriculture and cropping systems in the area; particularly, the sensitive crop yields might get lowered in the future if the warming continues. The previous studies evaluated the impact of climate warming on major crops around the world, even a 1 °C rise can influence the crop yield (Hultgren et al. 2025). While the warming shift might also offer a chance to test the native varieties for the changing climate, for which participatory research is needed in the study area.

Climate, coffee and a cascading future

The case study region farmers grow coffee variety *Coffea arabica*, which is climate sensitive variety and requires annual mean temperatures under 24 °C (Teketay n.d.). The present study estimated that under extreme emissions scenario annual temperatures can reach 25 °C by 2070 and 27°C by the end of 2100. Higher annual temperatures possess a risk for Coffee bean quality and increased pest risk (Davis et al. 2012). In 2025, news agencies reported that the local scientists identified coffee borer infestation in the regions near to the case study (Peri 2025). Though this cannot be directly attributed to the changes in climate, the pest occurrence can increase in future. Overall, the warming temperatures might affect the Coffee production in future, which can lead to a cascading economic effect on the CSB farmers, and their agricultural practices.

Climate adaptations and environmental resource management.

The farmers are using the dry sowing methods such as RDS, and PMDS to sow the seeds in the dry seasons. This dry sowing methods are coupled with the natural farming. There are limited studies and lack of detailed literature analysing the benefit of the dry sowing in this method of natural farming. But the staggered sowing or adapting the sowing dates to the rainfall patterns is a well-known climate adaptation used in the dry areas.

Limitations of this study

This study tried to offer a holistic perspective about the community seed bank, but still, there are limitations in certain areas which needs a great attention. These limitations can be used by the future research projects for a better understanding of the CSB. First the gender equity, the study did not address the issue of gender equity as adequate as it needs to be. Therefore, it is considered as a limitation for this study. Though the women are playing an important role in the conservation of seeds, their lack in the active fore front needs to be addressed in the future. Second, the climate models used in the study, the future studies can focus on using ensemble of multi-climate models, and wide climate variables, which this study had limited.

Suggestions based on the Agroecology and a broad view

The CSB is offering a platform for the farmers for achieving seed and food sovereignty. There are some suggestions which have been included in the subsections of the discussion part. A detailed suggestions were provided here which can be incorporated at farmers level by the CSB, and local NGOs. The suggestions recommended for the policy level can be implemented by local and national governments using comprehensive studies.

- Designing extension training programs tailored to the needs of the CSB farmers and local requirements.
- Horizontal integration of the CSBs with the local and national gene banks for a secured future of seed diversity, and risk aversion.
- Evolving a roadmap for participatory breeding and conservation activities, especially for the wild tubers and wild diversity.
- Creating a micro farmer enterprises and value chain for sustainable food products, using heirloom seed varieties and by products.
- Providing local employment for youth, and skill train them in the agriculture by using multiple stakeholders and CSB support.
- Educating the local farmers on the seed policies and regulations and bringing a participatory policy design for the future.
- Evaluating the nutritional parameters of the traditional seeds, wild tubers, and traditional foods. Educating the locals about the outcomes from the scientific evaluation.
- Creating and implementing roadmaps for climate change adaptation.

6. Conclusion

The present project aimed to provide a holistic view of the community seed bank by using the agroecology principles as a framework. This study used CSB as an institution and included the perceptions of the people involved with it and linked the quantitative climate data. Through these integrations the study aimed to offer a transdisciplinary view of the community seeds banks and agroecology.

The study has shown that the community seed bank is helping the agroecological transition in the study region by promoting the seed and food sovereignty movements. The CSB as institution is facilitating the mutual collaboration with other non-profit organisations and formal institutions. This close association is bringing the research, practice and farmers together.

The CSB has been a platform for socio-cultural exchange, and knowledge partner. Findings clearly indicate that grass-root thoughts of the people helped in formation and running the community seed bank for two decades. SB farmers are paving a road forward bringing sustainable food access directly to consumers through farmers markets. Similarly, the seed festivals organised by CSB are bridging the consumers with farmers. All these helped in the agroecological transition of the farmers and their local food system.

Despite the efforts of the farmers and its stakeholders there is a road ahead that still needs a roadmap. The primary issues that need addressal are tailored skill training for farmers, wild diversity conservation, value addition of the crop produce, assessing social dynamics change and climate change adaptation. As the climate forecasts of the region shows a warming pattern, it is important to consider required adaptations for securing the future of agriculture and wild diversity in the region. The region harbours wild tubers and seed diversity which needs to be conserved, documented in mutual collaboration between CSB, gene banks, and farmers. With climate change the wild diversity needs a sensitive conservation plan. For such determination, the present research highlighted the need for participatory research.

The local problems require a local solution, by involving the communities. Farming produce obtained from the traditional crops needs value addition, food science research, and tailoring food products to the local preferences. This means establishing a farmer enterprise and promoting local employment in the region. Shift in social dynamic and lack of youths' interest in agriculture needs its own study and policy framework to secure the ITK and the regions agriculture. The local forest patches that hold treasure of wild tubers, and seeds needs protection and conservation with the support of community. The wild resources should be preserved and not be exhausted for the research purposes.

In overall, the farmers and the stakeholders associated with the community seed bank showcased a bright example of agroecological transition. Their consistent effort depicted, that farmer led institutions can influence the seed sovereignty movement in a positive way. This marks a successful example for decentralised approach for seed conservation and food systems transformation. These decentralised case studies can inspire other farmers and practitioners across the globe, paving a way for better livelihoods and sustainable food systems.

The findings from this study will provide insights for the policy makers and researchers focussing on the agroecology and food sovereignty. Despite its broad range, the study did not address the issues of gender equity. Broad research is needed in the areas of gender equity, quantitate yields analysis, long term impact of CSB on social and mental health of people involved.

The Araku region and the hilly ASR district holds an immense potential for sustainable agriculture. This thesis concludes with the questions that raised from the field experiences and the perceptions of the Araku regions people. How will we ensure a safe space for the seeds and diversity that the farmers conserved? How will we protect these sensitive communities from the climate change, and ensure a bright future for the next generations? The agroecology and climate of the Araku region are a complex puzzle/system, and this study offered a piece of it. With many new questions for the future, this text ends here hoping bright days for the Araku region, its people, and nature.

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Appendix 1 Consent form in English

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of People and Society
Avinash Valluri

Independent Project in Agriculture Science

20/01/2025

Consent form: Processing of personal data in research

When you take part in the Community Seed Banks project, SLU will process your personal data. Consenting to this is voluntary, but without processing your personal data, we cannot carry out this research project. The purpose of this form is to give you the information you need in order to decide whether or not to consent to the processing of your personal data.

You can withdraw you consent at any time, and you do not have to justify it. SLU is responsible for the processing of your personal data. The SLU data protection officer can be contacted at dataskydd@slu.se. Your contact for this project is: Avinash Valluri, avva0002@stud.slu.se, Mats Gyllin mats.gyllin@slu.se

We will collect the following data from you: Age, location of farm, organization role, seed saving practices, agriculture practices in your farm and local region. The data is collected through semi-structured interviews, photographs and focus groups.

The purpose of the processing of your personal data is for SLU to carry out research within the field of Agriculture.

You will find more information on how SLU processes personal data and about your rights as a data subject at www.slu.se/personal-data.

☐ I consent to SLU processing my personal data in the way described in this document. This includes any sensitive personal data, if such data is provided.

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Signature　　　　　　　　　　　　Place and date

____

Name in block letters

Mailing address: Sundsvägen 5, 234 56 Alnarp, Sweden
Street address: Sundsvägen 5, 234 56 Alnarp, Sweden
VAT no: SE202100281701
www.slu.se

Phone: +46 18 67 10 00 (switchboard)
Avva0002@stud.slu.se

Appendix 2 Consent form in Telugu

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of People and Society
Avinash Valluri

Independent Project in Agriculture Science
20/01/2025

సమ్మతి ఫారమ్ తెలుగు అనువాదం:

మీరు విత్తన బ్యాంక్‌ల ప్రాజెక్ట్‌లో పాలుపంచుకున్నప్పుడు, SLU మీ వ్యక్తిగత సమాచారం ప్రాసెసింగ్ చేస్తుంది. దీనికి సమ్మతి స్వచ్ఛందం, కానీ మీ వ్యక్తిగత సమాచారం లేకుండా మేము ఈ పరిశోధన ప్రాజెక్ట్‌ను నిర్వహించలేము. సమ్మతించాలా వద్దా అని నిర్ణయించుకోవడానికి మీకు అవసరమైన సమాచారం ఇవ్వడమే ఈ ఫారమ్ యొక్క ఉద్దేశ్యం.

మీరు ఎప్పుడైనా మీ సమ్మతిని ఉపసంహరించుకోవచ్చు మరియు మీరు దానిని సమర్థించాల్సిన అవసరం లేదు. మీ వ్యక్తిగత సమాచారం ప్రాసెసింగ్‌కు SLU బాధ్యత వహిస్తుంది. SLU డేటా రక్షణ అధికారిని dataskydd@slu.seలో సంప్రదించవచ్చు. ఈ ప్రాజెక్ట్ కోసం మీ పరిచయం: అవినాష్ వల్లూరి Avinash Valluri, avva0002@stud.slu.se, మాట్స్ గిలిన్ Mats Gyllin mats.gyllin@slu.se

మేము మీ గురించి ఈ క్రింది సమాచారం సేకరిస్తాము: మీ వయస్సు, ప్రాంతం, విత్తన బ్యాంకులో పాత్ర, విత్తన పొదుపు పద్ధతులు మరియు, మీ స్థానిక ప్రాంతంలో వ్యవసాయ పద్ధతులు. ముఖాముఖి మరియు ఫోకస్ గ్రూపుల ద్వారా డేటా సేకరించబడుతుంది.

మీ వ్యక్తిగత డేటా ప్రాసెసింగ్ యొక్క ఉద్దేశ్యం SLU వ్యవసాయ రంగంలో పరిశోధనను నిర్వహించడం.

SLU వ్యక్తిగత డేటాను ఎలా ప్రాసెస్ చేస్తుంది మరియు డేటా సబ్జెక్ట్‌గా మీ హక్కుల గురించి www.slu.se/personal-dataలో మీరు మరింత సమాచారాన్ని కనుగొనగలరు.

☐ ఈ డాక్యుమెంట్‌లో వివరించిన విధంగా నా వ్యక్తిగత డేటాను SLU ప్రాసెస్ చేయడానికి నేను సమ్మతిస్తున్నాను. అటువంటి డేటా అందించబడితే, ఇందులో ఏదైనా సున్నితమైన వ్యక్తిగత డేటా ఉంటుంది.

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సంతకం — స్థలం మరియు తేదీ

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అక్షరాలలో పేరు

Mailing address: Sundsvägen 5, 234 56 Alnarp, Sweden
Street address: Sundsvägen 5, 234 56 Alnarp, Sweden
VAT no: SE202100281701
www.slu.se

Phone: +46 18 67 10 00 (switchboard)
Avva0002@stud.slu.se

Appendix 3 Interview Guide

Interview guide - Community Seed Bank project

Introduction:
**Information about research work and consent.
*Inform about time taken for interview.

Demographics
- Age.
- Gender.
- Area.
- Profession.
- Family.

CSB membership:
- Membership of CSB?
- How long have you been part of CSB?
- Experience of being part of CSB.

Agriculture
- Experience in agriculture.
- Crops grown.
- Type of cultivation.
- Water resources.
- External resources?
- Pest and disease control?
- Fertilisers?
- Extension and support?
- Information from external organisations?

Seeds
- Source of seeds for crops.
- How do you borrow and submit seeds?
- How do you harvest and save seeds?
- Exchange of seeds with farmers or neighbours.
- Any monetary exchange for seeds?
- Backup plans.
- Benefits of using own seed from CSB.
- Seed systems.

Challenges in seed saving
- Key challenges faced,
- Do you face any difficulties in seed saving?

Traditional Knowledge
- Sharing traditional knowledge with family and community.

Next generation and agriculture
- Is your next generation interested in agriculture? Why? Why not?
- Major factors affecting the next generation in agriculture.
- Participation of young people in agriculture.
- What do you think is the best practice to bring youth to agriculture or seed saving?

Climate change:
- Have you experienced any extreme weather events in recent years?
- Do you feel the weather patterns are changing in your area?
- Any adaptation measures used?

Interview guide - Community Seed Bank project

Consumption
- Do you consume the crops you grow?
- Sale of crops?
- Purchases from the market?

Food habits
- Did food habits change from last decades?
- What changes were observed?
- How do you feel about changes?
- Food habits and crop cultivation changes?

Policies
- What kind of support do you need for agriculture and seed saving?
- Opinion on present agriculture and seed policies?
- Future policies?

Diversity:
- Change in diversity of agriculture?
- Change in general biodiversity?

Economy:
- Self-sufficient?
- Expenses on agriculture?

General questions
- Any other things you might think we missed.
- Other inputs about seeds and agriculture.

Additional questionnaire orientated towards the stakeholders and CSB staff.

General information
- History.
- Areas of work.
- Historical changes.
- Structure of the organisation.
- Governing rules.
- Membership process.
- Funding of the organisation.

Seed bank
- When did the seed bank start its operations?
- Historical transformation.
- Statistics on members.

Seed storage
- How are seeds stored in the seed bank?
- Storage methods?
  - Any traditional methods.
  - Advantages of traditional methods.
- Selection of seeds for storage.
  - Quality assurance.
- Challenges in the seed storage?
- Any special techniques used in storage?

Seed distribution
- Seed distribution/loan/sales model.
- Plan for seed distribution.
- Planning of the seeds?
- Exchange with other seed banks.

Interview guide - Community Seed Bank project

Diversity
- Total diversity in crops.
- How is the diversity conserved?
  - Collection of diversity.
  - Storage of diversity.
  - Identification of diversity.

Collaboration
- Which organisation collaborates with CSB?
- How does CSB search for collaboration?

Gene banks
- Submission of varieties in external seed banks?
- Any collaboration with gene banks.

Farmers' varieties
- How do you submit for the registration of farmers' varieties?
- Is the process ok or difficult?
- What is assured by this registration.
- How many varieties are registered by the CSB in farmers' varieties?

Climate change
- Have you observed climate change in this region?
  * Main changes observed.
- Any severe weather events in recent years (Last 5/10 years?)
- How is it different from two decades back?
- How did the organisation adapt to the changes?
- Members' voices on climate change.

Policies
- What are the policies surrounding the CSB?
  - Forest rights, PPVFR, and seeds acts.
  - Intellectual property rights, biopiracy.
- Which policies are okay and which are not?
- Any policy recommendations or changes?

Food consumption and changes
- Change in food habits in the area?
- Supply of PDS?

Statistics
- Total diversity in the seed bank. (Crops, species)
- Number of farmers part of the organisation.
- Storage.
- Villages covered.

Popular science summary

Seeds play an important role in our daily lives, agriculture and food systems. Yet in the last century, the seeds moved from farmers baskets to the control of few corporations. This was resisted by farmers and non-profit organizations by establishing farmer run community seed banks (CSBs), where they have rights on seeds to own, exchange, and freely plant them every year. However, these community run seed banks are not well connected with the agroecology, and the climate studies. This study wants to fill the gap by studying a CSB as an institution for seed sovereignty.

We studied a CSB in Araku region, India by using an agroecological framework, principles. For that the project collected data by speaking with the farmers directly in the Araku region. We collected their opinions around their farming practices and to understand about the climate change in the study region, we checked the data from NASA dataset.

We found that the farmers in the Araku region CSB are saving seeds and combining them with the natural farming practices. They are leading a successful example for a sustainable farming that can mitigate climate change. They formed a community seed bank by the support and collective action from the farming community; this happened two decades ago. Now, they are able to meet their own seed needs and share them with other people. They are also organising annual seed festivals, encouraging all the people, scientists to interact each other.

We identified some key aspects in study that can be improved, these include changing the extension activities to favour farmer centric learning, encouraging participatory research. Preserving the wild diversity in the forest patches. Providing nutritional information for the wild diversity. This has become a very important with changing climate. The data analysis showed that Araku regions climate is warmed from 1950 to 2014, and it is continuing in a similar trend. If the same trend continues, the average annual temperature might rise by 1.8 °C to 4 °C by the end of 2100. Which can disrupt the locals' livelihoods and the biodiversity.

Therefore, this study proposed a roadmap for the future of CSB, and the farmers in the Araku region. This study suggests; education of farmers about the seed policies and tailoring the extension activities to their needs. Forming roadmaps for climate change adaptation at local and national level policies. The natural farming produce should be value added, and local micro enterprises should be established, encouraging youth employment and preventing migration.

Factsheet

A fact sheet for farmers on Community seed bank and climate change in the Araku region

Introduction

Community seed banks are local seed banks run and managed by farmers. In our project, we interviewed farmers from the Araku region and people working with Community seed bank (CSB). Additionally, we also evaluated how the climate is changing in the Araku region so that we can provide suggestions for future farming practices and policies.

Information

Why community seed banks are essential?

Community seed banks help preserve local seed diversity in a secure location and provide seeds to farmers at low cost or through exchange. These seeds are usually open-pollinated, allowing them to be planted for several generations. Because farmers run these CSBs they protect the farmers rights and interests.

What did our study find?

In our study we found that the Araku regions CSB in Killoguda is helping farming communities in several ways:

- Conserving the local seed diversity and distributing it through the formal system.
- Helping farmer in switching to natural farming and providing technical support
- Natural farming through the farmers market is connecting farmers and consumers directly, and offering fair prices for both.
- Organising seed festivals to connect farmers, scientists and consumers.

However there are few challenges identified in the study;

- Youth are not interested in pursuing agriculture.
- Labour shortages are increasing in the region.
- The Araku regions temperature increased from 1950 to 2025.
- Future temperatures could rise by about 1.8 ºC to 4.8 ºC by 2100 compared to the 1950-80 average.

Araku regions temperature will increase about 1.8 ºC to 4.8 ºC by 2100

Suggestions for the future

- As the youth are moving away to other regions and sectors from Araku region, it is important to make the agriculture valuable for the youth. The products from the natural farming should be value-added by creating local micro enterprises.
- Education of fellow farmers and people about seeds and the regulations around the seeds, so that you can influence the policy at the ground level in your local region.
- Join the local natural farming communities and attend the training sessions organised by the community seed bank.
- Attend the seed festivals to connect with fellow farmers, learn about new traditional varieties, and have a chance to purchase or exchange seeds with other farmers.
- Prefer locally grown food and vegetables, and including wide groups of vegetables in the diet.

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Prepared by

Avinash Valluri
Department of People and Society
Swedish University of Agriculture Sciences
Alnarp, Sweden

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