



AGROECOLOGY FOR CLIMATE JUSTICE

PARTICIPATORY ACTION RESEARCH
ON CLIMATE IMPACTS AND SOLUTIONS
IN SOUTH ASIA

AGROECOLOGY FOR CLIMATE JUSTICE:
Participatory action research on climate impacts and solutions in South Asia

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INTRODUCTION AND OVERVIEW

As one of the world's most climate-vulnerable regions, South Asia is experiencing increasingly frequent and intense extreme weather events, including prolonged heatwaves, erratic monsoon rains, severe flooding and extended droughts. The region's tropical and subtropical climate systems, historically reliant on relatively predictable seasonal monsoons, are becoming increasingly volatile, undermining agricultural stability, water security and rural livelihoods across diverse landscapes, from the Himalayas to low-lying deltaic plains.

For rural and farming communities, these climate shifts translate into immediate and compounding vulnerabilities. Agriculture in South Asia remains heavily dependent on rainfed systems and seasonal water sources, making crop production highly sensitive to thermal stress and changes in water availability. Rising temperatures can reduce yields and accelerate soil moisture loss, while altered precipitation patterns contribute to crop failures, pest and disease outbreaks, and land degradation. These environmental stresses disrupt farming calendars, undermine food production and reduce agricultural incomes, pushing resource-constrained households towards debt and economic insecurity. As Nasira Habib of Khoj Society for People's Education (Pakistan) argues in her article "Agroecology as a Climate Imperative", included in this report, climate change and the global food crisis are closely linked to the ecological vulnerabilities of an industrial agricultural model that relies heavily on monocultures, synthetic fertilisers and pesticides, fossil fuels, and other external inputs.

Beyond direct agricultural impacts, the climate crisis exacerbates deep-seated socio-economic inequalities throughout rural South Asia. Marginalised groups, including smallholder farmers, landless agricultural labourers, tenant farmers, women, and Indigenous and historically disadvantaged communities, often have fewer financial resources, less secure access to land and water, and weaker institutional support. Consequently, they face heightened risks of food insecurity, malnutrition, and loss of livelihoods. As agricultural returns become increasingly uncertain, distress migration to urban centres or foreign labour markets has become an important, though disruptive, coping mechanism, further reshaping rural communities.

Agroecology, land, and rights

These inequalities also have a human-rights dimension. The 2025 report of the United Nations Special Rapporteur on the right to food, Michael Fakhri, emphasises that concentrated corporate power in food systems can restrict people's access to the resources needed to produce food, including land, water and agricultural inputs, while disrupting local and territorial markets. The report also links input-intensive monocultures and industrial agriculture to biodiversity loss, pollution and the degradation of the ecological foundations of food production. It calls for stronger support for peasants, Indigenous Peoples, women and food-system workers, and explicitly recommends support for agroecology and food systems that prioritise people and nature over profit.

For PAN Asia Pacific (PANAP), and as Fakhri also stressed, agroecology cannot fulfil its transformative potential if the farmers who practise it do not have secure access to, ownership of, and control over the land they cultivate. The right to land is therefore not a separate concern from agroecology; it is one of its essential foundations.

Understanding these dynamics, therefore, requires examining how broad ecological, economic and rights-related pressures unfold in specific local contexts. Climate change is experienced directly by rural communities through changing rainfall patterns, rising temperatures, prolonged droughts, floods, declining water availability, soil degradation, pest and disease outbreaks, crop failures and growing uncertainty over agricultural production. For small-scale food-producing communities whose livelihoods depend heavily on land, water, biodiversity and seasonal cycles, these changes affect not only agricultural productivity but also food security, household income, health, education, employment and migration. The condition of soils and water is particularly important: soil health is central to the water–food nexus because it influences water storage, infiltration and runoff, while soil degradation and contamination threaten the foundations of food production.

Agroecology and the right to land

For small-scale farmers, land is not simply a productive asset. It is the material basis of their livelihoods, food security, culture and communities. Where farmers are landless, are tenants under insecure arrangements, or face the threat of eviction, their ability to make long-term investments in soil health, biodiversity, water management and diversified production is severely constrained. Agroecology requires farmers to work with ecological processes over time – restoring soils, conserving seeds, diversifying crops, integrating livestock, managing water and strengthening biodiversity. Such practices are difficult to sustain when farmers cannot be confident that they will continue to have access to the land they are improving.

This is why agroecology must be understood within the broader struggle for genuine agrarian reform and food sovereignty. Agroecology should not be confused with agrarian reform: agrarian reform addresses the fundamental question of who owns and controls land and agricultural resources, while agroecology provides approaches for developing agriculture in ways that are ecologically sustainable, socially just and locally grounded. The two, however, are deeply interconnected. Agroecology is non-viable without people's access to and control over land, while land redistribution without sustainable, farmer-centred production can leave farmers vulnerable to debt, dependence on costly external inputs, and continued poverty.

This distinction is particularly important because agroecological practices can otherwise be incorporated into exploitative agricultural systems. Organic or environmentally friendly production, for example, can coexist with large-scale plantations, export-oriented agriculture and unequal land relations. Farmers and farmworkers may produce commodities with fewer chemicals while still lacking ownership and control over the land. In such circumstances, changing production techniques does not necessarily change the underlying relations of production. Agroecology becomes genuinely transformative when it forms part of a broader process through which farmers gain secure access to land, exercise democratic control over production and participate meaningfully in decisions affecting their food systems.

The experience of PANAP's partner, the Society for Rural Education and Development (SRED) in India, demonstrates that agroecology becomes transformative when farmers have the power to decide what happens on the land they cultivate. In Pallur, Ranipet district, Tamil Nadu, SRED led 35 Dalit women to collectively cultivate five acres of land using composted manure, diversified crops and natural insect repellents as part of their village campaign to assert the right to land. SRED also runs the Kallaru Dalit Women Collective Model Farm, which is collectively managed by women and serves as a demonstration and learning site for small farmers and women. It combines vegetables, small grains, fruit, shade trees, medicinal plants and livestock. Animal waste is recycled into fertiliser, while vermicompost and natural pest-management methods are used in cultivation.

For Dalit women, securing access to land is not simply a prerequisite for farming; it is a process of overcoming caste and gender discrimination and gaining economic and political agency. Once women gain collective control over land, agroecology provides the means to make that land productive, restore soil fertility, conserve seeds, diversify food production and strengthen food sovereignty.

The SRED experience and other similar grassroots struggles and initiatives have important implications for policies promoting agroecology. Supporting farmers to adopt ecological farming techniques is not enough. Governments must address the structural conditions that determine whether farmers can practise agroecology in the first place. This includes secure tenure, redistribution of land to those who till it, protection against land grabbing and unjust eviction, recognition of women's land rights, and respect for Indigenous peoples' rights to their ancestral territories. Agricultural research, extension and financial support must likewise be oriented towards farmers rather than corporate interests.

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Participatory Action Research: Bangladesh, India, Nepal

The four Participatory Action Research (PAR) reports brought together in this collection, covering Bangladesh, India, and Nepal, document these realities from the perspectives of the communities experiencing them. Taken together, they demonstrate that the climate crisis is simultaneously an ecological, economic and social crisis. They also show that agroecology is not simply a set of alternative farming techniques but a locally grounded approach that can strengthen resilience, food sovereignty and social justice. This interpretation is reinforced by Habib's review, which brings together scientific evidence and case studies showing how agroecological systems can contribute to climate adaptation and mitigation through biodiversity, soil regeneration, biological nutrient cycling, reduced dependence on fossil-fuel-intensive inputs and farmer-led knowledge.

The reports were undertaken by Pesticide Action Network Asia Pacific (PANAP) partners in distinct agroecological and socio-economic settings.

The Bangladesh Resource Centre for Indigenous Knowledge (BARCIK) report focuses on Mundumala village in Tanore Upazila, Rajshahi, situated in the drought-prone Barind region of northwestern Bangladesh.

The Pesticide Action Network (PAN) India report expands the Indian perspective through field research in Yavatmal in Maharashtra, Adilabad in Telangana, and Thrissur and Adimali in Kerala, examining different farming systems, including cotton, rice, cardamom and mixed farming.

The Sahanivasa study covers 20 villages in Nimmanapalle Mandal of Annamayya district and Sodam Mandal of Chittoor district in the dryland Rayalaseema region of Andhra Pradesh, India. The research engaged landless agricultural workers, tenant and sharecropping farmers, small and marginal farmers, as well as farmers practising agroecological and conventional systems.

Finally, the Social Work Institute (SWI) study examines communities in Chaukune and Chingad Rural Municipalities in Surkhet District, Nepal, with particular attention to smallholder and marginalised farmers in Karnali Province.

Although geographically diverse, the four studies share a common methodological and political

orientation. They place rural communities at the centre of the research process rather than treating farmers simply as respondents or passive recipients of technical solutions. Focus group discussions, individual and key informant interviews, seasonal calendars, historical timelines, community mapping, case studies, Problem Tree and Solution Tree exercises, farmer surveys and direct observation were used in different combinations.

In Nepal, for example, the study involved two focus group discussions with 34 participants and 18 individual interviews with farmers, including Dalit and Raji farmers, as well as people from different generations. Sahanivasa similarly used participatory exercises to reconstruct changes in rainfall, agricultural seasons, water availability, land use and crop diversity over several decades. BARCIK explicitly approached community members as knowledge holders whose lived experiences, memories and observations were integral to understanding ecological and social change.

This approach is significant because the reports capture dimensions of climate change that are often obscured by aggregate statistics. Across the study areas, farmers describe a breakdown in the predictability of agricultural seasons. Rainfall is increasingly delayed, erratic or concentrated into short periods of intense precipitation, while dry spells and droughts are becoming more severe. Temperatures are rising, groundwater levels are declining, and the availability of water for farming is becoming increasingly uncertain. These changes disrupt sowing and harvesting calendars, reduce germination and yields, increase pest and disease pressures, and damage crops through drought, flooding, waterlogging and excessive heat. The PAN India study, for instance, documents how cotton farmers in Maharashtra experience delayed sowing, poor crop establishment, waterlogging, root damage, flower wilting, fungal diseases, pest outbreaks and declining fibre quality. In Bangladesh's Barind region, declining groundwater levels and rising irrigation costs have become particularly critical concerns.

Climate impacts

The reports also highlight that climate impacts cannot be separated from existing inequalities. Climate change does not affect rural communities uniformly. Those with fewer assets, less secure access to land and water, and greater dependence on agricultural labour are generally more exposed to

climate-related shocks. The studies repeatedly identify women, landless labourers, tenant and sharecropping farmers, small and marginal farmers, Indigenous or Adivasi communities, Dalit communities and rural youth as particularly vulnerable. In Andhra Pradesh, for example, climate-related crop failures reduce employment opportunities for agricultural workers while increasing indebtedness and migration. Women experience additional burdens related to food insecurity, unpaid care work, nutrition and agricultural labour. In Bangladesh, women, landless labourers and young people similarly experience disproportionate impacts as food shortages, declining employment and uncertain agricultural returns deepen existing vulnerabilities. These findings resonate with the Special Rapporteur's observation that structural inequalities in food systems disproportionately affect people who already face barriers to food access and that rural women and Indigenous women are particularly disadvantaged when they lack secure access to land, seeds, affordable markets and agricultural services.

A central finding across all four reports is therefore that the climate crisis is not simply reducing yields; it is undermining the wider foundations of rural livelihoods. Falling productivity and rising input and irrigation costs contribute to indebtedness; crop failures reduce food availability and employment opportunities; declining incomes affect healthcare and children's education; and uncertainty encourages younger generations to migrate or leave farming. In Andhra Pradesh, farmers reported that declining production of pulses and millets has increased dependence on purchased food and subsidised rice, whereas diversified agroecological farms provide households with a broader range of foods. The Bangladesh study similarly links climate stress to declining incomes, indebtedness, food insecurity, reduced employment and growing reluctance among young people to remain in agriculture.

Agroecology and climate justice

Against this backdrop, the reports offer an important counterpoint to narratives that portray rural communities simply as victims of climate change. Farmers are already adapting, experimenting and drawing on ecological knowledge accumulated over generations. Across the four studies, agroecological practices include crop diversification, mixed and intercropping, local and drought-tolerant seed conservation,

composting, mulching, agroforestry, livestock integration, natural pest management, water harvesting, soil moisture conservation, and farmer-to-farmer knowledge exchange.

The comparative evidence in the reports points to an important distinction between diversified agroecological systems and conventional input-intensive monocropping. Agroecological systems do not necessarily maximise the yield of a single crop under favourable conditions. Instead, their strength lies in reducing exposure to risk by maintaining diversity, recycling resources, improving soil health, conserving water and providing multiple sources of food and income. The SWI report describes agroecological farms as having greater yield stability, lower input costs, greater crop diversity and stronger climate resilience than conventional monocropping systems. Sahanivasa provides particularly concrete evidence: diversified groundnut systems required approximately ₹28,500 per acre compared with ₹48,000 under conventional monocropping, reducing production costs by about 41 per cent. BARCIK likewise finds that diversified systems have lower production costs, greater food diversity and stronger capacity to withstand climatic shocks. Habib's review provides a broader scientific rationale for these findings, noting that diversification can distribute ecological risk across crops and species while strengthening ecosystem services and resilience.

Importantly, the reports understand agroecology as more than a collection of techniques. Their findings point to a broader transformation in the relationships among farmers, land, seeds, water, biodiversity, markets, and institutions. Local knowledge and traditional practices are presented not as remnants of the past but as resources for addressing contemporary climate challenges. Seed saving, farmer-to-farmer learning, reciprocal labour, collective resource sharing and community organisation strengthen resilience alongside changes in farm management. In Nepal, traditional systems such as Aichopaicho and Armaparma reinforce cooperation, reduce costs and support seed, livestock and knowledge exchange. This people-centred and participatory orientation is consistent with the Special Rapporteur's recognition of food systems based on cooperation, mutual aid, democratic or participatory governance, autonomy and independence, and with his recommendation that States support agroecology and prioritise the voices of rights holders over corporate interests.

At the same time, the reports caution against placing responsibility for climate adaptation solely on individual farmers. Community-level innovation is constrained by insecure land and water access, inadequate public support, weak extension systems, market pressures, dependence on external inputs, limited access to finance and the insufficient recognition of women's roles and Indigenous and local knowledge. The Bangladesh report consequently argues for an integrated approach involving public investment, community seed banks, water conservation, ecological soil management, farmer-led innovation, fair markets and stronger farmer organisations. Sahanivasa similarly calls for secure land, seed and water rights, stronger social protection, public investment, women's recognition and collective rural action. These priorities are also supported by the Special Rapporteur's recommendations to strengthen support for peasants, Indigenous Peoples, women, and food-system workers, and to develop public procurement policies that source from local, small-scale producers and Indigenous Peoples.

The four reports therefore converge around a shared proposition: agroecology is both a climate adaptation strategy and a pathway towards climate justice and the realisation of the right to food. Building resilience requires investment not only in farms but also in the social and ecological systems that sustain them. This means protecting biodiversity and local seeds; restoring soils and water systems; reducing dependence on costly and hazardous external inputs; strengthening farmer-led knowledge and extension; ensuring fairer local and territorial markets; recognising women as farmers and decision-makers; creating meaningful opportunities for rural youth; protecting land and resource rights; and supporting farmer organisations and collective action. The Special Rapporteur's report strengthens this conclusion by framing access to land, water, and agricultural inputs; participation in food systems; and access to adequate and culturally appropriate food as questions of rights and power rather than merely technical or market concerns.

Evidence and action for agroecology

Taken together, the PAR reports and “Agroecology as a Climate Imperative” provide a people-centred account of both the scale of the climate crisis and the possibilities for confronting it. The PAR evidence shows that farmers are already developing locally adapted practices that strengthen resilience,

diversify food and income sources, rebuild soils and reduce dependence on external inputs. Habib's synthesis situates these experiences within a broader body of scientific and international evidence, arguing that climate mitigation and adaptation can be mutually reinforcing when food systems regenerate living soils, biodiversity, and ecological processes, rather than deepening dependence on fossil fuels and chemical inputs. At the same time, such a transition cannot be reduced to changes in farm management alone: it also requires addressing inequalities in access to land, water, seeds, markets and decision-making power, and protecting the rights and agency of the people who produce and consume food.

The collective evidence therefore makes a compelling case for shifting climate and agricultural policy away from narrow productivity-centred approaches and towards farmer-led, agroecological and socially just food systems. Such a shift is not only about improving agricultural resilience. It is about regenerating the ecological foundations of food production, strengthening food sovereignty, protecting the rights and agency of rural communities, and ensuring that public policy and investment serve people and nature rather than allowing concentrated corporate power to shape food systems primarily around profit.

Breaking the climate-industrial agriculture cycle: Why agroecology is a climate imperative

Nasira Habib

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Introduction

Climate change and the global food crisis are increasingly recognised as interconnected outcomes of the dominant industrial model of agricultural development. Modern industrial agriculture has contributed significantly to increases in greenhouse gas emissions through intensive fossil-fuel use, large-scale monocultures, dependence on synthetic fertilisers and pesticides, mechanisation, land-use change, and ecologically destructive production systems.

At the same time, agriculture remains among the sectors most vulnerable to climate disruption because food production depends heavily on climatic stability, ecological resilience, and functioning natural systems.

Global average surface temperatures have already increased by approximately 1.1 °C above pre-industrial levels, contributing to more frequent droughts, floods, heatwaves, erratic rainfall patterns, and ecosystem instability (IPCC, 2022). These climatic changes are increasingly disrupting agricultural productivity worldwide. Rising temperatures shorten crop growth periods, increase evapotranspiration, intensify water stress, accelerate pest reproduction, and destabilise food systems that historically depended on relatively predictable seasonal cycles.

The dominant policy response to agricultural climate impacts has largely focused on improving industrial efficiency through technological intensification, including precision fertiliser application, genetically modified crops, climate-smart seeds, digital agriculture, and expanded irrigation infrastructure. While such interventions may improve short-term efficiency, they often leave

the underlying structural drivers of ecological vulnerability intact: monocultures, soil degradation, biodiversity loss, fossil-fuel dependence, and external-input-intensive production systems.

This paper argues that agroecology offers a more systemic and scientifically grounded pathway for addressing the interconnected crises of climate change, ecological degradation, and food insecurity. Agroecology is not merely a collection of alternative farming techniques. Rather, it represents a broader ecological paradigm grounded in biodiversity, soil regeneration, biological nutrient cycling, ecological resilience, local knowledge systems, and reduced dependence on fossil-fuel-intensive external inputs.

Drawing upon scientific literature, international policy frameworks, and global case studies, this paper demonstrates that agroecological and regenerative farming systems can simultaneously contribute to climate mitigation, climate adaptation, biodiversity restoration, soil regeneration, and food-system resilience. Particular attention is given to the role of soil biology and soil carbon sequestration, the reduction of fossil-fuel dependence in food systems, and the growing international recognition of agroecology as a climate solution.

The structural crisis of industrial agriculture

Industrial agriculture has become one of the largest contributors to global environmental degradation and climate instability. According to the Intergovernmental Panel on Climate Change (IPCC), the agriculture, forestry, and land-use sector accounts for approximately 21–23% of global anthropogenic greenhouse gas emissions (IPCC, 2019; IPCC, 2022). Food systems as a whole—including fertiliser production, livestock, transport,

refrigeration, processing, packaging, and waste—contribute approximately one-third of global greenhouse gas emissions (Crippa et al., 2021).

Industrial agriculture is fundamentally organised around ecological simplification and dependence on external inputs. Large-scale monocultures replace biodiverse ecosystems with genetically uniform crop systems that require continuous chemical and fossil-fuel support. Fertility is maintained through synthetic fertilisers rather than biological nutrient cycling. Pest management depends heavily on pesticides rather than ecological regulation through biodiversity and predator–prey interactions.

The expansion of monocultures has dramatically transformed agricultural landscapes worldwide. In the United States, maize and soybean monocultures cover more than 70 million hectares, while soybean monocultures occupy more than 60 million hectares across Brazil and Argentina. In South Asia, rice–wheat monoculture systems dominate more than 13 million hectares across the Indo-Gangetic Plains. Such simplified ecosystems are often highly productive under stable conditions but increasingly vulnerable to climatic shocks, pest outbreaks, soil degradation, and ecological instability.

Industrial agriculture also degrades soil ecosystems. Intensive tillage, synthetic fertilisers, heavy machinery, and pesticide use reduce microbial diversity, accelerate erosion, and deplete soil organic matter. Lal (2004) estimates that cultivated soils globally have lost approximately 116–133 gigatonnes of carbon due to land conversion and intensive agricultural practices. This represents one of the largest historical transfers of carbon from ecosystems to the atmosphere.

Synthetic nitrogen fertilisers are among the largest sources of agricultural greenhouse gas emissions. Their production through the Haber–Bosch process consumes approximately 1–2% of global energy supply and emits substantial quantities of carbon dioxide (Erisman et al., 2008).

When emissions from fertiliser production and soil-based nitrous oxide emissions are combined, synthetic fertilisers contribute significantly to global warming. Nitrous oxide (N_2O) is particularly important because it has a global warming potential approximately 265–298 times greater than carbon dioxide over a 100-year period (IPCC, 2021).

Industrial food systems are also heavily dependent on fossil fuels through mechanisation, irrigation, processing, refrigeration, packaging, and long-distance transportation. Modern agricultural

systems, therefore, remain structurally linked to fossil-fuel-intensive economic systems.

Beyond incremental reform: the structural limits of industrial agriculture

Dominant policy responses to agricultural climate impacts have largely focused on improving industrial efficiency through technological intensification, including precision fertiliser application, climate-smart seeds, digital agriculture, expanded irrigation infrastructure, and genetic engineering. While such interventions may improve short-term efficiency, they often leave the underlying structural causes of ecological vulnerability intact.

Industrial agriculture remains fundamentally dependent on monocultures, external chemical inputs, ecological simplification, and fossil-fuel-intensive production systems. Fertility is maintained through synthetic fertilisers rather than biological nutrient cycling. Pest management relies heavily on pesticides rather than ecological regulation. Productivity depends upon continuous fossil-fuel inputs for machinery, fertiliser production, transport, refrigeration, and processing.

This distinction between efficiency and resilience is critical. Highly specialised industrial systems may produce high yields under stable conditions, but they are frequently more vulnerable to climatic shocks because ecological buffering mechanisms have been removed. Diversified agroecosystems, by contrast, distribute risk across multiple crops, species, and ecological interactions, making them better able to absorb climatic variability without catastrophic system failure.

The climate crisis increasingly exposes the ecological limits of industrial agriculture's dependence on monocultures, external inputs, and fossil-fuel-intensive production systems.

Agroecology as a climate solution

Agroecology has emerged globally as one of the most important alternatives to industrial agriculture because it simultaneously addresses climate change mitigation and adaptation, biodiversity conservation, soil regeneration, and food security.

Agroecology applies ecological principles to the design and management of food systems. Rather than maximising short-term yields through chemical intensification, agroecological systems seek

to strengthen ecological relationships among soils, plants, microorganisms, water systems, insects, animals, and human communities.

Key agroecological principles include:

- Biodiversity and crop diversification
- Soil regeneration and biological nutrient cycling
- Reduced dependence on synthetic inputs
- Ecological pest regulation
- Agroforestry and integrated farming systems
- Farmer knowledge and participatory learning
- Local seed systems and food sovereignty
- Reduced fossil-fuel dependence

Agroecological systems strengthen ecological resilience by restoring biodiversity and rebuilding the biological foundations of agricultural productivity. Diversified systems reduce vulnerability to climatic shocks because ecological risk is distributed across multiple species and interactions.

Meta-analyses show that diversified farming systems frequently maintain more stable yields under drought and climatic variability than highly specialised monocultures (Renard & Tilman, 2019). Diversification also strengthens ecosystem services such as pollination, nutrient cycling, water retention, and natural pest regulation.

Agroecology, therefore, represents not merely a technical modification of industrial agriculture but a broader ecological transition toward regenerative and climate-resilient food systems.

Soil life, soil health, and carbon sequestration

One of the most important yet frequently overlooked dimensions of climate mitigation is the role of soil life in regulating the global carbon cycle. Soils contain more carbon than the atmosphere and terrestrial vegetation combined, making them one of the largest carbon reservoirs on Earth (Lal, 2004; Paustian et al., 2016).

Healthy soils are living ecosystems composed of bacteria, fungi, protozoa, nematodes, arthropods, earthworms, plant roots, and complex microbial networks that regulate nutrient cycling,

decomposition, soil aggregation, and long-term carbon storage.

The process begins with photosynthesis, through which plants absorb atmospheric carbon dioxide and convert it into carbon-based compounds. A substantial proportion of this carbon is transferred belowground through roots and root exudates, where it feeds soil microorganisms (Jones et al., 2009). Soil microbes then transform this carbon into microbial biomass and stable soil organic matter.

Fungi, particularly mycorrhizal fungi, play an especially important role by transporting carbon deeper into soil systems and contributing to the formation of stable soil aggregates that physically protect carbon from oxidation and erosion.

Industrial agriculture disrupts these biological processes through intensive tillage, monocultures, and the use of synthetic fertilisers, fungicides, and pesticides. Tillage breaks apart soil aggregates, exposes protected organic matter to oxygen, and accelerates oxidation of soil carbon, releasing carbon dioxide into the atmosphere.

Agroecological and regenerative farming systems reverse this process by rebuilding biological activity and restoring ecological nutrient cycling. Practices such as composting, cover cropping, agroforestry, crop diversification, rotational grazing, reduced tillage, and mulching increase organic matter inputs while supporting microbial activity and aggregate formation.

Meta-analysis evidence demonstrates that organic and diversified systems consistently increase soil organic carbon relative to conventional systems. Gattinger et al. (2012), analysing 74 datasets globally, found that organic systems increased soil carbon stocks by approximately 3.5 Mg C ha⁻¹ on average, corresponding to sequestration rates of approximately 0.45 Mg C ha⁻¹ yr⁻¹. In simple terms, this means that each hectare of organically managed farmland stored approximately 450 kilograms of additional carbon in the soil annually compared with conventional systems.

The importance of biologically active soils becomes particularly evident under climate stress. Soils rich in organic matter and microbial activity retain more water, improve infiltration, reduce erosion, and buffer crops against droughts and floods.

The Rodale Institute's Farming Systems Trial demonstrated that regenerative organic systems outperformed conventional systems during drought years because healthier soils retained greater moisture and maintained higher biological activity (Rodale Institute, 2022; LaCanne & Lundgren, 2018). Similarly, long-term restoration projects in Tigray, Ethiopia, demonstrated that rebuilding soil fertility and vegetation cover significantly improved water retention, crop productivity, and resilience under semi-arid conditions (Nyssen et al., 2007).

The soil food web and biological regeneration

The Soil Food Web approach, developed by Elaine Ingham, has played an influential role in advancing biologically based understandings of soil regeneration and climate-resilient agriculture.

According to Ingham, soils function as complex living ecosystems whose biological communities regulate nutrient cycling, plant immunity, soil structure, water retention, and long-term carbon storage. The Soil Food Web framework argues that restoring complete microbial communities through composting, cover cropping, reduced tillage, and biodiversity can simultaneously improve soil fertility, reduce dependence on synthetic fertilisers and pesticides, increase water retention, and strengthen climate resilience.

The Soil Food Web School and associated practitioner networks report that farmers adopting biologically based soil management have reduced dependence on synthetic inputs while improving soil structure, moisture retention, and crop performance. According to Soil Food Web practitioner documentation, participating farmers have, in some cases, reported major reductions in chemical inputs and irrigation requirements following the restoration of soil biological functioning.

Although some claims about compost teas and microbial inoculations remain debated in the scientific literature, there is a growing consensus on the importance of soil biodiversity and microbial functioning for long-term agricultural sustainability.

Ingham's work helped shift global attention toward the biological foundations of soil health. It strengthened broader agroecological arguments that restoring soil ecology is central to both climate mitigation and climate adaptation.

Biodiversity and ecological regulation

One of the central weaknesses of industrial agriculture is ecological simplification. Monocultures reduce biodiversity, weaken ecosystem stability, and increase vulnerability to climatic shocks and pest outbreaks.

Agroecological systems instead increase ecological complexity through crop diversification, intercropping, agroforestry, habitat integration, and diversified rotations.

Diversified agroecosystems strengthen ecological pest regulation, pollination, nutrient cycling, soil fertility, biodiversity, water regulation, and yield stability.

Large syntheses show that agricultural diversification substantially increases ecosystem services while maintaining stable yields (Tamburini et al., 2020).

Climate change further underscores the importance of ecological regulation, as rising temperatures accelerate insect metabolism, reproduction, survival, and geographic expansion (Deutsch et al., 2018; Skendžić et al., 2021).

Agroecological systems strengthen populations of beneficial insects, pollinators, predators, and soil organisms that naturally regulate pest populations, thereby reducing dependence on synthetic pesticides (Altieri, 1999).

Evidence from ecological rice systems in Asia demonstrated that habitat diversification and conservation of natural enemies significantly reduced pesticide use while maintaining yields and improving biodiversity (Settle et al., 1996).

Agroecology and reduction of fossil-fuel dependence

Agroecological systems contribute to climate mitigation not only through carbon sequestration but also by reducing dependence on fossil-fuel-intensive external inputs.

Industrial food systems depend heavily on synthetic fertilisers, pesticides, mechanisation, industrial processing, refrigeration, packaging, and long-distance transportation.

Agroecological systems reduce these dependencies by replacing energy-intensive external inputs with ecological functions such as biological nitrogen fixation, nutrient recycling, ecological pest regulation,

biodiversity-based resilience, composting, and soil biological fertility.

Comparative studies show that diversified agroecological systems frequently reduce synthetic fertiliser and pesticide use while lowering fossil-energy demand (Pretty et al., 2006).

The Rodale Institute's Farming Systems Trial found that regenerative organic systems used approximately 45% less energy than conventional industrial systems while maintaining comparable yields after transition periods (Rodale Institute, 2022).

This evidence supports the broader agroecological argument that climate mitigation requires both rapid reductions in fossil-fuel dependence and ecological regeneration through restoration of living soils and ecosystems.

International recognition of agroecology as a climate solution

Over the past two decades, agroecology has gained increasing recognition within international scientific, policy, and multilateral institutions as a critical pathway to address climate change, biodiversity loss, soil degradation, food insecurity, and rural vulnerability.

One of the most influential international initiatives linking soil restoration and climate mitigation is the “4 per 1,000” Initiative, launched at the 2015 United Nations Climate Conference (COP21). The initiative proposed that increasing global soil organic carbon stocks by just 0.4% annually could substantially offset anthropogenic greenhouse gas emissions while simultaneously improving soil fertility, biodiversity, water retention, and food security (Lal, 2016; Minasny et al., 2017).

The Food and Agriculture Organisation (FAO) has also become one of the most prominent institutional advocates of agroecology within the United Nations system. FAO explicitly recognises agroecology as an approach capable of simultaneously improving biodiversity, strengthening resilience to climate shocks, restoring soils, reducing dependence on synthetic inputs, and supporting smallholder livelihoods.

The IPCC increasingly recognises the importance of soil carbon sequestration, agroforestry, diversified farming systems, ecosystem restoration, and sustainable land management within climate mitigation and adaptation pathways (IPCC, 2022).

Similarly, UNEP, the Convention on Biological Diversity, and the United Nations Convention to Combat Desertification increasingly recognise ecological restoration, sustainable land management, and biodiversity-based agriculture as essential components of climate resilience and ecosystem recovery.

Civil society movements such as PANAP and numerous farmer-led agroecological networks have also played a major role in advancing agroecology internationally through farmer-to-farmer learning, seed sovereignty, ecological farming systems, and climate justice advocacy.

From recognition to transformation: why industrial agriculture still dominates

Despite growing international recognition of agroecology, industrial agriculture continues to dominate global food-production systems, agricultural policy, subsidies, trade regimes, and scientific research agendas.

Most governments and international financial institutions still prioritise export-oriented monocultures, chemical-intensive production systems, genetically uniform crop varieties, large-scale mechanisation, and fossil-fuel-dependent supply chains as the primary pathway for agricultural development.

Global agricultural subsidies overwhelmingly favour synthetic fertilisers, industrial livestock systems, irrigation megaprojects, commodity monocultures, and agribusiness value chains rather than diversified ecological farming systems (IPES-Food, 2016).

This contradiction reveals a deeper structural tension within contemporary climate and agricultural policy. While international institutions increasingly acknowledge the ecological benefits of agroecology, these approaches often remain marginal within mainstream agricultural investment and policy frameworks.

Current agricultural transitions, therefore, frequently remain limited to forms of “sustainable intensification” or “climate-smart agriculture” that seek to improve efficiency within industrial systems rather than fundamentally transforming their ecological foundations.

Agroecological movements and many critical scholars argue that meaningful climate stabilisation requires not merely incremental reform of industrial

agriculture but a broader transition toward ecologically regenerative food systems grounded in biodiversity, living soils, local knowledge systems, reduced dependence on fossil fuels, and democratic control over food production.

Case studies in agroecological climate resilience

Soil food web approach: Elaine Ingham and biological soil regeneration

The Soil Food Web approach, developed by Elaine Ingham, is one of the most influential biologically based approaches to soil regeneration and climate-resilient agriculture.

According to Ingham, soils function as complex living ecosystems composed of bacteria, fungi, protozoa, nematodes, arthropods, earthworms, plant roots, and microbial interactions that regulate nutrient cycling, plant immunity, soil aggregation, water retention, and long-term carbon storage.

The Soil Food Web framework argues that industrial agriculture disrupts these ecological processes through intensive tillage, synthetic fertilisers, fungicides, pesticides, and monocultures. In response, the approach promotes composting, reduced tillage, biodiversity, cover cropping, rotational grazing, and restoration of microbial communities.

According to Soil Food Web practitioner documentation, farmers adopting biologically based soil management have, in some cases, reported substantial reductions in dependence on chemical inputs and in irrigation requirements following the restoration of soil biological function.

The Soil Food Web approach has significantly influenced global regenerative agriculture movements by helping shift the attention of scientists and farmers toward the biological foundations of soil health, carbon sequestration, ecological resilience, and climate adaptation.

Project Drawdown: Agroecological climate solutions and systemic carbon reduction

Project Drawdown has become one of the world's most influential climate-solution initiatives by synthesising scientific evidence to identify and rank practical pathways to reduce greenhouse gas emissions and stabilise the climate. A central contribution of Drawdown is its recognition that food systems are simultaneously major contributors

to climate change and important sites for ecological regeneration.

Drawdown identifies multiple agroecological and regenerative practices among the world's most important climate solutions, including agroforestry, improved annual cropping, regenerative grazing, composting, ecosystem restoration, silvopasture, and improved nutrient management.

These practices reduce emissions not only by increasing soil carbon sequestration but also by reducing dependence on synthetic fertilisers, fossil-fuel-intensive inputs, and environmentally destructive land-use systems.

The initiative's systems perspective is particularly important because it rejects the idea that climate stabilisation can be achieved through isolated technological interventions alone. Instead, Drawdown emphasises that climate mitigation requires simultaneous reductions in fossil-fuel emissions and restoration of ecological processes. Its framework, therefore, aligns strongly with agroecological approaches that integrate biodiversity restoration, soil regeneration, food security, and climate resilience.

Drawdown also highlights the climate costs of industrial food systems, including fertiliser manufacture, monocultures, land-use change, refrigeration, packaging, livestock emissions, and long-distance transportation. The initiative, therefore, supports diversified low-input systems, ecological nutrient cycling, reduced food waste, and ecosystem restoration as interconnected climate strategies.

Importantly, Project Drawdown adopts a relatively cautious scientific position regarding the limits of soil carbon sequestration. It recognises that regenerative agriculture alone cannot fully reverse climate change, but argues that restoration of soils and ecosystems represents an essential component of broader decarbonisation pathways.

Rodale Institute: Regenerative organic agriculture and climate resilience

The Rodale Institute's Farming Systems Trial (FST), established in 1981 in Pennsylvania, USA, is the world's longest-running side-by-side comparison of conventional and organic grain production systems. Over more than four decades, the trial has generated one of the most comprehensive bodies of scientific evidence demonstrating that regenerative organic agriculture can simultaneously contribute to climate-change

mitigation, climate adaptation, and long-term agricultural sustainability (Rodale Institute, 2022; LaCanne & Lundgren, 2018).

The Farming Systems Trial showed that regenerative organic systems use 45% less energy and produce 40% lower carbon emissions than conventional systems by replacing synthetic inputs with biological nitrogen fixation, crop rotations, cover crops, and compost (Rodale Institute, 2022). Decades of organic management increased soil organic carbon stocks by 23–40%, alongside higher microbial biomass, organic matter, and improved soil structure (Tkach et al., 2024). During droughts, organic maize yields were 31% higher due to better moisture retention and deeper roots (Rodale Institute, 2022). These findings align with LaCanne and Lundgren (2018), who confirmed that regenerative farming boosts water retention, biological health, and climate resilience while remaining economically competitive.

The Farming Systems Trial demonstrates that agroecological management mitigates climate change by cutting fossil-fuel dependence, lowering emissions, sequestering soil carbon, and boosting climate resilience. Unlike chemical-dependent conventional agriculture, regenerative organic farming relies on natural ecological processes to maintain productivity while renewing ecosystems. Ultimately, Rodale's long-term evidence proves that agroecology is not just a viable alternative, but an essential imperative for building climate-resilient, low-carbon food systems.

Brazilian biological nitrogen fixation: Replacing fossil-fuel fertilisers with ecological processes

Brazil provides one of the world's most compelling examples of how ecological processes can replace fossil-fuel-intensive agricultural inputs at the national scale. Since the 1970s, scientists at the Brazilian Agricultural Research Corporation (Embrapa), led by Mariangela Hungria and colleagues, have developed highly effective inoculants containing *Bradyrhizobium* species that fix atmospheric nitrogen in symbiosis with soybean roots. More recently, co-inoculation with *Azospirillum brasilense* has further enhanced biological nitrogen fixation (BNF), improving nutrient uptake and crop productivity (Hungria et al., 2023).

Nearly all of Brazil's 36–37 million hectares of soybeans rely on biological nitrogen fixation (BNF) rather than synthetic fertilizers, one of history's largest replacements of fossil-fuel inputs with natural processes. BNF saves Brazilian farmers

roughly \$15.2 billion annually and avoids ~183 million tonnes of CO₂-equivalent emissions per season. Adding co-inoculation technology boosts yields by 8% and adds over \$111/ha in profit, reaching one-quarter of soybean land by 2019–2020 (Hungria et al., 2023).

Brazil's adoption of soil microorganisms demonstrates that biological processes can replace synthetic nitrogen fertilizers, eliminating the need for fossil-fuel-intensive Haber–Bosch manufacturing and reducing nitrous oxide emissions. By using microbial symbioses instead of energy-heavy tech, Brazilian agriculture cuts emissions and input costs while maintaining high productivity. Ultimately, this success proves agroecological nutrient management is a practical, profitable strategy for decarbonizing modern farming.

Farmer-managed natural regeneration in Niger: restoring climate resilience through ecological regeneration

FMNR in Niger is a premier example of large-scale agroecological restoration. Instead of planting costly seedlings, farmers restore landscapes by managing living tree stumps and root systems surviving in their fields. Beginning in the 1980s, farmers stopped clear-cutting emerging shoots, choosing instead to selectively prune and protect the strongest stems while cropping around them. This simple, low-cost innovation uses natural ecological processes rather than expensive external inputs (Reij et al., 2009; Tougiani et al., 2009).

Over the following three decades, FMNR expanded across approximately 5 million hectares of agricultural land, resulting in the regeneration of an estimated 200 million trees. Species such as *Faidherbia albida*, *Guiera senegalensis*, and *Combretum glutinosum* restored multiple ecosystem functions by increasing litter inputs, enhancing biological nutrient cycling, improving soil organic matter, reducing wind and water erosion, moderating soil temperatures, and increasing water infiltration. The regenerated agroforestry parklands also created habitat for birds, insects, and other beneficial organisms, thereby enhancing biodiversity and strengthening ecosystem functioning across the Sahel.

FMNR's ecological restoration delivers clear agricultural and socioeconomic gains. Cereal yields increased by 31 to 350 kg/ha, adding roughly 500,000 tonnes of grain annually, while households gained extra income and saved time through

increased fuelwood, fodder, fruit, and timber production. Additionally, regenerated trees improved soil moisture and reduced drought-related crop losses, proving that restoration directly strengthens food security, rural livelihoods, and climate resilience.

FMNR drives significant climate mitigation by sequestering carbon across Niger's five million restored hectares. Agroforestry parklands store an estimated 1.6–10 tonnes of carbon per hectare in above-ground biomass, averaging roughly 30 million tonnes total, or 110 million tonnes of atmospheric CO₂ removed, with root systems holding comparable amounts. While litter and root turnover also build soil organic carbon, direct long-term data for soil storage remains sparse compared to the robust evidence for biomass accumulation, marking a key priority for future research.

FMNR's key strength lies in its minimal cost: farmers restore degraded land using native biodiversity and natural regeneration rather than expensive fertilizers, irrigation, or engineering. Niger's widespread, farmer-led adoption proves that ecological knowledge can simultaneously boost yields, restore ecosystems, build climate resilience, and sequester carbon. Ultimately, this success demonstrates that agroecological restoration is a scalable, cost-effective imperative for global climate mitigation and adaptation.

Conclusion

The climate crisis and the global food crisis are deeply interconnected outcomes of an industrial agricultural model built upon monocultures, fossil-fuel dependence, synthetic chemical inputs, ecological simplification, and the extraction of natural systems. Scientific evidence increasingly demonstrates that industrial agriculture is simultaneously a major contributor to climate change and one of its most vulnerable sectors. Rising temperatures, droughts, floods, biodiversity collapse, soil degradation, pest outbreaks, and ecological instability are already undermining agricultural productivity and threatening food security worldwide.

The evidence reviewed in this paper demonstrates that agroecological and regenerative approaches offer one of the most scientifically robust pathways for addressing these interconnected crises. Agroecology is not merely an alternative set of farming practices. It represents a systemic ecological transformation grounded in biodiversity, soil regeneration, biological nutrient cycling, ecological

resilience, farmer knowledge systems, reduced dependence on fossil-fuel-intensive inputs, and the restoration of ecological relationships.

Evidence from the Rodale Institute, the Soil Food Web approach, Project Drawdown, Brazil's biological nitrogen fixation programme, Farmer-Managed Natural Regeneration in Niger, and Participatory Action Research conducted across Bangladesh, India, and Nepal demonstrates that diversified ecological farming systems can simultaneously reduce fossil-fuel dependence, restore degraded soils, increase soil carbon sequestration, improve biodiversity, strengthen drought resilience, reduce chemical-input dependence, enhance food-system resilience, and improve rural livelihoods.

The implications extend beyond farm management. If governments are serious about meeting their commitments under the Paris Agreement, the Kunming–Montreal Global Biodiversity Framework, and the Sustainable Development Goals, agricultural policy must move beyond incremental improvements in industrial efficiency towards the ecological regeneration of food systems. Redirecting public investment from input-intensive agriculture towards agroecological research, farmer-led innovation, biodiversity conservation, local seed systems, soil restoration, and ecological knowledge-sharing would contribute not only to climate mitigation and adaptation but also to healthier ecosystems, more resilient rural economies, and greater food sovereignty.

Agroecology does not present soil carbon sequestration as a substitute for rapid reductions in fossil-fuel emissions. Rather, it recognises that meaningful climate stabilisation requires the simultaneous decarbonisation of industrial systems and the regeneration of living soils, biodiversity, forests, water systems, and agroecosystems. The climate crisis is fundamentally a crisis of broken ecological relationships, and its resolution requires rebuilding those relationships at every level of the food system. Agroecology offers one of the few approaches capable of integrating climate mitigation, climate adaptation, biodiversity restoration, soil regeneration, food security, public health, and social justice within a single coherent framework.

The weight of scientific evidence now suggests that agroecology should no longer be regarded as a niche alternative to industrial agriculture, but as an essential foundation for sustainable food systems and a climate imperative for the twenty-first century.

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Bangladesh: Barind Region

Bangladesh Resource Centre for Indigenous Knowledge (BARCIK)

Executive summary

Climate change has emerged as one of the most pressing challenges affecting rural communities worldwide. In Bangladesh, the impacts are particularly severe in drought-prone areas such as the Barind region of northwestern Bangladesh, where rising temperatures, erratic rainfall, prolonged dry spells, and declining groundwater levels are increasingly threatening agriculture, biodiversity, and rural livelihoods.

At the same time, growing scientific and policy discussions recognise agroecology as a promising pathway to address climate change, restore ecosystems, and strengthen food systems through biodiversity, local knowledge, and community-led innovations. Against this backdrop, this Participatory Action Research (PAR) documentation was conducted to understand how climate change is affecting rural communities in the Barind region and how agroecological practices are helping farmers respond to these challenges.

The study was carried out in Mundumala village under Mundumala Municipality in Tanore Upazila of Rajshahi District, located within the drought-prone Barind region of Bangladesh. The research adopted a participatory approach emphasising community voices, lived experiences, and co-generation of knowledge.

Data were generated through two Focus Group Discussions (FGDs) involving twenty participants (9 women and 11 men), seven Key Informant Interviews (KIIs) (3 women and 4 men), seasonal calendars, historical timeline exercises, community mapping, and a Solution Tree exercise. These participatory tools enabled participants to collectively analyse changes occurring in their environment, identify existing vulnerabilities, and envision possible pathways towards resilient futures.

Findings show climate change is disrupting agriculture and daily life in the Barind region through rising temperatures, longer summers, and unpredictable rain. Extended droughts, delayed monsoons, and extreme rainfall confuse planting

calendars, while dropping groundwater levels raise irrigation costs and deepen water scarcity. Consequently, farmers face declining crop yields, pest outbreaks, and soil degradation, with monocropping and input-dependent farms suffering the highest vulnerabilities and costs.

Climate impacts extend far beyond agriculture. Households reported declining incomes, increasing indebtedness, food insecurity, and growing uncertainties about the future. Women often bear disproportionate burdens during periods of food shortages and financial stress. Landless labourers face declining employment opportunities, while many young people are becoming increasingly reluctant to engage in farming. The findings indicate that climate change is not only an environmental issue but also a question of equity, livelihoods, and social justice.

One of the most important findings emerging from this study is that agroecology is already being practised in different forms within the community and contributes significantly to strengthening resilience.

Farmers have developed diverse strategies to cope with climatic stresses. These include adjusting planting dates, diversifying crops, mixed cropping, integrating trees and livestock, conserving local seeds, producing compost, practising mulching, and using ecological pest management approaches. Participants repeatedly emphasised that diversified farming systems provide greater stability under uncertain climatic conditions.

Households practising agroecological approaches reported lower production costs, improved soil fertility, increased crop diversity, and reduced dependence on external inputs. Home gardens, livestock, trees, and local seeds were found to contribute significantly to household food security and risk reduction.

The findings suggest that strengthening resilience in the Barind region requires more than technological solutions. Supportive policies, investments, and collective actions are equally important.

Overall, the findings suggest that climate change is profoundly affecting rural communities in the Barind region. Yet communities are not passive victims. They possess rich knowledge, adaptive capacities, and collective strengths that contribute to building resilience. Agroecology is already being practised through crop diversity, local seeds, soil and water conservation, and collective action. Strengthening climate resilience in the Barind region will require supportive policies, investments, farmer-to-farmer learning, and stronger social movements that recognise and build upon the knowledge and aspirations of farming communities themselves.

Objectives of the study

The overall objective of this PAR was to document how climate change is affecting rural communities in the Barind region of Bangladesh and to explore how agroecological practices contribute to building climate resilience.

The specific objectives were:

- To understand how rural communities perceive and experience climate change and its impacts on their lives and livelihoods.
- To document changes in climate, agriculture, biodiversity, water resources, and household well-being.
- To identify local responses and agroecological practices adopted by farmers.
- To explore how these practices contribute to climate resilience.
- To document community knowledge, experiences, and collective solutions for strengthening adaptation and food sovereignty.

The study was guided by two research questions:

1. How is the climate crisis impacting rural communities in the Barind region of Bangladesh?
2. How does agroecology contribute to climate resilience among rural communities in the Barind region of Bangladesh?

Study location

The study was conducted in Mundumala village, under Mundumala Municipality, in Tanore Upazila, Rajshahi District, Bangladesh. The village is situated in the Barind region of northwestern Bangladesh, which is widely recognised as one of the country's most drought-prone agroecological zones. The area is characterised by relatively low and erratic rainfall,

high summer temperatures, hard clay soils, and a heavy dependence on groundwater for irrigation. Over the years, increasing climatic variability and recurring water scarcity have become major concerns for farming communities.

Agriculture remains the principal source of livelihood in Mundumala village. Most households depend directly or indirectly on farming, agricultural wage labour, livestock rearing, and homestead production. Rice, wheat, maize, mustard, vegetables, mango, and seasonal crops are commonly cultivated, while livestock and homestead gardens provide additional sources of food and income.

The farming landscape reflects many of the characteristics of the wider Barind region. Farmers face recurrent drought, rising irrigation costs, declining groundwater availability, and growing uncertainty due to changing rainfall patterns. Participants repeatedly identified water scarcity and drought as the most pressing challenges affecting both agriculture and everyday life. During the discussions, an elderly farmer remarked: "*The Barind tract is synonymous with drought and water scarcity.*"

Despite these challenges, the village also represents a rich repository of local knowledge and diverse farming practices. Crop diversification, homestead gardening, livestock rearing, tree planting, local seed conservation, and various ecological farming practices are already present in the community and continue to support household livelihoods and resilience.

A location map of the study area is provided in *Annex 1*.

Participants

The study involved farmers and community members with diverse experiences and long-standing connections to agriculture and rural life. Efforts were made to ensure the participation of both women and men, as well as individuals representing different social and farming backgrounds.

Two Focus Group Discussions (FGDs), corresponding to the two research questions, were conducted with a total of twenty participants. Among them, eleven were men, and nine were women. In addition, seven Key Informant Interviews (KIIs) were conducted with four men and three women who had long-term knowledge and practical experience in farming, climate variability, and community life.

Participants included smallholder and marginal farmers, women farmers, elderly farmers, agricultural labourers, and community members who have been practising different agroecological approaches.

Several participants had more than thirty years of farming experience and were able to reflect on changes in climate, cropping patterns, water availability, and local biodiversity over time.

Particular attention was given to women's experiences and the memories of elderly farmers. Their observations and lived experiences provided valuable insights into changing weather patterns,

livelihood challenges, and locally developed adaptation strategies. The diversity of participants enriched the collective discussions and helped capture multiple perspectives on climate impacts and agroecological resilience.

Table 1 summarises the participants' profiles.

Table 1. Profile of participants per research method

Research Method	Male	Female	Total
FGD & Seasonal Calendar/Historical Timeline	11	9	20
Key Informant Interviews	4	4	8
Oral History	2	1	3
Case Study	1	1	2
Total participants	18	15	33

Participants include smallholder farmers, marginal farmers, women farmers, youth farmers, agricultural labourers, farmers practising agroecological approaches, and community members with long-term local knowledge.

Special attention was given to capturing the perspectives of women and experienced elders, whose knowledge and observations provided important insights into long-term changes and adaptation practices, as several participants belonged to more than one category.

The participant list is provided in *Annex 2*.

Research methods

Multiple participatory research methods were used to understand climate impacts and agroecological responses from community members' perspectives.

Focus Group Discussions (FGDs): Two FGDs were conducted. The first FGD explored how climate change is affecting rural communities and livelihoods, corresponding to research question 1 (*How is the climate crisis impacting rural communities in the Barind region of Bangladesh?*). The second FGD focused on agroecological practices and climate resilience, corresponding to research question 2 (*How does agroecology contribute to climate resilience among rural communities in the Barind region of Bangladesh?*). Each discussion involved ten participants and encouraged collective reflection and sharing of experiences.

Semi-structured interviews/Key Informant Interviews (KIIs): Seven KIIs were conducted with farmers and community members possessing diverse experiences and knowledge.

These interviews provided deeper insights into long-term environmental changes, farming practices, local knowledge, and adaptation strategies.

Seasonal Calendar: Seasonal calendar exercises were conducted to understand seasonal variations in rainfall, drought, cropping patterns, labour demand, food availability, diseases, and water scarcity. Participants compared the present conditions with those of previous years and reflected on changing seasonal patterns.

Historical Timeline and Oral History: Historical timeline exercises enabled participants to collectively reconstruct major changes experienced over the last few decades. Discussions focused on droughts, changes in rainfall, irrigation patterns, crop diversity, groundwater decline, changes in seeds and farming systems, and social and economic transformations. These reflections helped contextualise present challenges within broader historical processes.

Community Mapping: Community discussions and observations were used to understand important local resources, agricultural areas, water sources, and livelihood activities. Community Mapping is provided in *Annex 3*.

Solution Tree: A Solution Tree exercise was conducted to identify community visions, root causes, strategies, and desired outcomes for strengthening

climate resilience. This exercise enabled participants to collectively imagine pathways towards more sustainable and resilient futures. Solution Tree is provided in *Annex 4*.

Table 2 summarises the number of research methods carried out.

Table 2. Summary of research methods conducted

Research method	Number conducted
Focus Group Discussions	2
Semi-structured Interviews / Key Informant Interviews	7
Seasonal Calendar	1
Historical Timeline / Oral History	1

Using multiple participatory methods enabled the research to capture diverse perspectives and strengthen the credibility of the findings through triangulation. Throughout the research process, emphasis was placed on listening to people's experiences, documenting local knowledge, and creating space for collective reflection. In this sense, the research was not only about collecting information but also about learning together with the community.

FINDINGS: IMPACT OF CLIMATE CHANGE

Perceptions of climate change

The community's perception of climate change is deeply rooted in their historical memory. During the oral history sessions, elder farmers noted that while droughts occurred in the past (such as the severe dry spells of 1994 and 2006), the nature of modern droughts is fundamentally different. Historically, the ecosystem retained a capacity to recover, but contemporary climatic shifts exhibit prolonged heatwaves and unpredictable precipitation cycles that defy traditional weather patterns. This shift is vividly captured in the testimony of an elderly local farmer: *"Nature used to follow a rhythm; we knew the rains would arrive by the month of Asharh. Now, the clouds gather but do not yield rain. The scorching heat that once belonged only to Baishakh now stretches all the way into Kartika, burning our backs and drying our soils."*

Observed changes in climate and weather

Mundumala residents understand the climate crisis not through scientific metrics, but through lived experience and generational memory. Oral histories from 20 local farmers reveal that while historic droughts (such as those in 1982, 1994, and 2006) allowed ecological recovery, modern shifts do not.

Today's relentless heatwaves and volatile rainfall defy traditional seasonal patterns and exceed the ecosystem's capacity to adapt.

The community's detailed observations over the past decade converge around four interconnected climate themes:

- **Rising temperatures and extended heatwaves:** Participants universally reported a marked increase in summer temperatures, accompanied by prolonged periods of extreme heat (Dabahao). This intense pre-monsoon and monsoon heat exerts immense thermal stress on crops, limits safe working hours for smallholders in the fields, and rapidly bakes the characteristic Barind clay loam soil into a hardened crust.
- **Irregular rainfall and monsoon shifting:** The predictable rhythm of the monsoons has virtually collapsed. The onset of vital rainfall is consistently delayed, and the traditional six-season calendar no longer dictates farming schedules. The region now experiences extended dry spells during what used to be the wettest months, punctuated by sudden, destructive bursts of torrential rain.
- **Chronic ground- and surface-water drought:** The overarching climate crisis is exacerbated by a severe groundwater drought, locally described as the "sinking of the water table" (Panir Duba). With natural canals (Kharis), community ponds, and seasonal floodplains (Beels) drying up completely, the surface drought has intensified, leaving deep, gaping fissures across agricultural lands.
- **Unseasonal storms and temperature fluctuations:** Farmers highlighted a rising frequency of unseasonal localised windstorms and abrupt temperature shifts, such as sudden cold shocks in

late winter followed immediately by extreme spring heat waves, which severely disrupt the flowering and pollination cycles of both cash crops and traditional grains.

This profound ecological shift and the loss of natural rhythm are captured in the testimony of an elderly local farmer: *"Nature used to follow a rhythm; we knew the rains would arrive by the month of Asharh. Now, the clouds gather but do not yield rain. The scorching heat that once belonged only to Baishakh now stretches all the way into Kartika, burning our backs and drying our soils. In our red-soil region, there is a relentless trap of the sun, even during the monsoon! Far from soaking the earth, the intense heat causes our soils to crack open into deep fissures, and looking at this volatile behaviour of the weather, it has become impossible to calculate or rely on our traditional agricultural calendar anymore."*

Water scarcity and access

The historical timeline of Mundumala village reveals that the groundwater irrigation boom of the 1990s, initially hailed as a technological breakthrough for modern winter-crop cultivation, has gradually become an ecological trap. Decades of unregulated and intensive subsurface water extraction have severely depleted the local aquifer. This ongoing depletion has led to an acute water-justice crisis within the community, where smallholder, marginal, and indigenous farmers are completely losing access to shallow water tables, while wealthier commercial farmers with deeper tubewells monopolise the remaining water resources.

A village elder reflected on this socio-ecological transition during the focus group discussion, using the haunting metaphor of a water-noose: *"When the machines first started pulling water from deep beneath the earth in the nineties, we celebrated, thinking we had finally conquered the drought. We did not realise it was a water-noose (Jol Phanshi). Today, we are paying the price for that brief joy; our household wells have run dry, our community ponds are empty, and the belly of the earth is hollow. All the moisture of our red soil has dried up; now, when we try to farm, no water can be drawn from our ponds or canals. This market-driven chemical farming is slowly tightening the noose around our necks."*

Rising temperatures and extended heatwaves

Almost every participant identified unprecedented atmospheric heat as one of the most immediate and disruptive climatic shifts in Mundumala village. Farmers explained that summers have grown longer, more intense, and visually harsher than in previous decades. According to their observations, extreme

heatwaves (Dabahao) are now a frequent seasonal reality, making physical labour in the open fields during midday increasingly unbearable. This thermal stress directly impairs agricultural productivity and human well-being.

The immediate physical toll on farmers is captured in their field testimonies: *"It was hot in the past, but the heat nowadays feels like an open fire."* Another participant remarked: *"Working in the field for just two hours makes my head spin."* Women participants highlighted that this escalating heat is not confined to the fields; it deeply disrupts gendered household labour and domestic environments. As one woman explained: *"Cooking during the midday is painful now. Even inside our homes, the heat makes it impossible to stay."*

Furthermore, participants observed that crops and ecosystems suffer severely under prolonged heat stress. The intense solar radiation accelerates evaporation, causes vegetable crops to wither rapidly, increases irrigation demand, and induces heat stress in livestock, reducing milk and egg yields. A local farmer described this ecological strain: *"When the heat escalates, the soil moisture vanishes rapidly, and the crops become completely exhausted."*

Historical timeline exercises confirmed that elderly farmers perceive contemporary summers as structurally different from those of their youth. The heat is no longer a brief seasonal phase but an extended period of ecological distress that defies traditional weather calendars: *"We had heat before, but it never lasted this long. Nowadays, the heat simply refuses to leave."* Another elder observed the shift in the ecological calendar: *"The scorching heat that once belonged only to Choitro and Boishakh now stretches all the way into Joishto and Asharh."*

Irregular rainfall and uncertain seasons

Disruptions in historical precipitation regimes emerged as one of the most critical and frequently cited threats to the agricultural survival of Mundumala village. Participants repeatedly emphasised that rainfall has become volatile and deeply irregular over the past decade. The natural timing of the monsoons has been disrupted; prolonged dry spells occur precisely when crops require critical moisture, while unexpected, brief periods of torrential rain arrive during late harvest or land preparation, causing soil erosion and seedbed damage.

Consequently, many farmers stated that they can no longer depend on their traditional eco-centric

knowledge or ancestral weather lore with the same confidence as before. The physical signs of nature, such as cloud movements, wind directions, and animal behaviours, have become unpredictable due to global climate change. An elderly farmer reflected on this loss of ecological predictability during an oral history session: *"In the past, looking at the clouds and the sky was enough to predict almost everything about the weather. Now, even the sky deceives us humans."*

Women participants shared similar experiences of disorientation regarding their critical role in homestead production and biodiversity conservation. The shifting seasons directly disrupt their micro-farming schedules, affecting family nutrition and security: *"Historically, we had a perfect understanding of exactly which vegetable to plant in which month to get a good harvest. Now, most of the time, those calculations simply fail to match reality."*

Seasonal calendar mapping exercises conducted with the community further demonstrated that traditional cropping calendars have become increasingly uncertain and high-risk. Participants repeatedly stressed that the predictable, harmonious seasonal rhythms, remembered and passed down by older generations, are no longer reliable, leaving smallholders in a state of structural vulnerability.

More frequent and prolonged droughts

Mundumala residents universally identified drought as their most severe ecological threat. Historical Mapping and Oral Histories show a stark generational shift: once predictable, cyclical dry spells inherent to the High Barind Tract have become prolonged, chronic disasters driven by global climate change and local ecological imbalance.

The changing face of this environmental reality was contextualised by an elderly participant during an oral history session: *"Drought is nothing new to the Barind tract. However, the droughts of the past and the droughts of today are fundamentally not the same."*

Another farmer, participating in the seasonal matrix mapping, explained the physical transformation of the soil crust: *"In the past, even when rainfall was scarce, the soil retained enough residual moisture to yield something. Now, the earth dries out so completely that the fields crack open into deep fissures."*

During gender-segregated FGDs, participants provided layered descriptions of how these prolonged dry periods trigger a cascading crisis that paralyses the entire agrarian ecosystem. The impacts extend far beyond crop fields, creating severe stress for livestock,

obliterating homestead vegetable gardens (Bari), drying up traditional community ponds, and dangerously reducing the availability of domestic drinking water. This omnipresent water scarcity deeply impacts the psychological well-being of the community, transforming farming from a hopeful livelihood into a state of constant anxiety. A local smallholder observed this psychological and physical drying up of the village: *"When there is no water, it is not just the land that turns into a desert; the very spirit and mind of the people dry up as well."* Another participant added during the open discussion: *"During the reign of drought, everyone exists in a state of absolute, consuming worry."*

The FGDs conducted with women participants brought forward critical gendered dimensions of this ecological distress, highlighting how groundwater depletion directly increases their unpaid domestic workload. As surface water bodies and shallow household wells run completely dry, women and young girls are forced to walk long distances under the scorching sun to fetch drinking water from distant deep tubewells, facing physical exhaustion and body pain. One woman shared her daily struggle: *"When the water recedes into the deep belly of the earth, even the most basic household chores turn into an agonising ordeal."*

Ultimately, the ethnographic findings reveal that the contemporary manifestation of drought has deeply instilled a sense of systemic uncertainty, climate vulnerability, and constant fear within the community. The traditional safety nets of farming have collapsed under the weight of this prolonged water crisis. An elderly indigenous farmer quietly concluded the session with a haunting reflection on this psychological burden: *"The constant terror of an impending drought chases and haunts a human being every single moment of their life."*

Untimely heavy rainfall and temporary waterlogging

Unlike Bangladesh's flood-prone deltas, elevated Mundumala faces hydrological distress not from river overflow but from sudden torrential rain and waterlogging (Jola-boddhota). Because the High Barind Tract's dense clay soil absorbs water poorly, intense downpours rapidly submerge fields and ruin crops.

The devastating impact of these sudden, unseasonal rains on mature crops is vividly articulated in the extended testimonies of the local farmers: *"If a continuous, torrential downpour hits precisely when the paddy starts to ripen, everything is completely destroyed."*

The water accumulates rapidly in the fields, causing the heavy, mature crops to lodge and collapse. The ripe grains get submerged, turn mushy, and rot in the mud, leaving us absolutely unable to harvest or bring anything home."

Another farmer highlighted how this volatile weather mimics the damage of a flood without its physical presence: *"It is true that we do not experience river floods here, but these unseasonal storms and rains do no less damage to us. Just as we desperately search for subterranean water to survive the droughts, this untimely water falling from the sky acts like a knife slicing through our throats."*

Several participants recalled specific seasons when entire fields of mature winter crops or pre-monsoon varieties were ruined overnight by these extreme weather anomalies, pushing smallholders into sudden debt traps. A smallholder shared his experience: *"Often, a single night of torrential rain is enough to completely devastate the condition of the fields. The skies have become so merciless; right before we can harvest the mustard or onions we painstakingly planted, a single night of blinding rain turns the entire field into a waterlogged swamp, causing the crops to rot instantly."*

Women participants added that the consequences of these unseasonal heavy downpours extend directly into the domestic sphere, undermining household food security. Waterlogging in the family compound rots home gardens and ruins carefully preserved post-harvest produce stored in traditional mud structures: *"The vegetable gardens in our homesteads rot completely. The onions, chillies, and vegetables that we cultivate with so much physical effort around the house get drowned and decay when the local ponds and ditches overflow. Even the paddy stored inside our rooms catches moisture and gets ruined by the dampness."*

Changing rhythms of nature and disruption of seasonal calendars

During participatory sessions, specifically Seasonal Calendar Mapping and Oral History interviews, elderly residents of the High Barind Tract expressed deep anxiety about the collapse of the traditional six-season cycle (Shoro Ritu). As summer, monsoon, and winter blur together, farmers can no longer read nature's cues, disrupting generational seed-sowing, land-preparation, and multi-cropping schedules.

An elderly farmer reflected on this loss of ecological clarity during a seasonal calendar mapping session, holding a dry branch to illustrate his point: *"In the past, winter, monsoon, and summer were distinctly separate and recognisable; just by looking at the patterns of the sky and the wind, we knew exactly when it was time to work the soil. Now, everything feels tangled and*

blurred together; when winter is supposed to arrive, the heat lingers, and the rains crash down during the harvest. The fundamental laws and sacred balance of nature have become completely chaotic."

Another elderly participant sighed during the timeline verification, describing the psychological distance between humans and their environment: *"The very behaviour and temperament of nature have radically transformed. The trees, the birds, the soil's moisture retention, everything seems to have lost its internal compass. This Barind land we grew up in, a landscape we knew intimately for a lifetime, no longer feels like the same home."*

The Historical Timeline and Matrix Rankings further demonstrated that community members perceive climate change not through quantitative scientific measurements or global warming data, but through the visceral disruption of familiar ecological patterns that once safely guided their agricultural practices and daily community rituals. The disappearance of predictable biological indicators, such as the timing of bird migrations, the flowering of local trees, or the arrival of morning dew, has stripped farmers of their ancestral early-warning systems. As one insightful smallholder observed during the synthesis of the participatory maps: *"In the earlier days, human beings walked in perfect step with the rhythm of the seasons; there was no need to second-guess the sky to know when to prepare the seedbeds. Today, humans themselves cannot fathom which way the seasons are going or from where they are turning. The seasons are acting with a frantic madness from above, plunging our entire agriculture into absolute darkness."*

Community reflection: Navigating the landscape of absolute uncertainty

Across all FGDs and participatory mapping exercises, a unifying consensus emerged: climate change is not merely experienced as an increase in atmospheric temperature or prolonged periods of drought. Rather, its most destabilising manifestation within the community is the pervasive, compounding psychological and economic uncertainty. The destruction of predictable climate baselines has rendered traditional coping mechanisms obsolete, replacing a historically manageable ecosystem with an unpredictable environment where risk cannot be calculated.

An elderly farmer masterfully summarised this shared sense of vulnerability, contrasting past ecological hardships with the contemporary breakdown of generational knowledge: *"In the past, we faced hardships in the fields and endured cracked, drought-*

ridden soil, but there was always a predictable rhythm, a calculable pattern to it. We knew exactly when to sow the seeds and when the skies would turn harsh. Today, the struggles in the fields have multiplied manifold, and nature no longer retains any arithmetic or predictability. Everything is suspended in the dark, without a safety rope."

This profound disruption has forced the community to realise that reliance on past generational knowledge is no longer sufficient. Survival now demands a forced, ongoing process of autonomous adaptation, requiring smallholders to continually recalculate their agricultural investments and livelihood strategies to survive in an altered landscape.

A sharecropper concluded the session by articulating this imperative for climate resilience and forced survival: *"Nature no longer holds its old mercy or sacred rules; therefore, ordinary people like us must learn entirely new ways to endure if we wish to survive. By shifting our cropping patterns, altering our paddy varieties, and constantly waging war against the madness of the skies, we must somehow secure our daily rice."*

Impacts on agricultural production

Agriculture constitutes the foundational bedrock of socio-economic life and cultural identity in Mundumala village. For the vast majority of rural households in this terrain, farming is far more than a mere source of income; it is an existential anchor for securing household food sovereignty, maintaining livestock integration, and sustaining the community's everyday material realities. Consequently, the erratic fluctuations of a changing climate are felt most directly, immediately, and severely through the structural disruptions in agricultural production systems.

During the FGDs and participatory mapping sessions, local practitioners repeatedly emphasised that the agrarian calendar has been plunged into unprecedented volatility. While dry spells, cyclical droughts, and periodic crop losses were historically part of the High Barind Tract's risky landscape, elderly farmers recalled a distinct qualitative shift over the last decade. They observed that crop production has transitioned from a risky but navigable system into an increasingly unpredictable and chaotic gamble, stripping them of their traditional ecological foresight.

An elderly farmer from Mundumala vividly articulated this deep-seated anxiety during a seasonal mapping session: *"In the past, whether it was the early Aush or the traditional Aman paddy, once we cast the seeds into the earth, we could reasonably hope for a harvest; there was an internal trust that this fertile soil would return our labour. Now, before we even touch the soil, our minds are gripped by anxiety about whether the crop will ever reach our granaries or turn to dust on the road, our primary worry. We can no longer read the rules of the sky; everything has become like placing a blind wager in the dark."*

Another seasoned participant somberly remarked during the timeline verification: *"Farming has broken away from the rhythm of seasonal laws and now depends entirely on raw luck. The skies pour down fire when we need moisture, and when we need dry weather, they drown our ripe paddy. How can anyone cultivate land under such erratic and terrifying instability?"*

Historical timeline reconstructions further revealed that local farmers increasingly attribute these systemic drops in agricultural productivity to a compounding matrix of environmental stressors. They explicitly link their production vulnerabilities to rising daytime temperatures, highly erratic rainfall patterns, prolonged and intense dry spells, and a forced, counterproductive dependence on increasingly expensive external chemical inputs to compensate for the failing natural ecosystem.

Declining and unstable crop yields

Throughout the community consultations, participants consistently highlighted that agricultural crop yields have entered a period of alarming instability. While favourable weather anomalies in certain years can still produce isolated bumper harvests, local practitioners explained that such occurrences are now the exception rather than the rule. The baseline of agricultural production has become structurally unstable, stripping smallholders of any economic predictability.

According to detailed calendar mappings, the core drivers of this structural yield decline are irregular monsoon onset patterns coupled with prolonged, intense dry spells during critical vegetative stages. These climate anomalies severely restrict the normal growth, tillering, and physiological maturity of vital regional crops.

An elderly marginal farmer from Mundumala village detailed this ecological fatigue during an open-ended narrative session: *"In the past, whatever the land yielded came from an open, vibrant heart; today, even after*

forcing the soil through double or triple the chemical inputs, it no longer returns the same nourishment. It is as if the soil has been stricken with a chronic wasting disease; it gasps without chemical fertilisers and poisons, yet ultimately leaves us with a dwindling harvest. The earth seems to have withered from its very core."

Another elderly farmer echoed this sentiment during the crop calendar mapping: *"In this Barind farming, if luck favours you one year, a decent harvest comes home; but the very next year, all your mental calculations and financial layouts are so utterly ruined that you are left with nothing but destitution. There is no stable assurance; the seasons and nature are playing a cruel game of hide-and-seek with us."*

The discussion revealed that a wide spectrum of staple and cash crops, including high-input Boro rice, rain-fed Aman rice, winter vegetables, local pulses (such as lentils and grass peas), and oilseed mustard, are all suffering varying degrees of climate-induced stress. Farmers repeatedly correlated the escalating intensity of extreme summer heatwaves with poor grain filling (chaffy grains or Chita), severely reduced market-grade yields, and exponentially higher, economically draining groundwater irrigation requirements: *"When the scorching intensity of the sun and toxic heat waves rise, the paddy panicles dry up and turn into empty chaff before the milk stage can even form inside the grains. Inside the husks, there is no rice, only empty dust. We spend months pumping water into the fields, but it feels as though no amount of water can ever extinguish that atmospheric fire."*

Furthermore, women participants underscored a parallel but often invisible crisis in homestead-based agricultural production. Traditionally acting as the custodians of family nutrition, they noted a sharp decline in backyard agroforestry, kitchen gardens, and domestic seed rearing.

According to a female participant during the gender-segregated livelihood analysis:

"In the past, all around the house, in the front yards and backyards, there was a lush growth of gourds and pumpkins; our bamboo trellises were heavy with vegetables, and the plants remained healthy. Now, groundwater from ponds and dug wells has vanished, and even the nights are filled with such suffocating, humid heat that the vegetable leaves get scorched, and the young seedlings simply fail to survive."

Increasing crop failures and production risks

During the participatory risk mapping exercises, community members repeatedly emphasised that the

overall risk index of farming in the High Barind Tract has escalated exponentially. Local practitioners explained that smallholder agriculture has become highly hyper-vulnerable, where a single, unpredicted climatic shock can completely wipe out months of intense financial investment and physical labour, pushing households into a cycle of seasonal debt.

Reflecting on this profound systemic vulnerability, an asset-poor farmer shared his experience during the vulnerability ranking session: *"For four long months, we toil relentlessly, breaking our bones to stand a crop in the field. But when the sky unleashes its wrath, everything is utterly destroyed before our eyes in a single week's onslaught. Let alone our labour, even the principal capital borrowed from lenders ends up buried under the soil, and we are left as helpless spectators."*

The timeline discussions identified microclimatic droughts and prolonged dry spells as the primary catalysts for absolute crop failure in Mundumala. Farmers explained that these extended dry periods drastically reduce grain yields and, in severe instances, completely desiccate the standing crops before maturity.

Simultaneously, untimely and unseasonal heavy rainfall events were described as a rapidly growing threat to the regional harvest. An experienced Aman and Boro cultivator clarified the destructive nature of these sudden precipitation shifts: *"In the past, the seasonal transitions followed a predictable rule. Now, just as the paddy begins to ripen and is ready for harvest, if an unseasonal, disastrous rain pours down, our golden harvest rots under the water and is ruined. That kind of loss cannot be easily recovered."*

Compounding this issue, another middle-aged farmer noted during the water-logging assessment that even without classic riverine floods, structural vulnerabilities remain severe: *"It is true that we do not experience riverine floods in this elevated region, but the land is uneven, and if the sky pours incessantly, water stagnates even in this dry terrain, causing such chaos that the entire crop is ruined. This Barind soil cannot absorb sudden water quickly, and the field remains choked."*

Ultimately, participants noted that this pervasive climatic uncertainty has stripped them of their traditional agroecological planning capacities. An elderly, respected village elder summarised this breakdown of traditional agrarian calculations during the historical trend analysis: *"In the past, we used to cultivate by reading the patterns of the sky and the moisture of the soil; everything aligned perfectly regarding when to sow and when to harvest. Now, that calculus of nature has turned upside down; it is nearly impossible to match any calculation. Everything has to be done on pure guesswork."*

Increasing pest and disease outbreaks

One of the most insidious consequences of shifting microclimatic regimes in Mundumala is the exponential rise in agricultural pest infestations and novel crop diseases. During the participatory seasonal calendars and trend analyses, local practitioners extensively documented how altered temperature ranges, prolonged periods of high humidity, and erratic rainfall patterns have disrupted the natural ecological checks and balances, creating highly favourable conditions for biological outbreaks.

Farmers noted that the traditional baseline of minor, manageable pest cycles has shifted to a chronic state of biological vulnerability, forcing a counterproductive reliance on intensive chemical interventions. A perceptive farmer who actively tracks crop health explained this biological shift during an agronomic mapping session: *"In the past, field pests were never this aggressive; a few insects here and there didn't ruin the harvest, as birds would naturally prey on them and keep them in check. Now, even the nights don't cool down, and this suffocating, humid heat brings entirely new species of insects. We are exhausting our financial savings buying pesticides, yet the pests refuse to die. It is as if the insects themselves have developed complete immunity to these poisons."*

The focus groups highlighted that high-yielding staple monocultures, particularly Boro and Aman paddies, bear the brunt of these emerging pathogens. Local practitioners identified the rapid spread of Rice Blast disease (caused by *Magnaporthe oryzae*), Bacterial Leaf Blight, and intensive infestations of the Brown Planthopper (BPH) and Stem Borer as direct consequences of unseasonal thermal spikes and humidity fluctuations. An experienced sharecropper shared a vivid, harrowing account of losing a standing crop to sudden disease outbreaks during a recent season: *"Just as the paddy stalks begin to emerge during the panicle initiation stage, if the sky remains choked and heavy and a humid breeze blows, the fields are instantly struck by blast disease. Within the blink of an eye, the entire crop scorches, turns pale, and is reduced to ash. Before our very eyes, a golden field transforms into a graveyard of disease, and no systemic agrochemical can halt the rot."*

Furthermore, community discussions revealed that this biological stress is not confined to cereal crops. Winter vegetables, local oilseeds (mustard), and pulses, which historically formed the core of the High Barind Tract's climate-resilient alternative cropping system, are increasingly succumbing to aphid outbreaks, root rot, and severe powdery mildew.

Reflecting on the collapse of traditional intercropping resilience, a respected female seed-saver added during the agrobiodiversity inventory: *"Historically, when we intercropped linseed, lentils, and mustard, we never feared insect damage; one crop naturally protected the other. Nowadays, the erratic alternations between heavy fog and sudden heat are so severe that aphids suck the life out of the mustard plants before they can even flower. Saving our local seed varieties has become an immense struggle."*

Declining soil fertility and soil degradation

Throughout the participatory exercises, structural soil degradation and the compounding loss of natural soil fertility emerged as deeply critical concerns among the local practitioners. Participants repeatedly stated that the physical and biological characteristics of the local earth have fundamentally changed, explicitly noting that the soil no longer behaves or responds to traditional stewardship as it did in the past.

The community articulated a clear sense of ecological fatigue in the High Barind Tract (Barind region). An elderly farmer reflected on this systemic exhaustion with profound clarity during a historical trend mapping session: *"In the past, the inherent strength of the land was immense. Now, the soil itself has become weak, exhausted, and bedridden."*

During the detailed cause-and-effect matrix mappings, several participants systematically connected this baseline degradation to the pressures of modern agricultural shifts. They believed that continuous, intensive multi-cropping, the excessive and imbalanced application of chemical fertilisers, and chronic groundwater scarcity have severely affected the soil's organic matter and overall quality. A veteran farmer who has witnessed the green revolution transitions in Mundumala explained this artificial dependency: *"In the past, crops thrived even with minimal fertiliser. Nowadays, although applying more synthetic chemical inputs might increase the yield in some seasons, the production cost escalates significantly, and quite often, it ends up in a catastrophic crop failure."* This sentiment regarding the loss of the soil's vital life force was shared across different demographic groups. A local participant remarked during the agricultural input assessment: *"The vital strength and intrinsic force of the earth have vanished."*

Furthermore, women participants during the gender-segregated livelihood analyses shared parallel and deeply concerning observations about declining productivity in home gardens and homestead-based kitchen farming. They emphasised that the localised soil erosion and dehydration affect the micro-

environments around households. According to a female participant responsible for household food security: *“The vegetable vines and plants no longer grow with the same vitality or reach the healthy size they used to in the past.”*

The historical timeline discussions and community resource mappings revealed that many elderly farmers strongly associate the declining soil fertility with a growing, forced dependence on external commercial inputs and the gradual, systematic disappearance of traditional, ecologically sound farming practices.

Summarising this transition from ecological self-reliance to market dependency, a respected village elder observed: *“In earlier times, the application of organic cow dung manure was the mainstay of our farming. Now, our absolute reliance on synthetic chemicals is continuously escalating.”*

Comparing farming systems: Agroecological and conventional approaches

The community-led discussions and structural matrix mappings revealed a noticeable, systemic divergence in climate resilience between local farms that rely heavily on synthetic chemical inputs (conventional, input-intensive systems) and those that practice diversified, agroecological approaches. Local practitioners observed that conventional farming networks inherently create escalating economic vulnerability under fluctuating climate regimes, as they require continuous, high-cost expenditures on commercial fertilisers, chemical pesticides, proprietary seeds, and deep-groundwater irrigation.

Detailing the compounding psychological and financial stress of this high-input conventional pathway, a smallholder conventional farmer shared his reality during an input-cost verification session: *“When you have to cultivate by purchasing every single input, both the financial cost and the mental anxiety multiply. When seeds, fertilisers, pesticides, and even irrigation water must be bought by recharging prepaid cards with cash at the local market counters, the worry for the field outweighs the worry for the household hearth. The moment the card balance runs out, the water shuts off instantly, and if the crop fails under this strain, any path to recovery simply vanishes.”*

In sharp contrast, participants who actively maintain biological crop diversity, integrate livestock components, practice organic composting, and nurture diversified homestead kitchen gardens reported having a greater capacity to absorb and recover from climatic shocks. Under extreme weather stress, these diversified systems act as an autonomous socio-ecological safety net. An indigenous woman agroecological practitioner explained this inherent

buffering capacity during the livelihood diversity mapping: *“Even if one crop is completely ruined, something else always remains to sustain us. If the Boro paddy dies due to the madness of the skies, we still have lentils in the field, onions in the soil, or vegetables in the homestead yard. The earth never returns us completely empty-handed.”*

Furthermore, local practitioners noted that the systematic application of organic compost and traditional biomaterials directly helps maintain soil moisture retention and arrest soil degradation in the arid Barind terrain. A conservation-focused cultivator highlighted the physical difference in the soil crust: *“When you apply organic cow dung compost, the soil remains calm and cool. It retains its internal residual moisture, preventing the earth from cracking wide open, and the standing crops do not wither or burn up even under the scorching heat of the sun.”*

The gendered dimensions of this comparative analysis were brought to the fore by the women participants. They explained that diversified backyard kitchen gardens consistently provide essential nutrition and daily subsistence for the family, even when large-scale monoculture field crops are completely destroyed by drought or unseasonal rain.

Although agroecological and diversified farms are not entirely immune to severe regional droughts or compounding climatic shocks, participants felt strongly that diversified systems are generally more resilient, highly adaptable, and significantly less dependent on crippling external commercial inputs.

As an insightful elderly farmer summarised at the conclusion of the comparative trend analysis:

“If you rely on a single crop or input, the terror of ruin is absolute. When you maintain various kinds, a human being can survive. When nature unleashes its madness, you cannot navigate it with a rigid, single rule; you must embrace diversity and catch the harvest in newer, adaptable ways.”

Overall, the ethnographic and participatory findings indicate that climate change is actively destabilising agricultural production across the High Barind Tract through a multi-pronged matrix of environmental stressors. Local farmers are navigating a compounding reality characterised by declining and structurally unstable crop yields, accelerating crop failures, aggressive pest and disease outbreaks, and severe, systemic soil degradation.

At the same time, field evidence strongly indicates that diversified and agroecological farming practices provide

significantly greater structural flexibility, financial security, and ecological resilience than input-intensive, chemical-dependent conventional monocultures. For the participants in Mundumala village, the contemporary challenge has moved beyond merely optimising seasonal crop yields; it has become an existential battle to sustain farming itself amid increasingly volatile and uncertain ecological conditions.

Impacts on household well-being

Climate impacts in Mundumala extend far beyond agriculture into systemic socioeconomic distress. Driven by erratic weather, micro-droughts, crop failures, and rising input costs (like prepaid irrigation cards), households face a cascade of seasonal food insecurity, income loss, debt traps, health hazards, and compromised schooling for children.

Reflecting on how macroeconomic climate shocks immediately transform into intimate domestic crises, a marginalised sharecropper shared a poignant observation during a vulnerability assessment during focus group discussions: *“The agony of drought does not remain confined to the soil; it directly strikes the rice plates of our households. When the fields wither and the homestead wells dry up, the fire in our kitchen hearths also goes cold. A strike on the harvest is a direct strike on our survival.”*

Corroborating this systemic household vulnerability, another seasoned male farmer somberly remarked during the timeline verification session: *“When a harvest fails, it is not just the individual farmer who suffers, but the entire household that is plunged into distress. The burden of bank institutional debts, the verbal abuse of informal moneylenders, and the hunger of our children all combine to bury a human being alive.”*

Furthermore, gender-segregated FGDs revealed that women experience these climate-induced systemic shocks not merely as abstract macro-agricultural losses, but as a compounding tax on their everyday domestic labour and emotional resilience. As the primary managers of household subsistence, they bear the brunt of managing scarcity. A female participant from a resource-poor household articulated this invisible burden during the seasonal deprivation mapping: *“It is only when managing the daily household survival that one truly grasps the depth of this suffering. When the fields fail, the men sit paralysed with despair, but the harrowing question of what to feed the young children and where to fetch drinking water is a persistent anxiety that robs us women of our nightly sleep.”*

This structural pressure directly undermines household food security and alters dietary diversity

within Mundumala. While chronic, absolute starvation is historically rare, fluctuating agricultural returns and accelerating retail inflation have severely restricted the nutritional quality and frequency of household meals. Under seasonal stress, families are forced into coping mechanisms that involve eliminating high-value proteins and relying on cheaper, nutrient-deficient starches. A smallholder farmer detailed this nutritional regression during the seasonal analysis session: *“In the past, our meals were whole, accompanied by pulses, fish, and diverse greens; there was a sense of deep satisfaction in both the fields and the home. Today, after continuously paying for deep-tubewell water cards and skyrocketing fertiliser costs, we are drained of cash; most of the time, we must subsist on whatever basic food is available, even if it is just rice with salt and chillies. Even when we harvest paddy, purchasing vegetables becomes an impossible luxury.”*

Within this context of food rationing, intra-household distribution emerges as a starkly gendered vulnerability. Women routinely compromise their own nutritional intake, adopting altruistic fasting to protect children and elderly male members. A mother participating in the vulnerability analysis shared this coping strategy: *“I feed my children first, and only then do I think of my own sustenance. When the portions of rice shrink within the household, it is always the mothers who must tighten their belts and go hungry. The little ones do not understand that the sky has failed us.”*

Another female participant validated this cyclical deprivation, stating: *“Whenever economic hardship strikes the family, mothers are the first to ration their meals. Although we manage to save the family from total collapse by relying on homestead agroecology using organic cow dung compost, backyard greens, and egg sales, our own bodies are left completely depleted of physical strength.”*

This testimony reveals a critical nuance within the PAR documentation: while local, biodiverse homestead practices provide a vital safety net that keeps the household from total starvation, this resilience is directly subsidised by the hidden, self-sacrificing physical labour of women, leaving them in a state of severe physiological exhaustion.

This drop in nutrition is compounded by a profound crisis of declining household incomes and pervasive economic uncertainty. As traditional agroecological calendars collapse, agricultural yields diminish while production inputs grow costlier, rendering casual agricultural labour highly erratic and unstable. An agricultural labourer explained how micro-climatic shocks immediately paralyse the local labour market: *“When work in the fields decreases, our casual wages plunge to zero. During intense droughts when the earth*

splits open, the larger landholders themselves cannot afford the prepaid irrigation water cards; how can they hire us for labour? If we lose even a single day's wage, the entire household faces starvation."

To survive this persistent economic volatility, vulnerable households increasingly find themselves trapped in escalating cycles of structural indebtedness. Farmers are forced to borrow capital upfront from various informal and institutional networks, including microfinance NGOs, local input traders (Mohajons/mycrowcredit), and kin networks, merely to purchase high-priced commercial seeds, chemical pesticides, and deep tubewell water card load credits.

When unseasonal thermal spikes or sudden climatic shocks destroy the harvest, repayment becomes impossible, leading to a compounding debt trap. A debt-burdened cultivator reflected on this financial anxiety during a vulnerability assessment during focus group discussions:

"Before even starting cultivation, debt begins. Shopkeepers don't set prices based on poison; cash is needed even to load credit. If the crop is good, the debt is repaid; if it is bad, the debt only increases. In Barind agriculture, freedom has now become almost lost."

Highlighting the heavy psychological and emotional toll of this financial imprisonment, a female family member shared during a vulnerability assessment during focus group discussions: *"Debt is not only a financial burden, but it is also a mental burden. At night, when thoughts of repayment surround the mind, both body and mind become exhausted. The worry of money does not allow a person to live in peace."*

This structural stress is further amplified by severe public health hazards driven by extreme heatwaves, acute drinking water scarcity, and erratic seasonal transitions. Local practitioners documented a sharp increase in heat exhaustion, vector-borne fevers, diarrheal outbreaks, and water-borne skin diseases. These physiological illnesses present a dual blow: they simultaneously deplete physical labour productivity and impose catastrophic out-of-pocket medical expenditures on already strained household budgets. A farmer described this debilitating cycle of health expenditures: *"Remaining exposed under the scorching sun induces severe vertigo, and the suffocating heat in the fields completely breaks the body's physical endurance. It is already an immense struggle to manage production costs, but when illness strikes, the suffering multiplies. The cost of medical consultations and pharmaceutical drugs is extremely high; a single chronic illness can completely destabilise a household's economic condition."*

Inevitably, this compounding vortex of food rationing, volatile incomes, structural debt, and expanding healthcare costs creates a direct negative impact on children's education and long-term human capital formation. When household budgets are severely constrained during crop failures, families prioritise immediate food consumption over educational investments, leading to a structural breakdown in the continuity of schooling. An anxious father detailed this difficult compromise during the trend analysis session: *"When the harvest fails, securing the financial costs for our children's education becomes nearly impossible. When severe economic scarcity hits the household, immediate food survival takes absolute priority over schooling. If we cannot afford textbooks or pay tuition fees, our young children are pulled out of school and engaged in manual wage labour in the fields, and their education ends there."*

Consequently, agriculture is increasingly viewed by the younger demographic not as a sustainable livelihood, but as a trap characterised by high risk and low returns. This has triggered an accelerating decline in agricultural interest among the youth, forcing distress seasonal migration out of the Barind tract.

Ultimately, as an insightful village elder summarised during the Key Informant Interview (KII), climate change has institutionalised a culture of permanent vulnerability and systemic fear in everyday rural life: *"In the past, we faced hardships, but there was a sense of trust. Now, there is both suffering and fear. The rural household maintains a close relationship with nature; when nature changes, the household also changes, and all the old rules of predictability disappear."*

In summary, the field findings suggest that climate change affects household wellbeing in multiple, deeply interconnected, and mutually reinforcing ways. Reduced food security, highly volatile income flows, chronic indebtedness, worsening health profiles, and compromised children's education combine to create severe, multidimensional vulnerabilities for rural smallholders. These impacts, however, are not experienced uniformly across the community; specific socio-economic cohorts and marginalised groups are significantly more exposed and structurally vulnerable than others, a critical differential reality that will be comprehensively explored in the following analytical section.

Differential impacts across social groups

The climate crisis in the Barind region is a deeply stratified experience, where environmental stress interacts with pre-existing structural inequalities to dictate the level of survival risk. Through triangulation of FGD deliberations, KIIs, seasonal

calendar analysis, and participatory resource mapping, it becomes evident that vulnerability is not a monolithic condition but a product of varying levels of access to power and resources. For women farmers, vulnerability is fundamentally rooted in their "double-bind", they are denied formal land ownership (limiting their credit access) while simultaneously being forced to manage domestic survival amid receding water levels, a condition of extreme physical exhaustion noted during the FGD: *"When I go to check the vegetable garden by the pond in the morning, sometimes I find no water, and sometimes I see cracked, parched soil. Perhaps the traditional knowledge of ancestral farming (Shassyakala) could save us, but right now, I lack the physical strength to even try."*

This structural exhaustion is equally prevalent among landless labourers, whose vulnerability stems from their total dependence on agricultural cycles. As mapped during our seasonal calendar sessions, the decline in crop diversity has stripped them of year-round employment, leaving them with no economic buffer, as a respondent starkly captured during the resource mapping exercise: *"I have no land, so I have no means of survival. In the past, there was work throughout the year, but now I only get employment for a few days during the paddy season. The rest of the time is spent in hunger and uncertainty."*

In parallel, smallholders suffer from an input-cost-debt trap, a systemic vulnerability confirmed by our KIIs. They are forced into predatory credit markets to counter ecosystem degradation, creating an inescapable financial crisis where, as one farmer lamented, *"I could not survive just by farming. Now, I have to take loans from fertiliser shops to farm, and each year the debt keeps increasing."*

Finally, this systematic erosion of livelihood viability drives the youth's existential vulnerability. As surfaced in the FGD, they witness the intergenerational failure of traditional farming, and lacking institutional pathways for ecological transition, they view migration as the only rational response: *"Seeing the condition of our fathers' farming, we will no longer continue farming. There is no future here, which is why we are forced to rush towards Rajshahi, Dhaka, or other cities."*

Consequently, the climate crisis acts as a threat multiplier: it does not create the vulnerability; it formalises it by exploiting gendered asset gaps, the lack of safety nets for the landless, the predatory nature of input markets, and the loss of youth's connection to the land.

Throughout the discussions, participants repeatedly emphasised that climate change is widening existing inequalities and making vulnerable groups even more vulnerable. As one elderly farmer summarised: *"Nature's erratic behaviour or the shock of climate change does not fall upon everyone equally. It essentially breaks the backbone of the poor and the destitute, because in their struggle for survival, they have no extra resources or safety nets to fall back on."* Another participant quietly remarked: *"He who has the least to rely on bears the greatest fear."*

These findings suggest that climate change is not only an environmental issue but also a question of social justice and inequality. Women farmers, landless labourers, smallholders, and rural youth experience different forms of vulnerability because of their unequal access to resources, opportunities, and decision-making power. Understanding these differences is essential for designing locally appropriate adaptation strategies and strengthening community resilience.

AGROECOLOGY AND CLIMATE RESILIENCE

Farmers' responses to climate stress

Despite climate threats and rising costs, Mundumala farmers actively adapt by drawing on generational knowledge, observation, and collective learning. Though rarely labelled as "agroecology," their strategies mirror its core principles: crop diversity, reliance on local resources, seed saving, and reduced dependence on external inputs.

The findings reveal that farming communities in Mundumala village are not passive victims of climate change. Over the years, farmers have continuously observed environmental changes and gradually adjusted their farming practices in response to increasing drought, erratic rainfall, rising temperatures, pest outbreaks, and increasing production costs. Rather than relying on a single strategy, most households have adopted multiple responses based on their experiences, local knowledge, and collective learning.

Participants explained that farming calendars have changed considerably over the last decade. Many crops that were traditionally planted at fixed times are now cultivated more flexibly depending on rainfall and soil moisture conditions. Farmers repeatedly emphasised that seasons no longer follow predictable patterns, forcing them to adjust sowing and

transplanting dates according to changing weather conditions.

One elderly farmer explained: *“Earlier, I used to think about planting paddy as soon as the month of Ashar arrived. Now, relying on dates or calendars no longer works. I have to wait and understand when the rain will actually come before sowing seeds.”* Another participant said: *“I used to farm by looking at the calendar; now, I farm by looking at the sky.”*

Adjusting planting dates

In response to erratic rainfall and heatwaves, Mundumala farmers now rely on real-time weather data, soil moisture readings, and experience rather than the traditional Bengali agricultural calendar. Fixed planting schedules, such as transplanting Aman rice in Ashar and Shraban, have given way to more flexible, cautious timing.

As one elderly farmer explained: *“Previously, we prepared seedbeds in Ashar and transplanted during Shraban. Now that schedule no longer works. Without rainfall, we cannot enter the fields. Earlier we farmed according to the calendar; now we farm by watching the sky.”*

Farmers repeatedly emphasised that delayed rainfall has forced them to postpone Aman transplantation. In some years, they wait for two or three spells of rainfall before preparing land and transplanting seedlings. Several participants noted that if seedlings are transplanted too early without adequate moisture, they can suffer heat stress and may eventually die, leading to additional replanting costs.

A woman farmer participating in the discussion shared her experience: *“The time we used to transplant paddy no longer has sufficient water. I wait for two or four bouts of rain to see the ground soften before I finally step into the field. If we transplant in a hurry, the crops wither away later. Then we have to spend extra money to replant them again. Because of this, we now prefer crops that require less water, such as sesame, flax, and barley.”*

Another farmer explained how changing weather patterns have made farming increasingly uncertain: *“There is no reliability in the weather anymore. Just because it rains once, one cannot assume it will rain again. Earlier, there was consistent rainfall; now it rains for one day and stays sunny for ten. That is why one has to be very mindful of the timing and work accordingly.”*

Participants also noted that winter crops such as mustard, wheat, lentils, and vegetables are increasingly planted earlier or later depending on the availability of

residual soil moisture. Farmers reported that warmer winters and declining soil moisture have altered cropping cycles, requiring constant adjustments in planting decisions.

One farmer remarked: *“Earlier, we used to sow mustard in the month of Kartik. But now, if there is no moisture in the soil, how will the seeds germinate? So, sometimes we sow earlier, sometimes later. We have to do it by understanding the condition of the land.”*

Participants further explained that rising temperatures and prolonged dry spells have affected seed germination and early crop growth. High temperatures often dry out seedbeds and reduce plant survival. In response, some farmers now prepare seedbeds later than before or wait until moisture conditions improve.

During a discussion, an experienced farmer observed: *“The heat has increased so much that seeds don't sprout like before just by sowing them. If the seedlings don't get a little water, they get scorched. That is why we have to adjust the timing, sometimes sowing earlier or later to match the weather.”*

These experiences suggest that adjusting planting dates has emerged as an important adaptive strategy among farming households. Rather than relying solely on fixed calendars, farmers are increasingly using their own observations, accumulated experiences, and local ecological knowledge to make decisions. This shift reflects not only a response to changing climatic conditions but also the adaptive capacity and resilience embedded within local farming systems.

As one elderly participant concluded: *“Farming is no longer what it used to be. The climate has changed, so we also have to change our calculations. Without adapting, it will be difficult to survive.”*

This gradual adjustment of planting schedules demonstrates how farmers are continuously learning and adapting in response to climatic uncertainty. Rather than abandoning agriculture, they are modifying their practices based on experience, observation, and local knowledge, thereby strengthening their capacity to cope with increasing climate stress.

Crop diversification as a strategy for reducing risk

One of the most commonly observed responses was crop diversification. Participants emphasised that cultivating multiple crops has become an important strategy to reduce risks associated with climate

uncertainty. Instead of depending solely on a single crop, many households now combine rice with vegetables, pulses, maize, mustard, fruit trees, spices, and livestock. Several participants explained that crop diversity provides food, reduces market dependency, and spreads risks during drought years.

One farmer noted: *"One cannot rely on just a single crop anymore. If the paddy gets ruined, then there are vegetables, mustard, wheat, lentils, and sesame. Something or other will definitely survive."*

Another farmer shared: *"Earlier, I only thought about paddy. Now, I have lentils on one side of the land, vegetables on the other, and I also keep fruit trees around the house. Everything combined helps run the family."*

Women participants also highlighted the importance of homestead gardens in maintaining household food security. One-woman farmer stated: *"It is difficult to run a household if one has to rely entirely on vegetables from the market. So, I plant whatever I can around the house—bottle gourd, malabar spinach, okra, chilli, and eggplant. This provides our food and also saves our expenses."*

Crop diversification emerged as perhaps the most important adaptation strategy discussed by participants. Farmers repeatedly emphasised that depending on a single crop has become increasingly risky under changing climatic conditions. As a result, many households now cultivate a wider range of crops than before.

To enhance resilience, participants maintain a highly diversified farming system integrated with cereals, pulses, oilseeds, vegetables, and homestead orchards. Alongside traditional and drought-tolerant crops, farmers rely heavily on uncultivated, wild-grown food and medicinal plants (like thankuni, neem, and tulsi) found along field edges and ponds. Requiring zero external inputs, these wild species provide critical nutrition and natural remedies, forming a self-sustaining ecosystem.

Changing crop varieties: Searching for resilient seeds

A critical component of climate adaptation in Mundumala involves a fundamental shift in seed selection. Farmers noted that historical cropping patterns were largely designed for a predictable climate, but as rainfall patterns have become erratic and droughts more prolonged, the standard varieties are no longer sufficient. Farmers are now systematically evaluating and experimenting with shorter-duration, drought-tolerant, and locally adapted seeds to mitigate the risk of crop failure.

One farmer highlighted the necessity of this search for resilience: "Now, I look for seeds that can survive even with very little water." This shift is rooted in the realisation that modern high-yielding varieties are often fragile under climate stress. As another farmer remarked on the decreasing reliability of traditional market seeds: *"All the seeds from before don't produce yields like they used to."*

Several participants explained that they are gradually rediscovering the value of traditional and local seeds because these varieties are often more resilient under stressful conditions.

One experienced farmer explained: *"I used to run only after hybrids. Now I realise that not every hybrid variety performs well every year. Local varieties have their own inherent strength."*

Another participant said: *"We now want to return to the seeds that survive and thrive in our local area."*

In response to this instability, there is a renewed interest in reviving traditional and indigenous seed varieties. Participants observed that these local varieties possess a built-in resilience that commercial hybrids lack. As an elderly farmer reflected, *"Local seeds can often endure hardship."* This movement is significantly strengthened by the active participation of women, who play a pivotal role in seed conservation and community knowledge sharing. Beyond the ecological benefit, seed autonomy is a matter of economic survival. One woman explained the importance of self-reliance: *"If you have your own seeds, at least you don't have to run to the market for them."*

The Barind region is currently witnessing a growing movement towards farmer-led seed exchange and the establishment of community seed banks. These initiatives are not merely about preservation; they represent a strategy to reduce dependence on external markets and corporate seed suppliers. By maintaining climate-adapted varieties, farmers are effectively "banking" their future, ensuring they possess the biological diversity necessary to survive in an increasingly unpredictable landscape. This transition from external dependence to seed sovereignty is a cornerstone of the broader agroecological transformation observed in the region.

Integrating livestock and homestead production

Participants described livestock and homestead production as important buffers during periods of climatic stress. Cattle, goats, poultry, and homestead gardens provide food, manure, and additional income when crop production is uncertain.

A farmer explained: *“Crops do not always provide security. But if one has cattle or goats, they can be sold in times of need to run the household.”* Women participants particularly emphasised the importance of poultry and homestead gardens in supporting household nutrition.

Learning through experience and observation

Farmers repeatedly stressed that adaptation is a continuous learning process. Many strategies have emerged through trial and error rather than external recommendations. Participants often exchange experiences with neighbours, relatives, and fellow farmers.

As one participant remarked: *“In farming, experience is more valuable than books. One person observes something, and another learns from it. This is how we are carrying on.”* Another elderly farmer reflected: *“The climate has changed, so we are also changing little by little. Sitting idle won't help.”*

Overall, the findings suggest that farmers in Mundumala village are actively responding to climate stress through flexible planting schedules, crop diversification, switching crop varieties, homestead production, livestock integration, and continuous learning grounded in local knowledge and experience. These responses are not isolated technical practices; rather, they represent a dynamic process of adaptation through which farming households seek to maintain their livelihoods and strengthen resilience in the face of increasing climatic uncertainty.

Learning, experimentation, and collective adaptation

A significant finding from this research is that climate adaptation in Mundumala is rarely an isolated or individual pursuit. Instead, it is a dynamic, community-driven process in which knowledge is co-created through observation, discussion, and collective experimentation. Adaptation is not a static set of rules handed down from above; rather, it is a living practice that emerges from the continuous exchange of experiences among neighbours, relatives, and fellow farmers.

Farmers in the region have established a sophisticated informal network of knowledge sharing. By visiting each other's fields, they observe which varieties perform well, which mulching techniques retain the most moisture, and how different crops respond to heat stress. This visual learning often transcends the need for formal agricultural training.

As one farmer noted on the power of observation, *“When someone does something good, others learn from it as well.”*

The collective nature of this knowledge system means that the community acts as a massive, decentralised research and development hub. Farmers trust the tangible results they see in their neighbour's fields far more than theoretical advice from external sources. As one participant insightfully remarked, *“The greatest school for a farmer is another farmer's land.”*

This collective learning process has been vital in enabling farmers to navigate the escalating uncertainties of the Barind landscape. Despite limited institutional support or formal extension services, these informal networks ensure that successful innovations ranging from the adoption of indigenous seeds to water-saving soil management techniques spread rapidly across the village. By sharing their successes and failures, the farmers of Mundumala are building a shared pool of resilience that enables the entire community to adapt to the changing climate. This transition from individual coping mechanisms to a collective adaptive strategy is perhaps the most significant indicator of the community's long-term sustainability and strength.

Community reflection: The path towards agroecological resilience

The findings from Mundumala village offer a compelling narrative of human ingenuity in the face of ecological disruption. The farmers are not merely victims of climatic uncertainty; they are active agents of change, consistently recalibrating their agricultural practices to align with a shifting landscape. By adjusting planting schedules, diversifying crops, and embracing the resilience of local seeds, these households are systematically reducing their risk exposure and securing their livelihoods.

These adaptive strategies, while seemingly individual, represent a broader, collective movement towards agroecological sustainability. They illustrate a fundamental truth about agricultural resilience: when formal systems fail to provide solutions, the community fills the void through shared knowledge and lived experience. As one elderly farmer reflected on the necessity of this ongoing evolution: *“Since nature is changing, the farmer cannot afford to stand still.”*

This shift is not merely a reaction to stress; it is a profound demonstration of the human capacity to innovate in the face of adversity. The farmers' journey is a testament to the fact that survival is not a passive act but an active, creative process of seeking new solutions. As another participant concluded: *“To survive, humans find new paths, and that is exactly what the farmers are doing.”*

These adaptive responses serve as the bedrock upon which more robust, sustainable agroecological practices are built. By transitioning from the fragility of input-intensive monoculture to the strength of biodiversity and ecological wisdom, the farmers of Mundumala are creating a roadmap for resilience that is both locally rooted and globally relevant. The following sections will explore these agroecological practices in greater detail, examining how they are being operationalised to strengthen the fabric of everyday farming systems in the Barind region.

Agroecological practices observed: A synthesis of tradition and resilience

The discourse with farmers in Mundumala village reveals that agroecology is not merely a modern academic framework but an ancestral way of farming rooted in local knowledge, biodiversity, and reciprocal relationships with the environment. While many participants may be unfamiliar with the formal term “agroecology,” their farming systems demonstrate a sophisticated, long-standing application of its principles and practices, inherited from previous generations and continuously refined to withstand contemporary climatic stressors.

Farmers repeatedly emphasised that the rising economic burden of external agricultural inputs, coupled with the environmental pressures of recurrent droughts and erratic rainfall, has compelled households to turn inward. There is a concerted effort to rediscover and strengthen farming methods that prioritise locally available resources, biological diversity, and natural ecological processes.

Crop diversity: Mixed cropping and intercropping

Crop diversity has emerged as the most robust ecological practice in Mundumalage. Participants consistently emphasised that relying on a single-crop monoculture has become an increasingly dangerous gamble due to intensifying droughts, rising temperatures, and unpredictable rainfall. In response, farmers have adopted strategies such as mixed cropping and intercropping, cultivating multiple varieties within the same season, often on the same plot of land, to distribute risks and optimise resource use.

The common combinations practised by farmers include field crops such as mustard with lentils, onions with chillies, and maize with various seasonal vegetables. Climbing crops include pumpkins and bottle gourd. Homestead systems are a layered approach featuring papaya, banana, and various vegetables, integrated with seasonal leafy greens, spices,

and medicinal plants. Reflecting on the risk-mitigation strategy behind this approach, one farmer explained: *“There is a greater fear when you rely on only one crop.”*

This strategy provides a crucial safety net for farming households, ensuring that the failure of one crop does not lead to total catastrophe. As another participant remarked, *“If one crop is damaged, another one saves us from losing everything.”* Women participants, who are primary managers of homestead gardens, highlighted that these systems are essential for household stability. One woman explained: *“If there are greens, chillies, bottle gourd, and papaya around the house, it helps the household in many ways.”* The practice of crop diversity offers multifaceted benefits: it ensures food availability throughout the year, provides supplementary income, enhances household nutrition, and significantly reduces dependency on external markets. Ultimately, this agroecological diversity serves as a mechanism for human resilience. As an elderly farmer summarised: *“If there is diversity, a person never loses completely.”*

Soil health practices: Restoring fertility through organic wisdom

Maintaining soil health has become a primary concern for the farmers of Mundumala as they grapple with long-term degradation from excessive chemical inputs. To counteract the loss of soil structure and rising production costs, farmers are increasingly turning towards a circular, organic fertility management system. This approach relies on the synergistic use of compost, green manure, and protective mulching, transforming the farm into a self-renewing ecosystem.

Integrated organic fertility management

The bedrock of these efforts remains the use of cow dung, household organic waste, crop residues, and decomposed leaves. Farmers recognise that these materials restore the earth's vital life force. Beyond traditional compost, farmers are now experimenting with a diverse array of nutrient-rich inputs. This includes vermicompost (earthworm-processed waste) for rapid growth, bone meal and blood meal for phosphorus and nitrogen enrichment, fish emulsion for plant vitality, and poultry manure for a potent N-P-K blend (nitrogen, phosphorus, and potassium). Additionally, biogas slurry has emerged as an efficient, nutrient-dense liquid fertiliser that is easy to apply. As one farmer remarked, *“Applying cow dung fertiliser brings the soil to life.”*

Supporting this, another participant added: *“Chemical fertilisers might be needed, but without cow dung, the*

land does not gain strength.” Women play a critical role in this cycle, often managing the decomposition processes at the homestead level. One woman explained her process: *“I gather household waste, leaves, and cow dung in one place, and later apply it to the field.”*

To further reduce dependence on market-bought, toxic agrochemicals, farmers have mastered the preparation of liquid fertilisers and botanical biopesticides. By fermenting mixtures of cow dung, molasses, mustard oil cake, and beneficial soil microbes, they create potent soil conditioners. Similarly, they protect their crops using extracts from Neem (fruit and leaves), Dhatura, Tobacco, Tulsi, and Bel leaves, along with additives like garlic paste and wood ash. These botanical solutions act as natural repellents against pests and diseases, ensuring that both the produce and the farm environment remain safe.

Green manuring and mulching

Farmers also integrate green manuring by cultivating specific crops to be incorporated as biomass, thereby maintaining soil nitrogen levels and structural integrity. Alongside this, mulching has become a vital strategy to combat heat stress and moisture loss in the Barind landscape. By covering the soil surface with straw, weeds, and harvest residues, farmers regulate soil temperature and retain humidity. A participant explained: *“If you put straw over the soil, the water doesn’t dry up quickly.”* Adding to this, another farmer noted: *“The layer of straw keeps the soil cool even during the heat.”* Regarding the efficiency of this practice, a woman participant noted: *“Weeds grow less, and it also requires less water.”*

This integrated approach represents a profound shift from a linear, consumption-heavy agricultural model towards a circular, regenerative system. Farmers view their land not as a factory for yield, but as a living entity that requires nurturing. Summarising the philosophical shift towards this organic wisdom, an elderly farmer reflected: *“Previously, nothing from the land went to waste; everything used to return to the soil.”* By reclaiming these traditional practices and adapting them with modern organic innovations, the farmers of Mundumala are successfully enhancing soil porosity, water-holding capacity, and overall resilience to the region's challenging climate.

Water management: Adapting to scarcity in the Barind Region

Given the chronic water scarcity that defines the Barind region, water management has evolved from a routine chore into a critical survival strategy for the farmers of Mundumala. The discussions revealed that local adaptation is driven by a sophisticated

understanding of hydrology, where every drop is treated as a precious resource. This holistic approach integrates soil moisture conservation with efficient water harvesting and judicious usage, reflecting a deep-seated ecological awareness.

To mitigate evaporation and conserve essential soil moisture, farmers have adopted a series of regenerative practices. Rather than relying on intensive tillage, which disrupts the soil structure and triggers water loss, farmers prioritise minimal soil disturbance. They consistently maintain a protective layer over the soil by leaving crop residues, incorporating organic matter, and applying thick mulch. Furthermore, the strategic planting of trees creates shaded microclimates that effectively prevent the soil from drying out under the scorching Barind sun. This commitment to moisture retention is rooted in a fundamental realisation of scarcity, as one farmer explained: *“Even a single drop of water has value.”* Echoing this sentiment, another participant emphasised the priority of modern farming: *“Retaining moisture in the soil is the biggest priority now.”*

In parallel with soil-based conservation, farmers are innovating in water harvesting and use efficiency. The reliance on erratic rainfall has compelled households to maximise rainwater storage in ponds and rejuvenate traditional water sources. Irrigation is no longer a wasteful practice; it is highly targeted and conservative. Farmers are increasingly adopting low-water vegetable production techniques and reusing homestead water to nourish their crops. This conscious transition in farming behaviour is significant, as one participant noted: *“Saving water is now a part of farming itself.”* The gravity of the current water crisis is further highlighted by the contrast with the past, as another farmer remarked: *“Previously, we didn’t have to calculate our water usage so strictly.”*

In this landscape of scarcity, women participants have been instrumental in reviving traditional, highly efficient techniques such as clay-pitcher irrigation. By burying porous clay pots filled with water near the base of plants, they ensure a slow, steady supply of moisture directly to the roots, minimising wastage. One woman shared the efficiency of this method: *“If water is supplied slowly through a pitcher, plants survive even with very little water.”*

Ultimately, this integrated approach to water management reflects the inseparable bond between the people of Barind and their natural resources. It is a testament to their resilience and their ongoing efforts to harmonise farming with the harsh reality of the local environment. An elderly participant succinctly summarised the existential importance of this resource: *“There is no life in Barind without water.”*

Integrated natural pest management

Farmers in Mundumala village have expressed growing concern about the increasing frequency of pest outbreaks and the prohibitive costs of chemical pesticides. In response, they have increasingly shifted towards locally available, low-cost ecological pest management practices. Many farmers have come to realise that reliance on synthetic drugs is not a universal panacea, asserting that sustainable solutions lie in maintaining ecological health. One farmer aptly reflected this sentiment, stating: *“Medicine is not the solution to all problems.”*

To reduce their dependency on market-bought, toxic agrochemicals, farmers have mastered the preparation of potent liquid bio-inputs and botanical biopesticides. By fermenting mixtures of cow dung, molasses, mustard oil cake, and beneficial soil microbes, they create effective soil conditioners that improve plant immunity. Furthermore, they protect their crops using diverse botanical extracts from neem (fruit and leaves), datura, tobacco, tulsi, and bel, often supplemented with garlic paste and wood ash. These organic solutions act as natural repellents, ensuring that both the produce and the farm environment remain safe from toxic residues. As one farmer noted regarding the efficacy of these methods: *“Neem leaves often work very effectively.”*

Women participants have been particularly proactive in integrating these traditional methods within their homestead vegetable gardens. Simple practices, such as the strategic application of wood ash or the manual removal of insects, have proven to be surprisingly effective. As one woman shared, *“Applying ash often reduces pest infestation.”*

Beyond direct interventions, farmers emphasise biodiversity-based approaches as the most sustainable way to manage pests. They have observed that diversified farms experience significantly less pest pressure compared to monocropping systems. One farmer explained this ecological phenomenon: *“When the same crop is grown everywhere, pest infestations are higher.” “When there is a variety of plants, nature maintains its own balance.”*

This holistic approach integrates the role of trees, birds, frogs, and beneficial insects, which act as natural guardians of the farm. An elderly participant summarised the loss of this biological control in recent times: *“There were more birds in the past, and consequently, fewer pests.”*

By combining botanical innovations with traditional ecological wisdom, the farmers of Mundumala are successfully transitioning towards an integrated pest

management system. This strategy not only reduces the economic burden of farming but also restores the inherent resilience of the agricultural landscape, in which the farm functions as a self-regulating ecosystem.

Local seeds and community resilience: Preserving heritage and autonomy

Seed diversity is the heartbeat of agroecological resilience in Mundumala village. In line with the principles of ancestral farming, local seed varieties are not merely planting materials; they are repositories of cultural heritage and ecological adaptation. Farmers consistently emphasised that indigenous varieties possess an inherent ability to thrive under the harsh conditions of the Barind region, enduring prolonged droughts and erratic rainfall while requiring significantly fewer external chemical inputs than commercial varieties. Recognising this resilience, one farmer remarked: *“Local seeds are capable of enduring great hardship.”* The growing uncertainty of the market and the rising costs of synthetic inputs have pushed farmers to reconsider their dependency, with one participant noting, *“One cannot always rely on market-bought seeds.”*

This quest for food sovereignty is actively sustained through community-based seed-saving and seed-banking practices. Seed saving is a deeply social activity, predominantly managed by women and elderly farmers, who treat these seeds as precious family assets. Seeds are meticulously selected, dried, and stored using traditional methods, then exchanged among relatives, neighbours, and community members. This practice of reciprocity not only maintains biodiversity but also strengthens community bonds. As one woman shared, *“If one has one’s own seeds, there is a sense of confidence and courage.”*

There is a sense of confidence when one has their own seeds. Reflecting on the era before the prevalence of industrial agriculture, another participant added: *“Previously, there was no need to buy seeds.”*

These practices have led to the conceptualisation of informal community seed banks, where farmers collectively preserve rare crop varieties. This model, championed by BARCIK’s philosophy, transforms the seed from a commodity into a common good, ensuring that genetic resources remain accessible to all, especially vulnerable households. By reducing financial dependence on the market, seed saving directly bolsters household self-reliance and fosters a sustainable agricultural future. An elderly farmer aptly summarised the profound connection between seed preservation and survival: *“If we can save the seeds, we can save the future.”*

Agroforestry: Integrating trees with crops

Agroforestry serves as a cornerstone of the land-use strategy in Mundumala, where trees are seamlessly integrated into the agricultural landscape to create a multi-layered, resilient system. Farmers actively maintain a diverse range of species, including fruit-bearing trees such as mango, guava, papaya, and banana, as well as nutrient-rich drumstick trees, valuable timber varieties, and essential medicinal plants. This integration is far more than a mere agricultural technique; it is a long-term investment in the land's ecological and economic stability. As one farmer aptly summarised the multifaceted value of trees: *"Trees not only provide fruit, but also offer shade and protect the soil."*

Beyond immediate yields, farmers view these plantations as a strategic asset for the future, with one participant remarking: *"Trees represent savings for the future."* Women play a pivotal role in this system, particularly through the management of homestead forests, which significantly contribute to household nutrition and food security. The availability of fresh fruits and greens reduces the economic burden on the family, as one woman explained: *"If there are fruit trees at home, one doesn't have to go to the market as often."*

The integration of trees also provides critical ecological services vital to the Barind landscape. By creating shaded microclimates, these trees effectively mitigate heat stress, conserve soil moisture, and support local biodiversity. Furthermore, they serve as a crucial mechanism for income diversification, buffering households against the volatile market cycles often associated with single-crop cultivation. Ultimately, agroforestry in Mundumala represents a holistic approach in which farming is harmonised with nature, transforming the farm into a productive, self-sustaining ecosystem.

Livestock integration: A circular economy of resilience

In the agricultural landscape of Mundumala, livestock integration is not merely an auxiliary activity but a fundamental component of a circular farming system. The relationship between crops and livestock is deeply symbiotic; the animals rely on crop residues for fodder, while their manure provides the essential fertility that sustains the soil. This nutrient recycling loop significantly diminishes the reliance on external chemical inputs and plays a critical role in restoring long-term soil health. Farmers recognise this interdependence as the bedrock of sustainable production, with one farmer observing: *"If one has cattle, one also has fertiliser."* Another participant highlighted this bond, stating, *"Land and livestock are inseparable."*

Beyond their role in nutrient management, livestock serve as a vital economic buffer and a reliable coping mechanism during periods of agricultural crisis. In the volatile environment of the Barind region, where crop failure can be devastating, cattle, goats, and poultry act as living household assets. These animals provide the financial liquidity needed during emergencies, offering a safety net that prevents total household collapse. As one farmer remarked regarding their importance, *"Cattle and goats are often friends in times of distress."* This resilience is further reflected in the sentiment: *"Even if the crop fails, if one has cattle, one does not break down completely."*

Women participants particularly emphasised the socio-economic significance of poultry and goats, which are often managed within the homestead. These small-scale livestock operations are essential for maintaining day-to-day household food security and providing women with a sense of financial independence. Summarising the role of this small-scale integration, one woman explained: *"Poultry and goats often provide security for the family."*

Ultimately, the integration of livestock in Mundumala exemplifies a regenerative agricultural model. It effectively combines ecological nutrient cycling with a robust risk-mitigation strategy, ensuring that farming households remain economically viable and socially secure even in the face of environmental and market challenges.

Community reflection

The findings suggest that the agroecological practices observed in Mundumala village are not merely isolated techniques but interconnected systems built around biodiversity, indigenous knowledge, and deep-seated ecological relationships. These practices enable farmers to effectively mitigate risks, conserve precious resources, lower production costs, and significantly strengthen their adaptive capacity against climatic uncertainties. The community's journey towards sustainability reflects a shift in philosophy, where the farm is no longer viewed as a factory for yield, but as a living entity that requires nurturing. As one elderly farmer reflected: *"If one remains in harmony with nature, nature also assists humanity."* Reinforcing this sense of self-reliance and the value of local wisdom, another participant concluded: *"Everything does not need to be purchased; one can survive by relying on one's own knowledge and diversity."*

Ultimately, these integrated practices form the foundation of climate resilience in Mundumala and provide valuable, replicable lessons for building more sustainable and autonomous farming systems across the wider Barind region.

Evidence of resilience outcomes

The investigation into the farming practices of Mundumala reveals that while agroecological interventions cannot entirely neutralise the impacts of climate change such as drought, heatwaves, or erratic precipitation, they significantly enhance the adaptive capacity and risk-mitigation potential of rural households. The findings suggest that transitioning from input-intensive monocropping to a diversified, resource-integrated system provides a critical safety net, allowing families to recover from climatic shocks with greater agility. This resilience is observed primarily through three interconnected outcomes: yield stability, strengthened food security, and robust economic resilience.

Yield stability: Maintaining production through diversification

A key observation is that diversified farming systems exhibit a much higher degree of yield stability compared to monocropping. When farmers integrate mixed cropping, organic composting, and livestock, total farm failure becomes rare. Even when a primary crop like paddy suffers from unfavourable weather, other elements, such as pulses, vegetables, or homestead livestock, ensure that the household remains productive. One farmer insightfully articulated this protective strategy: *“Even if rice yields are low, we still have lentils, vegetables, and cattle; there is always something to rely on.”*

This systemic stability is not merely about production volume but about risk distribution; as one elderly farmer reflected, if one crop fails and there is nothing else, the household faces a catastrophe. In contrast, in a diversified system, the damage is contained, reinforcing the collective wisdom that *“Everything does not perish at once. This is our primary security.”*

Strengthening household food security

Food security in Mundumala is directly linked to the diversity within the farm. By maintaining homestead gardens, fruit trees, and livestock (poultry, goats, cattle), households secure year-round access to a nutritious diet comprising eggs, milk, fruits, pulses, and spices. This diversity reduces the household's reliance on market-purchased commodities, which are often subject to volatile price hikes. Women participants, in particular, emphasised that these resources act as a nutritional shield. As one woman shared, *“Having greens, eggs, chillies, and papaya provides immense support to the household.”*

Furthermore, the conservation of local, resilient seeds significantly bolsters this security, as it grants farmers autonomy over their planting materials, decoupling them from dependence on external seed markets and ensuring that the foundation of their next harvest remains within reach.

Economic resilience: Reducing costs and diversifying income

Agroecological practices have proven to be an effective antidote to the rising costs of input-intensive agriculture. As expenses for chemical fertilisers, pesticides, and irrigation continue to soar, farmers using organic inputs such as cow dung manure and farm-saved seeds are successfully minimising their production costs. This fiscal discipline is supplemented by income diversification; livestock acts as a form of “living savings” that can be liquidated during times of acute financial stress. Reflecting on this economic safety net, a farmer noted:

“Cattle and goats are often a greater source of security than banks.”

By maintaining multiple income streams, whether from vegetable sales, livestock products, or diverse seasonal harvests, households ensure that a single failure does not lead to complete economic collapse.

Adaptive capacity and community confidence

Beyond material outcomes, the most profound indicator of resilience is the community's growing psychological and intellectual adaptive capacity. There is a palpable shift in perspective; farmers are no longer passive recipients of climatic misery but active experimenters seeking ways to thrive in uncertainty. The culture of collective learning, where neighbours exchange experiences and women share traditional gardening methods, has fostered a resilient community identity. As one farmer summarised: *“I cannot stop the drought, but I am learning how to survive alongside it.”*

Ultimately, resilience in Mundumala is not defined by the absence of climatic shocks but by the community's capacity to absorb, recover from, and adapt to them. It is a testament to the fact that when ecological diversity is restored, the human capacity to persist and flourish is significantly amplified.

COMPARATIVE INSIGHTS

The discussions revealed that climate impacts are experienced differently depending on farming practices, livelihood diversity, and dependence on external inputs. Although no farming system is completely immune to drought, heat stress, and erratic rainfall, participants consistently observed that diversified and agroecological farming systems offer greater flexibility and resilience than input-intensive and monocropping systems.

Farmers repeatedly emphasised that resilience does not necessarily mean obtaining the highest yield in a single season. Rather, resilience means maintaining production, reducing risks, lowering dependence on external inputs, and ensuring household food and income security despite climatic uncertainties.

Agroecological versus input-intensive conventional farming

The divide between these two systems is defined by their reliance on external versus internal resources. Conventional farming is predicated on an input-response logic, in which high yields are achieved through synthetic fertilisers, hybrid seeds, and

chemical pesticides. While this model can produce significant yields during ideal climatic years, it often leads to a “dependency trap.” The heavy reliance on external inputs leaves farmers vulnerable to market price fluctuations and creates a cycle of soil degradation, in which the land gradually loses its natural fertility, requiring ever-increasing levels of chemical intervention.

Conversely, agroecological farms are structured around synergistic biological processes. By leveraging internal resources such as livestock manure, vermicompost, botanical bio-pesticides, and farm-saved seeds, these systems build a self-sustaining foundation. This approach prioritises soil health as the primary driver of production, ensuring that the farm ecosystem is equipped to handle climatic variability. The economic stability of these farms is not driven by external market forces but by the inherent health of the ecosystem, which drastically reduces the fiscal risks associated with farming.

Comparative overview of farming systems

Table 3 provides a synthesis of the key structural and ecological differences between the two systems as observed in the study area.

Table 3. Agroecological farms versus conventional/input-intensive farms

Indicators	Agroecological farms	Conventional/input-intensive farms or chemical farms
Yield Stability	Relatively stable across varying seasons	High volatility; high yield in ideal years, collapse during shocks
Production costs	Significantly lower; reliance on internal inputs	High: rising costs for synthetic inputs and irrigation
Dependence on inputs	Minimal; relies on circular nutrient recycling	High; dependent on external market supply chains
Crop diversity	High; promotes biodiversity and resilience	Low; typically monocropping or limited rotations
Soil health	Proactively maintained through organic matter	Gradual degradation and loss of structure
Water retention	High; enhanced by mulching and organic matter	Low; poor structure leads to moisture loss
Pest pressure	Relatively lower; managed via ecological balance	Frequent outbreaks due to reduced natural predators
Climate resilience	Strong, built-in adaptive capacity	Highly vulnerable to climatic extremes
Household food diversity	High; emphasises multi-crop nutrition	Low; centred on market-driven cash crops
Debt risks	Lower; reduced dependency on credit	Higher; increased risk due to input loans
Market dependence	Moderate; balanced by household production	High; entirely subject to market prices
Post-shock recovery	Faster; high adaptive capacity	Slower; dependent on external aid or credit

Diversified farming systems versus monocropping systems

The comparative analysis between diversified farming systems and monocropping further underscores the logic of resilience. Monocropping, characterised by the cultivation of a single crop over a vast area, represents an all-or-nothing strategy. While it may simplify management and yield high returns under perfect conditions, it renders the farming household extremely fragile. The farmers of Mundumala articulated the danger of this lack of variety, with one stating: *"If there is only rice in all the fields, the fear is greater."*

In contrast, diversified systems, which incorporate an array of seasonal vegetables, pulses, fruit trees, and livestock, function as a strategic hedge against uncertainty. Each component acts as a pillar of support; when one is threatened by climate or pests, the others sustain the household's nutritional and economic needs. This logic is encapsulated by a participant's realisation: *"Diversity means security."*

Table 4 summarises the comparison between diversified farming systems and monocropping systems along various indicators.

Table 4. Comparative overview of diversified farming systems and monocropping

Indicators	Diversified farming systems	Monocropping systems
Sources of food	Multiple (vegetables, pulses, fruits, etc.)	Single (Market-dependent)
Sources of income	Multiple (diversified seasonal produce)	Limited (single cash crop)
Exposure to risk	Lower (distributed risk)	Higher (concentrated risk)
Household nutrition	Better (diverse dietary intake)	Limited (low dietary diversity)
Pest outbreaks	Lower (ecological balance)	Higher (high host-plant density)
Drought tolerance	Better (adaptive plant selection)	Lower (high water demand)
Flexibility	High (adaptable to climate change)	Low (rigid management)
Capacity to recover	Stronger (resilience-based recovery)	Weaker (slow recovery)
Dependence on markets	Lower (Higher self-sufficiency)	Higher (total dependency)

As evidenced in the table above, the transition towards diversified systems represents a shift from vulnerability to agency. By moving away from the "efficiency" of monocropping towards the "resilience" of biodiversity, farmers effectively decouple their survival from the whims of the market and the harshness of a changing climate, ensuring they have the flexibility to thrive amid adversity.

Comparing knowledge systems

Discussions also revealed differences between farming systems based on local knowledge and those relying mainly on purchased technologies. A summary of the comparison between local knowledge-based systems and external input-dependent systems based on various indicators is provided in **Table 5**.

Table 5. Local knowledge-based systems versus external input-dependent systems

Indicators	Local knowledge-based systems	External input-independent systems
Seed source	Own seeds and exchanges	Commercial seeds
Fertility management	Compost, nature	Chemical fertilisers
Pest management	Ecological approaches	Pesticides
Learning process	Farmer-to-farmer	Input dealers and markets
Costs	Relatively low	Higher
Self-reliance	Higher	Lower
Long-term sustainability	Stronger	More uncertain

Community reflection: Towards a balanced agricultural future

It is important to note that the participants do not advocate for a total rejection of modern agricultural advancements. Instead, they demonstrate a sophisticated understanding of balance, emphasising the need to integrate modern productivity with the sustainability and resilience of traditional ecological wisdom. There is a widespread recognition that farming must evolve not just to yield more, but to remain viable in the long run. As an elderly farmer pragmatically observed, *“We are not against new things, but if everything has to be bought, the farmer cannot survive.”* This sentiment reflects a call for “sovereign farming,” a system in which productivity is not achieved at the cost of the farmer’s financial independence. The community’s perspective is grounded in the belief that the health of the land and the health of the human are inseparable. Another participant emphasised this symbiotic relationship: *“If one farms in harmony with nature, both the human and the land survive.”*

The findings consistently indicate that diversified agroecological systems possess a superior capacity to withstand climatic shocks, safeguard year-round food security, and insulate households from the volatility of costly external markets. For the farmers of Mundumala, true resilience is not measured by the maximisation of output in a single season. Rather, it is defined by the endurance of livelihoods, the active protection of natural resources, and the commitment to ensuring that farming remains a dignified and viable profession for future generations. By embracing diversity and local knowledge, the community is not merely farming; they are securing

its future against the uncertainties of a changing climate.

Community solutions and collective action

Throughout the research process, participants repeatedly emphasised that climate change is not only creating problems but also pushing communities to think collectively about solutions. During the Solution Tree exercise, farmers, women, elders, and other participants reflected on the changes occurring in their lives and discussed what should be done to strengthen climate resilience and secure their future livelihoods.

The exercise revealed that participants do not view agroecology simply as an agricultural technique. Rather, they see it as a pathway towards restoring soil and water, protecting biodiversity, strengthening local knowledge, ensuring food sovereignty, and improving the wellbeing of rural communities. As one elderly farmer remarked: *“There is no gain in fighting against nature; one must move in harmony with it.”*

Another woman participant explained: *“We want such agriculture that will save both the land and the people.”*

The community vision, strategies, and expected outcomes emerging from the Solution Tree are presented below.

Vision (Tree Trunk): Expanding agroecology for a resilient future

At the core of the community’s vision lies a shared aspiration: *“Increasing the expansion of agroecology to build climate-resilient and sustainable rural livelihoods.”*

Participants articulated that agroecology is not just about replacing chemicals or optimising output; it is a movement to reconnect farming with natural rhythms, optimise local resources, and foster self-reliance. In the drought-prone Barind region, there is a consensus that reliance on expensive external inputs is a path to vulnerability. Instead, they envision a future built on agricultural diversity, local seed sovereignty, soil regeneration, water conservation, and community-based knowledge exchange.

- **Sustainability and future generations:** Participants of all ages highlighted that the current model is unsustainable. One young participant noted, *"Agriculture must be such that young people can also see a future in it"*.
- **Reviving traditional wisdom:** Reflecting on the past, older generations recalled a time of ecological harmony, suggesting that the path forward lies in integrating ancestral knowledge with modern adaptive thinking — "We must move forward by blending old wisdom with new ideas".

The vision of the Solution Tree trunk can be summarised as: More agroecology, less dependence, stronger communities, and a healthier relationship between humanity and the environment.

The Solution Tree put together by the participants is provided in **Annex 4**.

Strategies (Roots): Community pathways towards agroecological transformation

The "roots" of the Solution Tree symbolise the foundational actions, policy requirements, and collective endeavours that the community deems essential to foster climate resilience in the Barind region. The participants collectively emphasised that agroecology is not merely a technical adjustment; it is a profound socio-ecological transformation. Achieving this requires moving beyond individual farm-level changes towards a coordinated ecosystem of support involving communities, government institutions, civil society, and market systems.

As one elderly farmer wisely observed, success lies in collective responsibility: *"The responsibility cannot be placed on the farmer alone; everyone must work together."*

The following thematic strategies represent the community's roadmap for a resilient agricultural future:

- **Regenerating soil and water health:** Recognising that agricultural productivity is inseparable from environmental health, farmers prioritised organic practices, including composting, vermicompost, and mulching, alongside rainwater harvesting and the conservation of natural water bodies
- **Seed sovereignty and genetic diversity:** To mitigate drought risks, participants advocated preserving drought-tolerant indigenous varieties through community seed banks and robust farmer-to-farmer exchange networks
- **Ecological diversification:** The strategy shifts focus from monocropping to diversified systems integrating mixed cropping, crop rotation, and agroforestry to reduce pest pressure and enhance the landscape's natural resilience
- **Decoupling from chemical inputs:** A central pillar is the gradual reduction of synthetic inputs. Participants emphasised the local production of organic alternatives (biopesticides and compost) to regain financial autonomy
- **Policy and public investment:** The community called for a national agroecology policy, fair credit facilities, and a shift in state incentives away from chemical support towards ecological farming
- **Market justice and livelihoods:** Addressing the economic squeeze, farmers emphasised the need for fair market access, value-chain support for ecological products, and the curbing of market syndicates
- **Knowledge valorisation:** Recognising that "research" is not limited to laboratories, participants advocated for the formal recognition of indigenous knowledge and the expansion of farmer-led innovation networks
- **Gender and youth inclusion:** There is a critical need to recognise women's indispensable roles in seed and food security, while simultaneously creating sustainable pathways for the youth to engage in agriculture
- **Biodiversity and collective solidarity:** Finally, the community emphasised protecting natural habitats, such as those for birds and beneficial insects, and strengthening farmer networks to amplify their collective voice

Table 6 summarises the community strategies based on the various areas of agroecological transformation.

These strategies illustrate that the community views agroecology as a comprehensive social and political process. It is a roadmap that demands not only the protection of land and water but also the restoration of human dignity and social justice. As the

participants emphasised, the future of the Barind region depends on these interconnected elements. One elderly farmer's words encapsulate this sentiment: *"It is not just about the land; we must save*

the people, the seeds, the water, and the relationships, everything." Another participant concluded: *"Agroecology is not just about farming; it is the path to saving our future."*

Table 6. Strategic framework for agroecological transformation

Thematic area	Community strategies
Soil and water health	Mulching, composting, vermicompost, rainwater harvesting, water conservation, protecting natural water bodies
Seed systems	Community seed banks, local seed conservation, drought-tolerant varieties, seed exchange
Crop diversity	Mixed cropping, crop rotation, agroforestry, biodiversity conservation
Ecological farming	Organic fertilisers, biopesticides, and reducing chemical dependency
Policy support	Agroecology policy, incentives, low-interest loans, increased public investment
Markets and livelihoods	Fair markets, stopping syndicates, increasing market access, diversified livelihoods, value-chain support for bio-products
Knowledge systems	Recognition of indigenous knowledge, farmer-to-farmer learning, advocacy, indigenous knowledge documentation
Gender and youth	Support for women farmers, youth engagement, capacity building
Biodiversity protection	Tree planting, bird protection, habitat restoration
Collective action	Farmer networks, community seed banks, solidarity and cooperation
Social inclusion	Support for women farmers, youth-oriented sustainable programmes

Expected outcomes (Branches): Community aspirations for a resilient future

The "branches" of the Solution Tree represent the long-term aspirations of the Mu ndumala community. Participants envisioned a future where farming is not just productive but fundamentally restorative and just. They emphasised that the expansion of agroecology is a pathway to achieving structural changes that go beyond seasonal yields. As one elderly farmer aptly summarised: *"We do not just want higher yields; we want a future that will last."*

The following are the core outcomes identified by the participants:

- Climate resilience:** Building a system that does not just resist climate shocks but effectively absorbs them. Through drought-tolerant seeds, soil moisture conservation, and diversified cropping, the community expects to remain productive despite erratic weather
- Food sovereignty:** Securing complete control over seeds, production methods, and dietary choices. The aspiration is to move away from market dependency, ensuring that households have autonomy over their nutritional security
- Biodiversity restoration:** Actively reversing ecological degradation by creating landscapes that support birds, beneficial insects, and a wide variety of flora. This restoration is seen as the biological insurance for farming
- Soil and water health:** Achieving long-term fertility through organic recycling and groundwater recharge, ensuring that the land remains productive for future generations.
- Economic self-reliance:** Reducing the "cost-squeeze" by eliminating dependency on expensive chemical inputs. By utilising internal farm resources (livestock manure, compost), households aim to increase net savings and reduce debt
- Nutrition and food diversity:** Ensuring that the farm provides a balanced diet including vegetables, fruits, pulses, milk, and eggs, thereby enhancing family health and reducing the need for market-bought processed foods
- Women's empowerment:** Transforming women from "helpers" into recognised partners in agriculture, with leadership roles in seed banks, homestead management, and community decision-making

- **Youth engagement:** Creating a dignified, profitable, and ecologically conscious farming model that attracts the younger generation and retains them in the agricultural sector
- **Stronger social networks:** Strengthening the "social fabric" of the community through collective seed banks, knowledge-sharing platforms, and mutual support systems that act as a safety net during crises

A summary of the expected outcomes put together by the participants in the Solution Tree exercise is provided in **Table 7**.

Ultimately, the community envisions a future where farmers are respected, the land is cherished, and the next generation finds hope in the soil. As a woman participant concluded:

"Agroecology is not just a method of farming; it is a pathway to survival."

Table 7. Summary of expected outcomes (Branches of the Solution Tree)

Outcome dimension	Key community aspirations
Climate resilience	Adaptive capacity, drought tolerance, faster recovery from shocks
Food sovereignty	Control over local seeds, self-reliance, reduced market dependency
Biodiversity restoration	Habitat for beneficial species, tree cover, diverse crop varieties.
Soil & water health	High organic matter, improved water retention, groundwater recharge
Economic stability	Reduced input costs, diversified income, lower debt risks
Nutrition & health	Year-round access to diverse, nutritious, and safe food
Social capital	Collective action, empowered women, youth participation, solidarity

KEY INSIGHTS: SYNTHESISING THE FINDINGS

This participatory action research in Mundumala village demonstrates that climate change is a multidimensional crisis affecting not only the environment but the very fabric of rural livelihoods, social cohesion, and household well-being. Crucially, the study reveals that the community is not a passive victim; rather, it is a hub of active adaptation, leveraging deep-rooted indigenous knowledge and collective ingenuity to navigate an increasingly uncertain climatic future. As one elderly farmer noted: *"Nature is changing, but humans are not standing still."* The following insights encapsulate the core findings of this study:

Agroecology as a strategy for resilience

Agroecology is the most effective pathway for climate adaptation in the Barind region. Practices like crop diversification, seed saving, and livestock integration act as a 'biological insurance' policy. While these methods may not eliminate climatic shocks such as drought or heatwaves, they fundamentally transform a household's ability to absorb and recover from these shocks, shifting the focus from maximising yield to ensuring existential continuity.

Climate change as an amplifier of inequality

Climate impacts are inherently unjust. Women, landless labourers, and smallholders bear a disproportionate burden due to their limited access to resources and decision-making power. The study reveals that climate change is not merely an ecological problem; it is a profound issue of equity, justice, and access, where those with the least "cushion" face the highest risk.

The primacy of local and indigenous knowledge

Local knowledge is a dynamic, evolving resource that has allowed the Barind community to survive for generations. The study indicates that top-down technological interventions are often less effective than solutions derived from local experimentation. As one farmer remarked, Farmers also conduct research; only their language is different, suggesting that future adaptation efforts must recognise and integrate this wisdom rather than replace it.

Resilience as a collective social construct

Individual resilience is fragile; true stability is built through collective action. Farmer networks, community seed banks, and mutual support systems are the hidden "social infrastructure" that sustains the community during crises. The findings emphasise that resilience is as much about strong social relationships as it is about agricultural techniques.

The centrality of water sovereignty

Water scarcity has emerged as the defining challenge of the Barind region. The study suggests that long-term resilience is impossible without a paradigm shift in water management, moving from exploitative groundwater extraction to regenerative practices like rainwater harvesting, pond restoration, and soil moisture conservation.

Redefining success beyond production

The findings challenge the narrow economic metric of “yield per hectare.” For the farmers of Mundumala, success is measured by food sovereignty, reduced dependence on inputs, soil health, and social stability. A farming system that yields high output but drains the farmer’s finances and degrades the land is seen as a failure. Resilience is redefined here as the ability to maintain a dignified livelihood while protecting the natural capital for future generations.

Overall reflection: A pathway to survival

The evidence from Mundumala proves that agroecology is far more than a set of farming techniques; it is a holistic socio-ecological movement. It is a pathway towards social justice, ecological restoration, and genuine food sovereignty. As we look towards the future, the community’s message is clear: survival depends on our ability to align our agricultural practices with the rhythms of nature. As one participant concluded: *“Agroecology is not just a method of farming; it is a way to survive.”*

POLICY AND ADVOCACY IMPLICATIONS: A CALL FOR STRUCTURAL CHANGE

The findings of this research establish that the climate crisis in the Barind region is not merely an environmental hurdle; it is a systemic crisis of equity, biodiversity, and food sovereignty. While community-led adaptation is underway, it remains constrained by structural limitations. To transition from isolated pockets of resilience to a region-wide agroecological movement, proactive state intervention and institutional support are non-negotiable. As one elderly farmer aptly noted: *“The farmer cannot do everything alone; the state must also stand by them.”*

Based on the participatory insights, the following policy and advocacy pathways are proposed:

Institutionalising agroecology. Current agricultural policies remain heavily skewed towards input-intensive monocropping. A paradigm shift is required

to integrate agroecology into national climate adaptation strategies.

Recommendation: Formulate a National Agroecology Policy Framework that provides institutional legitimacy and financial incentives for ecological farming, ensuring it receives equal footing with conventional practices in agricultural extension services.

Securing seed sovereignty. Seed is the primary means of production. Dependence on commercial seeds undermines both the farmer’s financial stability and the region’s climate resilience.

Recommendation: State recognition and protection of indigenous, drought-tolerant seed varieties. Policy must support Community Seed Banks and formalise farmer-managed seed exchange networks as a public good.

Context-specific climate adaptation. The Barind region requires distinct interventions compared to other agroecological zones of Bangladesh.

Recommendation: Prioritise large-scale investment in water-sovereignty infrastructure such as rainwater harvesting, pond restoration, and groundwater recharge rather than relying solely on high-cost, electricity-dependent deep tubewells.

Promoting soil and ecological health. Soil degradation is a slow-motion disaster. Policy must pivot to restore the land’s biological integrity.

Recommendation: Redirect subsidies currently flowing towards chemical fertilisers to promote the production and application of organic fertilisers (compost, vermicompost) and bio-pesticides at the village level.

Democratising agricultural knowledge. The “expert-led” extension model needs to be replaced by a horizontal, participatory approach.

Recommendation: Establish Farmer-led Innovation Centres to document and validate indigenous knowledge. Training programmes should focus on ecological principles rather than just “input recipes.”

Social justice and empowerment. Policy must address the “invisibility” of key contributors to rural resilience.

Recommendation: Formally recognise women as primary farmers and provide them with direct access to credit, training, and land-use decision-making. Furthermore, create incentives for youth-

led eco-enterprises to make agriculture a socially dignified and economically attractive profession.

Market integrity and fair trade. Production is rendered meaningless if the farmer is exploited by market syndicates.

Recommendation: Establish direct-to-consumer market linkages for ecological produce. Government procurement policies should prioritise ecological products to create a guaranteed market for farmers transitioning away from chemicals.

Strengthening collective action. Resilience is a form of social capital. Policy must facilitate the growth of farmer networks and collective solidarity platforms.

Recommendation: Provide legal and financial support to farmer organisations to enable them to engage in local advocacy and collective bargaining, which are essential for long-term climate justice.

Policy reflection: An integrated vision

The participants have made it clear that agroecology is not a 'technical package' to be distributed; it is a movement. Policies must, therefore, be designed to protect not just the land, but the relationships between people, seeds, and nature. As one participant concluded:

“Agroecology is not just a farming method; it is a movement for human survival.”

Table 8 summarises the key priorities identified by the participants for policy advocacy.

The findings suggest that building climate resilience in the Barind region requires more than technological solutions. It requires supportive policies, stronger institutions, recognition of community knowledge, and collective action. Participants repeatedly emphasised that the future of agriculture depends not only on productivity but also on justice, diversity, and solidarity.

Table 8. Policy and advocacy priorities emerging from the research

Areas	Key priorities
Policy	Agroecology policy, increased public investment, incentives
Seed sovereignty	Community seed banks, indigenous seeds, farmer seed systems
Climate adaptation	Water conservation, drought-resilient crops, local adaptation programmes
Soil and biodiversity	Composting, biopesticides, ecosystem restoration
Development programmes	Training, farmer-to-farmer learning, participatory research
Women farmers	Recognition, access to resources, leadership opportunities
Youth engagement	Skills, innovation, ecological enterprises
Collective action	Farmer organisations, solidarity networks, advocacy
Markets	Fair prices, market access, and reducing syndicates
Movement building	Climate justice, food sovereignty, farmer-led networks
Movement building	Climate justice, food sovereignty, farmer-led networks

CASE STUDIES

Case study 1

From an improved stove to an agroecology learning centre: The journey of Kobul Jan

Profile

Kobul Jan (55), a resident of Haridevpur in Tanore Upazila, Rajshahi District, exemplifies how local knowledge, women's leadership, and simple innovations can contribute to ecological sustainability and community resilience. Although she never had the opportunity to receive formal education, she has spent decades learning through experience and practice. Her contributions to environmental conservation and sustainable livelihoods earned her the prestigious Joyeeta Award in 2016, awarded by the local administration in recognition of her outstanding achievements as a rural woman entrepreneur and community leader.

Married in 1978, Kobul Jan entered a household struggling with poverty and livelihood insecurity. Like many rural women, she started her life with limited resources but gradually transformed everyday challenges into opportunities for serving her community.

Beginning with environment-friendly stoves

Kobul Jan's journey began with a simple idea. Seeing how women around her suffered from smoke, excessive fuel consumption, and unhealthy cooking conditions, she started experimenting with improved clay stoves. Over the years, she developed the skills to construct nine different types of fuel-efficient, environmentally friendly stoves tailored to household needs.

Today, her innovations have spread far beyond her village. Through farmer networks and word of mouth, her work has expanded to nearly 95 villages across nine upazilas and three districts. She has personally constructed around 3,000 environment-friendly stoves in the Barind region.

Remarkably, she never promoted her work through campaigns or advertisements.

As Kobul Jan explained, *"People needed it, so people themselves spread the word. I never had to campaign. They came to me and said, 'Kobul Jan, please make a stove for us.'"*

Her stoves use less fuel, emit less smoke, keep kitchens cleaner, and are built from locally available

materials. Some designs even allow three or four households to cook simultaneously from a single stove, making them particularly suitable for densely populated areas.

With support from BARCIK after 2015, Kobul Jan began conducting training workshops. Through fairs, farmer gatherings, and practical demonstrations, many rural women and youth learned the skills and started producing similar stoves in their own communities. Haridevpur village itself has become locally known as an "environment-friendly stove village."

Building an agroecology learning centre

What started as a small homestead vegetable garden gradually evolved into a vibrant agroecology learning centre. Today, her thirty-decimal homestead hosts a remarkable diversity of plants and farming practices. The learning centre conserves around 121 species of fruit trees, medicinal plants, flowers, timber species, and uncultivated edible plants; approximately 140 varieties of indigenous seeds; diverse seasonal vegetables and crops grown throughout the year; and vermicompost production units and botanical pest management practices. Although she owns only a small amount of land, she leases additional plots each year to cultivate a diverse range of crops using ecological methods. Her husband, Mobarak Hossain, actively supports her work.

Walking around her courtyard reveals an extraordinary diversity of life. Gourds climb bamboo trellises, medicinal plants grow beside vegetables, and earthen seed containers line the walls of her seed house.

She proudly says: *"My home is not just a home; it is a place for learning. No one returns empty-handed. If someone needs seeds, seedlings, or advice, I try to help."*

Climate challenges and her response

Living in the drought-prone Barind region, Kobul Jan has witnessed rising temperatures, declining rainfall, water scarcity, and a growing dependence on chemical agriculture.

She observes: *"Earlier, people used fewer chemicals. Now everyone thinks only about production. But who thinks about the health of the soil?"* Concerned about soil degradation and biodiversity loss, she adopted ecological farming practices. She now uses vermicompost, botanical pesticides, mulching, seed conservation, mixed cropping, and homestead biodiversity management. According to her, *"If the soil remains healthy, crops will remain healthy; and if crops remain healthy, people will remain healthy."*



Kobul Jan prepares organic biopesticides and maintains vermicompost as part of her agroecological practices, helping reduce her dependence on chemical inputs.



Seed conservation and farmer-to-farmer learning

One of Kobul Jan's most remarkable contributions is her role as a community seed custodian. Her seed house conserves numerous indigenous varieties, and every season, farmers from surrounding villages come to collect seeds and exchange experiences.

Nearly 900 farmers and rural women have benefited from seed sharing and knowledge exchange through her centre. She regularly encourages women to conserve seeds, cultivate vegetables, prepare botanical pesticides, and reduce dependence on purchased inputs.

She says: *"If farmers possess their own seeds, they will never be poor. We cannot depend entirely on the market."*

Expanding ecological practices

Kobul Jan has also established a vermicompost production unit and has distributed earthworms and organic fertiliser to neighbouring farmers. More than 40 farmers have received vermicompost support, and 15 have started their own composting activities using earthworms she provided. Her experiences demonstrate how agroecology is not simply about farming techniques but about rebuilding relationships among soil, seeds, biodiversity, women, and communities.

Farmers, women farmers, and youth share experiences and learning from one another at Kobul Jan's agroecology learning centre

Lessons from Kobul Jan's journey

Kobul Jan's story illustrates that climate resilience does not always emerge from large-scale projects or expensive technologies. Sometimes, profound transformations begin with simple local innovations and dedicated individuals.

Her journey highlights several important lessons:

- Women are central actors in agroecological transformation
- Local knowledge and practical innovations can create large-scale environmental benefits
- Seed sovereignty and biodiversity conservation strengthen community resilience
- Farmer-to-farmer learning is an effective pathway for scaling agroecology.
- Ecological agriculture contributes not only to food production but also to social solidarity and environmental restoration

Reflecting on her life's work, Kobul Jan quietly remarked: *"I have not done anything extraordinary. I simply shared what I know. If people and nature benefit from it, that is my happiness."*



Case study 2

Growing with nature: How Shafiqul Islam is turning the dry Barind landscape into a living learning space

Farmer profile

Md. Shafiqul Islam (53) is a farmer and environmental steward from Jotgorib under Mundumala Municipality in Tanore Upazila, Rajshahi District. After working abroad for several years, he returned home with a dream that went beyond farming for income. He wanted to transform the barren landscape of the drought-prone Barind region into a greener and more ecologically balanced environment. Today, his homestead and orchard have become a living example of agroecology in practice. Over the last decade, he has planted more than 5,000 trees and collected diverse plant species from twelve districts of Bangladesh. His farm now hosts around 140 species of indigenous and exotic fruit, forest, and medicinal plants.

Reflecting on his vision, he said, *“We should not think only about ourselves. Birds are our friends. My effort is to become a friend of nature.”*

Climate challenges faced

Like many farmers in the Barind region, Shafiqul Islam faced the harsh realities of prolonged drought, increasing temperatures, declining biodiversity, and the gradual degradation of natural resources. When he purchased five bighas of land after returning from abroad, the area was almost barren. There were no trees, little biodiversity, and very limited vegetation. He recalled: *“There was nothing except the dry and harsh landscape of Barind.”* In addition, he observed that modern commercial farming often prioritises production while neglecting biodiversity and ecological balance. The widespread use of harmful nets in orchards, excessive pesticide use, and declining bird populations deeply concerned him.

Agroecological practices adopted

In 2014, he began planting indigenous Ashwina mango trees. Gradually, he diversified his farm into a complex agroecological system that integrates fruit trees, medicinal plants, biodiversity conservation, livestock, composting, renewable energy, and ecological pest management.

Biodiversity-based orchard management

Unlike many commercial orchards, Shafiqul Islam does not use harmful nets that trap and kill birds. Instead, he intentionally leaves several fruit trees

unharvested so that birds can feed on them. He explained: *“Not all fruits are meant only for humans. Birds also have a right to eat.”* Small ponds have been created inside the orchard to provide drinking water for birds and wildlife.

Creating habitats for beneficial species

At the centre of his orchard, he has established a small sanctuary covering about five decimals of land where shrubs, vines, and native plants are left undisturbed. This space has become a refuge for frogs, bees, insects, and many other species.

According to him, *“Many creatures live here, and they help maintain the health of the orchard.”* He believes biodiversity itself is a form of pest management.

Ecological pest management

Instead of relying heavily on chemical pesticides, he uses sex pheromone traps, yellow sticky traps, habitat conservation for beneficial insects, and natural decomposition processes.

He allows damaged and overripe fruits to fall to the ground, where insects feed on them, and the decomposed fruits contribute organic matter to the soil. He explained: *“Nothing in nature is useless. Fallen fruits feed insects and eventually nourish the soil.”*

Soil health and circular nutrient systems

Shafiqul Islam operates a biogas plant that supplies energy to households. The slurry from the biogas system is used to prepare Tricho-compost, which is applied to his orchard.

He also avoids herbicides. Instead of treating weeds as enemies, he sees them as resources.

He remarked: *“I do not use herbicides. Many grasses are nutritious food for cattle.”*

Medicinal plants and homestead diversity

One corner of his homestead contains a diverse medicinal garden with indigenous species used for both family healthcare and livestock treatment. His home garden also produces vegetables for household consumption throughout the year. Today, his homestead has evolved into what many visitors consider an informal agroecology learning centre.

Integrating wildlife into farming

Rather than using plastic barriers, he fenced his orchard with wire mesh and allowed climbing plants, especially ivy gourd (*Coccinia grandis*), to grow naturally.

The fruits of ivy gourd attract birds, which in turn feed on harmful insects, reducing pest pressure. According to him, *“Birds eat fruits, but they also help protect the orchard.”*

Community contributions beyond his farm

Shafiqul Islam's efforts extend beyond his own land. During the COVID-19 pandemic in 2020, he planted around 500 palmyra palm seeds along roadsides. About 120 trees have survived and are growing today. He has distributed fruit, forest, and medicinal plant saplings to 1,120 students in five schools. More importantly, he regularly visits the households of those students to monitor the condition of the plants and provide guidance. He also conserves seasonal fruit seeds and disperses them along roadsides and fallow lands during the rainy season.

Reflecting on this work, he said: *“Trees should not remain only inside my homestead. They should spread throughout the community.”*

Results and outcomes

Over the years, his farm has become much more than a commercial orchard. The agroecological system has contributed to:

- Increased tree cover and biodiversity;
- Improved soil fertility;
- Reduced dependence on chemical inputs;
- Habitat restoration for birds and beneficial species;
- Household food security;
- Renewable energy production through biogas;
- Community awareness about ecological farming;
- Increased interest among young people and neighbouring farmers.

Visitors from different areas regularly come to observe his practices and exchange experiences.

One neighbouring farmer remarked: *“His farm shows that farming and caring for nature can go together.”*

Lessons for climate resilience

The experience of Md. Shafiqul Islam demonstrates that agroecology is not merely a set of agricultural techniques. It represents a way to rebuild relationships among people, biodiversity, and ecosystems.

His story highlights several important lessons:

- Biodiversity conservation and farming can complement each other
- Ecological pest management can reduce dependence on chemical pesticides
- Trees, birds, insects, and soil organisms are allies in building resilient farming systems
- Individual initiatives can inspire broader community action
- Agroecology extends beyond food production to ecosystem restoration and environmental stewardship

Looking towards the future, Shafiqul Islam hopes to distribute indigenous fruit, forest, and medicinal tree saplings to students across the area and expand compost production to improve soil health.

He dreams of covering the dry Barind landscape with diverse trees. In his own words: *“If I can leave even a little more greenery for the future, that will be my greatest achievement.”*

Reflection

The story of Md. Shafiqul Islam illustrates that climate resilience is not only about coping with drought and heat stress. It is also about restoring ecological relationships and nurturing hope. His farm represents how one person's vision and commitment can transform a barren landscape into a living example of agroecology and coexistence with nature.

CONCLUSION

This participatory action research documentation explored how climate change is affecting rural communities in Mundumala village of the Barind region and how agroecological practices are contributing to climate resilience. The findings reveal that climate change is no longer perceived by farmers as a distant or abstract phenomenon; rather, it is experienced through changing seasons, increasing temperatures, erratic rainfall, prolonged drought, declining groundwater availability, rising production costs, and growing uncertainties in agricultural livelihoods.

Over the last decade, community members have observed significant changes in local weather patterns. Delayed rainfall, prolonged dry periods, intense heat waves, occasional heavy rainfall, increasing pest infestations, and declining soil fertility have affected crop production and household well-

being. These changes have not only reduced agricultural productivity but have also increased production costs, indebtedness, and livelihood insecurity. Women farmers, smallholders, landless labourers, and rural youth were found to be particularly vulnerable due to their limited access to land, water, resources, and alternative income opportunities. The findings suggest that climate change is also deepening existing social and economic inequalities within rural communities.

However, the study also demonstrates that communities are not passive victims of climate change. Farmers in Mundumala village have continuously developed and refined their own responses through experience, local knowledge, collective learning, and adaptation practices.

The research documented a wide range of agroecological practices already present within the community, including crop diversification, mixed and intercropping systems, local seed conservation, composting, mulching, natural pest management, agroforestry, livestock integration, water conservation practices, and homestead gardening. These practices are not isolated technical interventions; rather, they represent an interconnected system that supports ecological sustainability, food security, and livelihood resilience.

Evidence from discussions, interviews, and participatory exercises indicates that agroecological practices significantly strengthen resilience. Households practising diversified farming systems were found to be better able to cope with climatic stresses and economic shocks. Crop diversity, lower dependence on external inputs, integration of livestock, use of local seeds, and reliance on locally available resources helped reduce production risks and increase adaptive capacity. Agroecological farms generally showed greater yield stability, lower production costs, improved dietary diversity, and multiple income sources compared to more input-intensive and specialised farming systems. Farmers repeatedly emphasised that biodiversity and diversification function as important forms of insurance in times of climatic uncertainty.

Another important finding emerging from this study is that local knowledge remains central to adaptation. Community members possess valuable experiences accumulated through generations of farming and interaction with the local environment. Seasonal observations, seed-saving traditions, collective learning, and farmer-to-farmer exchanges continue to play an important role in shaping adaptation strategies. The findings reaffirm that climate resilience cannot be achieved solely through technological solutions; it must also recognise and strengthen the knowledge, practices, and capacities already existing within communities.

Md. Shafiqul Islam and his diverse agroecological orchard show how a farmer's vision can restore biodiversity and transform the dry Barind landscape into a thriving ecosystem



The study further highlights the importance of collective action. Through the Solution Tree exercise, participants articulated a shared vision for expanding agroecology as a pathway towards climate resilience, biodiversity conservation, food sovereignty, and sustainable livelihoods. Farmers emphasised the need for stronger seed-sharing networks, farmer organisations, ecological restoration, local knowledge systems, and supportive public policies. Their reflections indicate that resilience is not only an individual process but also a collective social process rooted in cooperation, solidarity, and community institutions.

Overall, the findings suggest that agroecology offers a practical and locally grounded response to the multiple challenges posed by climate change in the drought-prone Barind region. Agroecology is not merely a collection of farming techniques; it represents a broader ecological, social, and cultural approach that values biodiversity, local knowledge, and community empowerment. Strengthening agroecological transitions can simultaneously contribute to climate adaptation, food sovereignty, ecological restoration, and rural well-being.

Looking ahead, there is a need to move beyond isolated practices and support the scaling up of agroecological transitions. This requires greater public investment, supportive policies, farmer-to-farmer learning processes, stronger local institutions, recognition of traditional knowledge, and collective efforts involving communities, civil society organisations, researchers, and policymakers. Building climate-resilient rural futures in the Barind region will depend not only on technological innovations but also on nurturing the ecological wisdom, diversity, and solidarity that already exist within farming communities.

As one elderly farmer from Mundumala village reflected during the discussions: *“The climate has changed, and therefore we too must change. But if we can protect our land, seeds, trees, and people, there will always be a way to survive.”*

In this sense, the experiences of Mundumala village suggest that the pathway towards climate resilience lies not only in adapting to change but also in strengthening the ecological relationships, local knowledge, and collective capacities that sustain rural life.

Young people gain hands-on knowledge in agroecology through knowledge exchange on the preparation and management of vermicompost and quick compost



India: Maharashtra, Telangana, Kerala

Pesticide Action Network (PAN) India

Executive summary

These impacts are particularly severe in the semi-arid regions of Maharashtra and Telangana and the plantation-based farming systems of Kerala, where climate variability has intensified existing environmental and livelihood vulnerabilities.

This study adopted a qualitative participatory research approach to examine the impacts of climate change on small-scale food-producing communities and to explore the role of agroecological practices in building climate resilience. The study addressed two key research questions: (i) how the climate crisis is affecting rural poor and small-scale food-producing communities in Maharashtra, Telangana and Kerala, and (ii) how agroecology can contribute to strengthening climate resilience among these communities. Primary data were collected through Focus Group Discussions (FGDs), farmer surveys, semi-structured interviews, case studies, and Participatory Rural Appraisal (PRA) techniques, such as Problem Tree Analysis, across Yavatmal (Maharashtra), Adilabad (Telangana), Thrissur, and Adimali (Kerala). The study engaged diverse stakeholder groups, including organic and conventional farmers, non-chemical farmers, landless agricultural workers, women farmers, youth farmers, and beekeepers. Secondary literature was reviewed to complement and contextualise the field findings.

The findings demonstrate that climate variability has significantly altered agricultural systems across all study locations. Farmers consistently reported increasingly erratic rainfall, prolonged dry spells, recurrent droughts, rising temperatures, floods, and unseasonal precipitation. These climatic changes have disrupted traditional cropping calendars, delayed sowing, reduced seed germination, increased water scarcity, and intensified pest and disease incidence. Crop failures, declining yields, deteriorating crop quality, and rising production costs have emerged as common challenges affecting

diverse farming systems. In addition to reducing agricultural productivity, climate change has increased uncertainty in farming operations, making it increasingly difficult for producers to plan cultivation activities.

Among cotton farmers in Yavatmal district, Maharashtra, respondents identified heavy and untimely rainfall, rising temperatures, prolonged droughts, declining groundwater availability, and changing soil conditions as the most significant climatic challenges. Farmers reported delayed sowing, poor crop establishment, waterlogging, root damage, flower wilting, fungal diseases, pest outbreaks, reduced boll formation, and declining fibre quality. These production challenges have resulted in lower yields, increased cultivation costs, and substantial financial losses. Climate-related occupational health risks were also highlighted by accounts of farmers' deaths reportedly linked to extreme heat and adverse weather while working in the fields. Household surveys further revealed that climate change has affected household food expenditure, education, healthcare, livestock productivity, and employment opportunities, particularly for landless labourers and vulnerable family members.

The study also revealed important differences between conventional, non-pesticidal, and organic cotton farming systems. Organic and non-pesticidal farmers reported adopting a wider range of ecosystem-based adaptation measures, including mixed cropping, compost preparation, tree planting, border crops, seed conservation, biological pest management, trenching, ridge-and-furrow cultivation, and the use of locally prepared bio-inputs such as Jeevamrut and Dashparni Ark. These practices contributed to improved soil health, enhanced biodiversity, better water management, and greater resilience to climate variability while reducing dependence on costly external inputs.

In Adilabad, Telangana, non-chemical cotton farmers reported that excessive heat, prolonged

droughts, floods, and erratic rainfall have disrupted cotton production, reduced yields and quality, increased irrigation and pest management costs, and contributed to a shift from diversified farming towards cotton monocropping. Participants also expressed concern about the loss of indigenous crop varieties, declining soil fertility, growing dependence on external inputs, and the erosion of traditional agricultural knowledge.

Among cardamom farmers in Adimali, Kerala, climate variability has emerged as an equally serious concern. Farmers reported excessive rainfall, prolonged droughts, reduced rainfall, floods, soil erosion, declining groundwater levels, and increasing moisture stress as the primary drivers of declining productivity. The severe floods of 2018 and the prolonged drought experienced in recent years were identified as major climatic events that caused widespread damage to cardamom-based fields and livelihoods. Farmers observed reduced flowering, poor fruit set, increased fungal diseases, plant rot, plant drying, and declining yields, resulting in substantial reductions in farm income. Increased dependence on irrigation, chemical fertilisers, and external inputs has further raised production costs while placing additional pressure on already fragile farming systems.

Beyond agricultural production, climate change has generated widespread socio-economic consequences for farming households. Declining productivity, rising cultivation costs, unstable market returns, and increasing indebtedness have significantly weakened livelihood security. Participants expressed concern that continued climate-related losses could accelerate rural poverty, increase migration, reduce youth participation in agriculture, and contribute to severe psychological and financial distress among farming families. Farmers also highlighted inadequate institutional support, delayed compensation mechanisms, weak extension services, limited access to weather information, and poor awareness of government programmes as major barriers to effective climate adaptation.

The findings from rice-growing communities in Kerala further demonstrate the growing vulnerability of food production systems. Farmers reported that traditional environmental indicators previously used to predict seasonal changes have become increasingly unreliable due to climate change. Irregular rainfall, prolonged humidity, rising temperatures, and changing pest dynamics have reduced productivity and increased crop losses. Kole wetland farmers also observed declining grain weight despite satisfactory harvest volumes, increased reliance on pesticides, deteriorating soil quality, increasing soil and water acidity, and the

gradual replacement of traditional organic farming practices with chemical-intensive production systems. Most farmers described their adaptation as reactive rather than planned, responding to changing weather conditions seasonally rather than implementing structured, climate-resilient agricultural practices.

Despite these challenges, the study identified numerous examples of locally developed adaptation strategies that strengthen resilience. Common adaptation measures included mixed cropping, crop diversification, contour bunding, ridge-and-furrow systems, drainage management, trench construction, shade management, border tree planting, seed conservation, compost preparation, natural pest management, and the use of weather advisories delivered through mobile applications. Farmers also relied heavily on indigenous knowledge, farmer-to-farmer learning, community cooperation, and collective resource sharing to cope with climate variability. These locally adapted practices were particularly prominent among organic and non-chemical farmers and reflected core principles of agroecology.

Overall, the study demonstrates that agroecology provides a practical pathway for strengthening climate resilience among small-scale farming communities. By improving soil health, conserving biodiversity, enhancing water-use efficiency, reducing dependence on synthetic inputs, diversifying production systems, and strengthening local knowledge systems, agroecological practices simultaneously improve ecological sustainability and livelihood resilience. However, widespread adoption of these practices requires stronger institutional support, improved extension services, accessible climate information, strengthened farmer organisations, better market linkages, timely compensation mechanisms, and supportive public policies. Integrating agroecology into national and state-level climate adaptation strategies will be essential for promoting sustainable agriculture, enhancing food security, and improving the long-term resilience of vulnerable rural communities in the face of accelerating climate change.

Introduction

India is highly vulnerable to climate change due to its widespread impacts on various sectors of society (Rao et al, 2020). Climate change presents a significant challenge to the semi-arid tropics, regions characterised by low and erratic rainfall, degraded soil fertility, inadequate infrastructure, widespread poverty, and growing population pressures. These

conditions intensify the environmental, economic, and social vulnerabilities faced by farming communities, threatening agricultural productivity and rural livelihoods. As climate-related risks continue to increase, adaptation has become a critical priority for farmers, researchers, development practitioners, and policymakers. Strengthening climate adaptation strategies and promoting resilient agricultural practices are essential for informing policies and interventions that effectively address the challenges posed by climate change and support the sustainability of farming communities.

Agriculture is one of the sectors most vulnerable to climate change. This vulnerability threatens food security and intensifies socio-economic impacts. Climate change is having significant biophysical impacts on agriculture worldwide by affecting crops, livestock, forests, fisheries, pastures, and rangelands. Rising temperatures, changing rainfall patterns, and increased atmospheric carbon dioxide influence the physiological growth, productivity, and quality of cultivated crops, forage, and livestock products. Climate change also alters the quantity and quality of essential natural resources, including land, soil, and water, leading to soil degradation, reduced water availability, and declining agricultural productivity in many regions. Furthermore, warmer temperatures and changing climatic conditions create favourable environments for the spread of weeds, pests, diseases, and alien invasive species, posing additional challenges to agricultural production. In coastal areas, sea-level rise and changes in ocean salinity threaten agricultural lands and freshwater resources, while rising sea temperatures affect marine ecosystems and drive fish species to shift their geographic ranges, disrupting fisheries and the livelihoods that depend on them. Together, these biophysical changes have profound implications for global food production, ecosystem health, and agricultural sustainability. Climate change has significant socio-economic impacts on agriculture, including changes in crop yields and overall agricultural production, which can reduce the agricultural sector's contribution to gross domestic product (GDP) over the long term. It also contributes to greater fluctuations in global market prices, alters the geographical distribution of agricultural trade, and increases the number of people vulnerable to hunger and food insecurity. These challenges can further exacerbate poverty, drive migration, and contribute to social tensions and civil unrest, particularly in regions that are highly dependent on agriculture for livelihoods and economic stability (Satapaty et al, 2011).

Farmers are among the most vulnerable groups affected by climate change, as they directly experience its impacts on agricultural production and livelihoods. Rising temperatures, shifting rainfall patterns, and the increasing occurrence of extreme weather events such as droughts, floods, and storms have made farming more uncertain and increased the risk of crop failure. These climatic changes contribute to land degradation, soil erosion, and water scarcity, making food production more challenging and, in some cases, unviable. The resulting disruptions affect not only agricultural productivity but also farmers' ability to market and distribute their produce effectively. Consequently, climate change poses a significant threat to food security and rural livelihoods, particularly in regions where agriculture serves as a primary source of income and employment. As these challenges intensify, farming communities face growing economic vulnerability and an increased risk of poverty (Soubry et al, 2010).

Approximately 87% of India's districts and 93% of its population are moderately to highly vulnerable to drought. Exposure to fluctuating market conditions often forces them to sell their produce at lower prices, further aggravating financial insecurity. Occupational diversification and the sale of productive assets, particularly livestock, are common coping mechanisms adopted during drought periods. The movement of labour out of agriculture between cropping seasons was found to increase in proportion to crop losses, with many households relying on low-paying casual employment. In several cases, even educated members of farming households were compelled to engage in readily available manual labour to supplement household income. Furthermore, livestock, an important household asset, was often sold at significantly reduced prices during drought, reflecting the financial distress experienced by farming families. Strengthening crop insurance schemes is essential for enhancing the resilience of rural livelihoods to climate variability. It also highlights the need to create locally relevant employment opportunities and provide skill development for rural youth to reduce dependence on climate-sensitive agriculture and improve long-term livelihood security (Choragudi, 2025).

Climate change has become a major contributor to agricultural distress in India, particularly through its effects on crop productivity and farmers' economic stability. In the Marathwada region of Maharashtra, 3,090 farmer suicides were reported between 2022 and 2024, averaging nearly three deaths per day. Experts attribute this crisis primarily to mounting

debt, repeated crop failures, and climate-related challenges. The scale of climate impacts on agriculture is further evident from reports indicating that extreme weather events affected 3.2 million hectares of farmland across India in 2023, an area exceeding the size of Belgium. Maharashtra alone accounted for more than 60% of the affected agricultural land. These statistics demonstrate the growing vulnerability of farming communities to climate change and its far-reaching consequences for rural livelihoods. Climate change has reduced agricultural productivity and increased farmers' dependence on costly inputs such as irrigation and fertilisers, often forcing them into debt. Limited access to formal credit compels many smallholder farmers to rely on high-interest loans from informal lenders, further aggravating their financial distress. In drought-prone regions such as Marathwada, severe water scarcity, crop losses, and mounting indebtedness have intensified livelihood insecurity and contributed to the agrarian crisis. Studies indicate that drought conditions and below-average rainfall are associated with increased farmer suicides in rural India. An analysis conducted across five states, Chhattisgarh, Karnataka, Madhya Pradesh, Maharashtra and Telangana, with high suicide rates found that periods of reduced rainfall corresponded with a rise in farmer suicides, highlighting the severe impacts of climate change on farming livelihoods.

This study was undertaken to document the impacts of climate change on rural communities, particularly small-scale food-producing communities, and to examine the potential of agroecology as a climate solution. The research focuses on understanding the impacts of the climate crisis on the rural poor and small-scale food-producing communities in the Indian states of Maharashtra and Kerala, and on assessing the effectiveness of agroecological practices in strengthening their climate resilience. Through this approach, the study explored both the climate-related challenges faced by rural farming households and the role of agroecology in enhancing their adaptive capacity and long-term sustainability.

Methodology

This study adopted a qualitative participatory research approach, complemented by primary field investigations, case studies, and a secondary literature review, to examine the impacts of climate change on small-scale food-producing communities and to explore the role of agroecological practices in building climate resilience.

Research questions

1. How is the climate crisis impacting the rural poor and small-scale food-producing communities in Indian states such as Maharashtra and Kerala?
2. How can agroecology contribute to strengthening climate resilience among rural communities?

A review of relevant literature was undertaken to establish the broader context of climate change, rural livelihoods, and agroecology across South Asia. Primary data collection was conducted across selected study locations in India, namely Yavatmal (Maharashtra), Adilabad (Telangana), Thrissur and Adimali (Kerala). The study focused on diverse groups representing small-scale food-producing communities, including small and subsistence farmers, landless agricultural workers, women farmers, youth farmers, and both organic and conventional farmers. A combination of qualitative research methods, including FGDs, semi-structured interviews, farmer surveys, and case studies, was employed to capture community experiences, local knowledge, and adaptation practices.

In Yavatmal, the study included surveys of 30 farmers representing three farming systems: 10 conventional farmers using chemical pesticides, 10 farmers who had transitioned away from pesticide use and adopted non-chemical farming practices, and 10 organic farmers. In addition, six in-depth farmer case studies were documented to understand individual experiences of climate change, farming transitions, and resilience-building practices. Two FGDs were conducted separately with organic and conventional farmers to facilitate comparative discussions on production practices, climate risks, and adaptation strategies.

In Thrissur district, fieldwork was conducted in Mattathur and Vellangallur, comprising five farmer surveys and eight semi-structured interviews with three conventional farmers, three organic farmers, and two beekeepers. Case studies were developed for one organic farmer and both beekeepers to document their experiences with climate variability, livelihood adaptation, and ecological farming practices. One mini Focus Group Discussion was conducted with organic farmers, along with two larger FGDs involving farming communities to explore collective perceptions of climate impacts and local adaptation measures.

In Adimali, Idukki district, six FGDs were conducted with farming communities to understand location-specific experiences of climate change, challenges in plantation and mixed farming systems, and the adoption of agroecological practices.

In Adilabad, Telangana, one Focus Group Discussion was conducted with nine non-chemical cotton farmers using a participatory Problem Tree approach. The discussion explored farmers’ perceptions of climate change, its impacts on cotton and mixed farming systems, socio-economic challenges, and the adaptive responses developed by the community.

The study employed participatory rural appraisal techniques to encourage community-led analysis of climate-related challenges. Among these, Problem

Tree Analysis was used as a participatory tool to identify the root causes, immediate effects, and long-term consequences of climate change on agricultural livelihoods. This exercise also enabled participants to collectively identify potential agroecological solutions and locally relevant adaptation strategies. Data collected through surveys, interviews, FGDs, case studies, and participatory exercises were triangulated with secondary literature to strengthen the validity of the findings. This mixed-methods approach enabled a comprehensive understanding of the lived experiences of rural communities while also highlighting the potential of agroecology as a viable pathway to enhancing climate resilience and sustainable livelihoods.

Table 1 summarises the methods used in the PAR.

Table 1. Methods adopted for the study

Methods adopted	Number conducted	Total participants	Purpose
Focus group discussion & problem tree	10	153 farmers	Climate impacts and mitigation strategies
Individual interviews	40	Small farmers	Vulnerability insights
Case studies	7	7 farmers	Climate impacts and Agroecology strategies

CLIMATE CHANGE AND THE LIVELIHOOD CHALLENGES OF FOOD-PRODUCING FARMERS

Field insights: The impact of climate change on cotton-based farming systems in Maharashtra

Cotton is one of the principal crops cultivated in western Vidarbha and parts of the Marathwada region of Maharashtra, with its productivity highly dependent on prevailing temperature and rainfall. The optimum temperature for cotton cultivation ranges from 21°C to 27°C, although the crop can withstand temperatures up to 43°C, provided sufficient soil moisture is available. Temperatures below 21°C, however, adversely affect crop growth and development. Cotton requires an annual rainfall of approximately 600–1000 mm during its growing season, but excessive rainfall and prolonged soil moisture during the budding, boll formation, and boll bursting stages can substantially reduce both yield and fibre quality. Climate projections indicate that moderate increases in maximum temperature may enhance cotton productivity in certain districts by the 2040s. Nevertheless,

temperatures exceeding the crop's optimal threshold, along with increasing rainfall variability and extreme precipitation events, are expected to adversely affect crop growth, boll development, maturation, and overall productivity, thereby posing significant challenges to sustainable cotton cultivation (MHSAPCC, 2025). Introduced in India in 2002, Bt cotton was initially promoted as a breakthrough technology due to its ability to reduce bollworm infestations, lower pesticide use, and increase crop yields. However, the benefits have been undermined in many regions by rising production costs and increasing climate-related stresses such as droughts and erratic rainfall. For smallholder farmers dependent on rain-fed agriculture, these combined challenges have made cotton cultivation economically unsustainable and heightened their vulnerability to financial distress.

Cotton-based farming systems in the Vidarbha region offer significant opportunities for crop diversification through intercropping and crop rotation with high-value legumes and oilseed crops. Common rotational and companion crops include wheat (*Triticum aestivum* L.), linseed (*Linum usitatissimum*), pigeonpea (*Cajanus cajan*), chickpea (*Cicer arietinum*), groundnut (*Arachis hypogaea* L.), and greengram (*Vigna radiata*). These diversified cropping systems

promote more efficient utilisation of natural resources, including light, water, and soil nutrients, while reducing pest incidence and improving soil health. In the predominantly rain-fed areas of Vidarbha, crop sequences involving multiple crops help minimise the risk of crop failure during drought years and enhance the resilience of farming systems. Moreover, crop diversification supports sustainable agricultural development by improving farm profitability, strengthening food and nutritional security, generating employment, and promoting the efficient use of land and water resources while reducing environmental degradation associated with monocropping (Latkar et al, 2024). Pigeonpea production is increasingly threatened by climate change, as rising temperatures, irregular monsoon patterns, and extreme weather events have led to substantial yield reductions, especially during delayed monsoons and heatwaves (Thakkar, 2025). Legume productivity is increasingly threatened by climate change, with rising temperatures, altered precipitation patterns, elevated atmospheric carbon dioxide concentrations, more frequent extreme weather events, and changing pest and disease dynamics adversely affecting crop performance (Dave et al, 2024).

FGD findings: Cotton farmers of Yavatmal, Maharashtra

The FGDs conducted by PAN India with cotton farmers in Yavatmal district, Maharashtra, captured farmers' perceptions of climate change, its impacts on cotton cultivation, and the adaptation strategies adopted to cope with changing climatic conditions. Erratic rainfall patterns, rising temperatures, prolonged dry spells, and changing weather conditions are the most significant climatic changes affecting cotton farming. Heavy and untimely rainfall has become increasingly common, often occurring during critical stages of crop growth and harvest. At the same time, increasing temperatures and recurring drought conditions have intensified moisture stress and reduced water availability for irrigation. Farmers also observed that soil has become harder and more compacted, while the organic farmer additionally highlighted soil erosion, declining soil biodiversity, reduced farm biodiversity, and deforestation as factors that aggravate the impacts of climate change.

Table 2 provides an overview of the FGD discussions held in Yavatmal, Maharashtra.

Table 2. Overview of FGDs conducted in Yavatmal, Maharashtra

Target Group	No. of participants	Location of FGD	Key points discussed
Non-chemical cotton farmers	8	Aanji Village, Ghatanji Taluka, Yavatmal District, Maharashtra	Climate change causes, impacts, and adaptation measures followed
Conventional cotton farmers	7	Titavi Village, Ghatanji Taluka, Yavatmal District, Maharashtra	
Organic cotton farmers	10	Murli Village, Ghatanji Taluka, Yavatmal District, Maharashtra	

Changes in climate events have disrupted the agricultural calendar. Delayed sowing has become a major concern because fields remain unsuitable for cultivation due to either prolonged rainfall or inadequate soil moisture. Respondents reported poor seed germination, making gap filling and re-sowing increasingly common. The conventional farmer noted that hybrid seeds are particularly affected under these conditions, while the organic farmer observed that declining soil microbial activity further reduces seed establishment. During crop growth, farmers reported multiple climate-induced stresses. Excess rainfall frequently causes waterlogging and poor soil aeration, resulting in root damage and reduced plant vigour. High temperatures often cause flowers to wilt and leaves to scorch, while excessive soil moisture limits plant

height and delays normal crop development. The conventional farmer also reported an increase in fungal diseases and pest-related problems associated with prolonged humidity. The organic farmer further observed a decline in beneficial birds, pollinators, and soil microorganisms, indicating that climate change is affecting the broader agroecosystem, not just crop productivity.

Harvesting has become increasingly difficult due to rainfall occurring during crop maturity. According to the respondents, excessive moisture damages cotton bolls, reduces fibre quality, and lowers market value. Poor boll development, uneven crop growth, reduced plant height, root damage, and increased disease incidence collectively contribute to substantial yield reductions. Consequently,

participants reported considerable economic losses due to declining productivity and rising production risks. Although their farming systems differed, the respondents have adopted several adaptation measures to minimise climate-related losses. Common practices include the ridge-and-furrow method to improve drainage and moisture management, the construction of trenches and field drains to prevent waterlogging, and timely or pre-sowing field preparation wherever climatic conditions permit. The conventional farmer has modified cropping patterns and relies on mechanised land preparation using tractors to improve soil conditions. The non-chemical farmer has adopted seed-drill sowing techniques and protective net-based farming practices to improve crop establishment. The organic farmer follows a broader ecosystem-based approach, including planting border trees, cultivating border crops, practising mixed cropping, preparing compost,

preserving farm-saved seeds for subsequent seasons, and exclusively using non-chemical inputs to improve soil health and ecological resilience.

Beyond production-related challenges, the interviews also revealed the increasing human cost of climate change. The respondents referred to incidents of farmer deaths associated with extreme weather conditions. One respondent recalled the death of a farmer from Tarota village who reportedly experienced severe suffocation while working in the fields under adverse climatic conditions. Another respondent referred to the death of a farmer from Titavi village, who reportedly succumbed to heatstroke while working on his farm. These incidents illustrate that climate change is not only affecting agricultural productivity but is also posing serious occupational health risks for farming communities.

Focus group discussions (FGDs) conducted in Yavatmal, Maharashtra



Farmer interviews: Major insights

Farmer interviews conducted among cotton farmers in Yavatmal district by PAN India revealed that climate change has significantly affected agricultural production, livelihoods, and household well-being. Most respondents, who had more than a decade of farming experience, reported noticeable changes in weather patterns over the past 10–20 years, including erratic monsoons, rising temperatures, prolonged droughts, heavy rainfall, floods, soil erosion, and increasing pest infestations.

These changes have resulted in crop failures, declining groundwater levels, drying wells and ponds, higher cultivation costs, and annual financial losses exceeding ₹50,000 for many households. The impacts extend beyond agriculture, contributing to reduced household spending on food and education, increased healthcare expenses, and greater dependence on savings and borrowing. Landless labourers also

experienced reduced employment opportunities during climate shocks, while youth and elderly family members faced additional socio-economic challenges.

Cotton, soybean, and pigeon pea were identified as the crops most severely affected, resulting in reduced yields, declining crop quality, and substantial economic losses. Rising cultivation costs, particularly for irrigation, fertilisers, pesticides, and labour, have further increased the financial burden on farming households. Several respondents also indicated that extreme weather events had reduced the number of working days, household income, and livestock productivity, particularly milk production.

Women farmers were found to be disproportionately affected due to limited access to agricultural training, credit, and institutional support, while male migration has increased women's responsibilities in farming. At the same time, women play a vital role in conserving local seeds, maintaining agro-biodiversity, and promoting agroecological knowledge.

Farmers interviewed in
Yavatmal, Maharashtra



Field insights: The impact of climate change on cotton-based farming systems in Adilabad, Telangana

In Adilabad, Telangana, an FGD was conducted with nine non-chemical cotton farmers using a participatory Problem Tree approach. The discussion

explored farmers' location-specific experiences of climate change, the challenges affecting cotton and mixed farming systems, the socio-economic consequences of these changes, and the adaptive responses used to strengthen resilience.

Table 3 provides an overview of the FGD discussions held in Adilabad, Telangana.

Table 3. Overview of the FGDs conducted in Adilabad, Telangana

Target group	9 non-chemical cotton farmers
Location	Adilabad, Telangana
Key points discussed	Climate change causes, impacts, and adaptation measures

FGD findings: Cotton farmers of Adilabad, Telangana

Farmers identified excessive heat, prolonged droughts, floods, and increasingly unpredictable and intense rainfall as the main climate-related challenges affecting cultivation. They reported that these changes have become more frequent in recent years, making agricultural planning increasingly uncertain. Climate variability has affected cotton yields and quality, reducing profitability. Farmers also observed the emergence of unfamiliar pest infestations and a substantial increase in weed growth, which they associated with changing rainfall patterns and climatic conditions. These changes have increased labour requirements and the cost of weed and pest management.

Participants also described a gradual shift from diverse farming systems towards monocropping. Farmers recalled that they once cultivated nearly 14 different crop varieties, including several food crops. However, changing climatic conditions, market pressures, and declining productivity of traditional crops have contributed to a growing concentration on cotton. This reduction in on-farm diversity has reduced food-crop production and increased households' dependence on external markets for food. Farmers further reported that the sowing period for Rabi crops has shifted, often being delayed by irregular monsoon onset and erratic rainfall, affecting crop planning, input application and overall farm management.

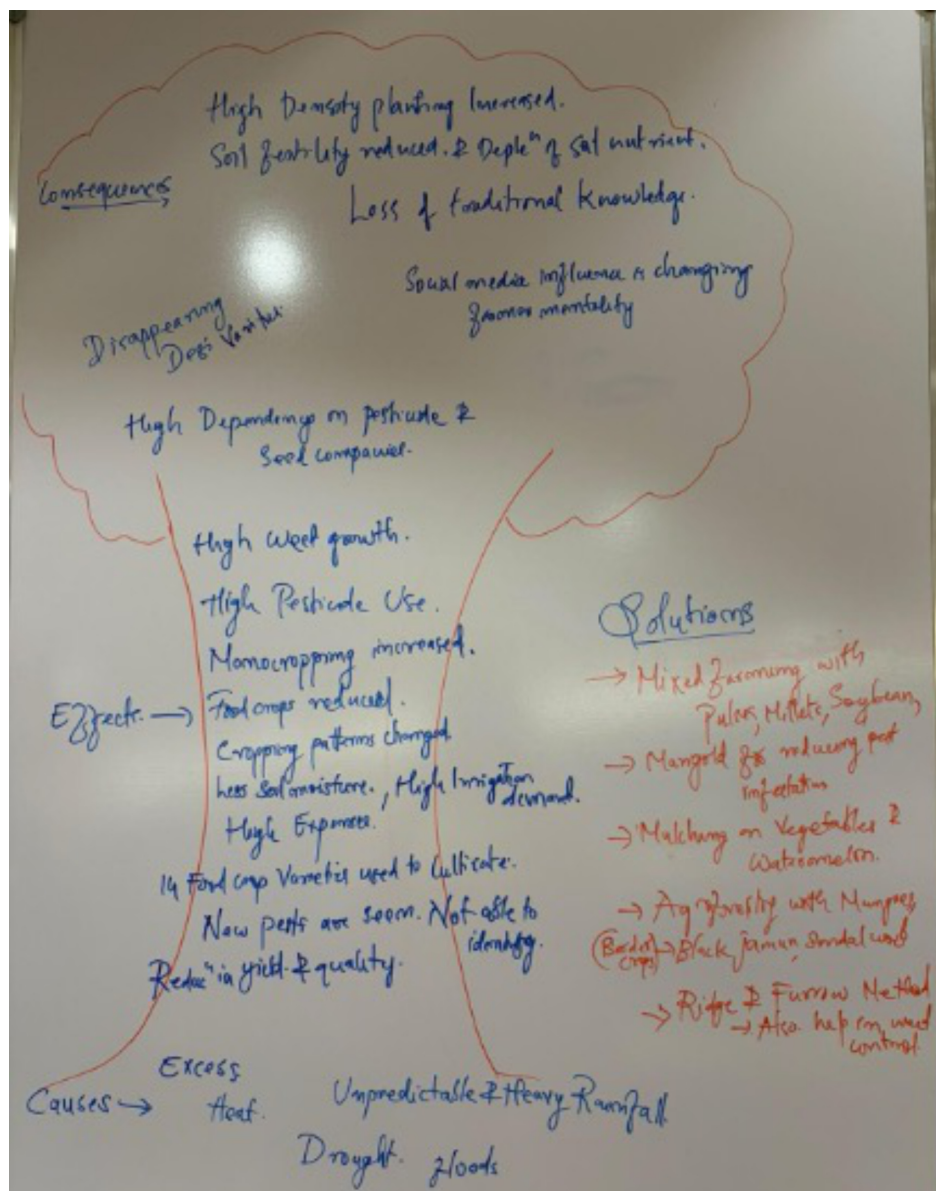
Farmers highlighted that declining soil moisture and reduced soil-water availability have increased irrigation requirements and, consequently, cultivation

costs. Greater expenditure on irrigation, energy and water management means that maintaining productivity now requires substantially more financial investment. At the same time, many farmers reported more frequent use of chemical pesticides in response to increased pest pressure and the fear of crop loss under unpredictable climatic conditions.

The longer-term effects extend beyond immediate crop losses. Participants expressed concern about the gradual disappearance of indigenous (desi) crop varieties, which were traditionally adapted to local climatic conditions and required fewer external inputs. They also observed a shift towards high-density plantation systems, driven by the pursuit of higher yields. Farmers associated these intensive systems with declining soil fertility and greater dependence on chemical fertilisers and other external inputs.

The FGD also revealed important socio-cultural changes accompanying these agricultural transitions. Participants were concerned about the erosion of traditional agricultural knowledge, particularly among younger generations, as indigenous practices are increasingly replaced by commercially driven approaches. They observed that social media and digital platforms are influencing farmers' decisions, particularly within tribal communities, by promoting monocropping and profit-oriented farming models. This has contributed to greater dependence on commercial seed and agrochemical companies and reduced reliance on locally conserved seeds and traditional farm-management practices. Participants emphasised that the loss of crop diversity and growing external dependence are making farming systems less resilient to climate variability and more vulnerable to market pressures.

Problem Tree exercise conducted with cotton farmers in Adilabad, Telangana



FGD conducted in Adilabad, Telangana



Field insights: The impact of climate change on cardamom farmers in Idukki, Kerala

Cardamom is a shade-adapted crop that naturally grows under forest canopies, where it benefits from a humid microclimate and filtered sunlight. Its growth, development, and productivity are highly dependent on the quantity and seasonal distribution of rainfall, making the crop particularly vulnerable to climate variability and changing environmental conditions (Murugan et al, 2023).

In Idukki, Kerala, a major hub of cardamom cultivation, farmers are facing significant challenges due to weak monsoon conditions and rising temperatures. These changing climatic conditions have resulted in reduced yields, delayed harvesting, and poor flowering, placing the farming community in an increasingly vulnerable position. As most farmers in the region rely almost entirely on cardamom cultivation for their livelihood, these impacts pose serious economic and social challenges to their subsistence and well-being. These adverse climatic conditions have contributed to an increase in crop diseases, such as yellowing and capsule drop, negatively affecting cardamom health and productivity. In addition, the prevailing weather has been unfavourable for flowering, a critical stage in the crop's growth cycle, raising concerns about future yields. Many farmers who applied lime and sulphur in preparation for the anticipated heavy monsoon rains have also incurred financial losses, as the expected rainfall did not materialise.

A study investigated the impact of climate change on cardamom productivity in the Vandanmedu and Kumily regions of Idukki district, Kerala, where cardamom cultivation is highly sensitive to changes in rainfall, temperature, and humidity. Using primary data collected from 30 farmers through questionnaires, interviews, and field visits, along with secondary data from government reports and research publications covering 2020–2025, the study examined farmers' perceptions of climate change and its effects on crop performance. The findings revealed that irregular rainfall, rising temperatures, and increased pest and disease incidence have adversely affected cardamom yield and quality, resulting in reduced productivity and farmer incomes. The study emphasised the importance of adopting climate-resilient agricultural practices, strengthening crop management strategies, and enhancing institutional support to improve farmers' adaptive capacity. It also aligns with earlier reports indicating that erratic monsoons and climate-induced crop losses have contributed to fluctuations in cardamom production and significant economic

impacts on farming communities (Irshad & Kader, 2026).

A study analysing climate and crop yield data from the Indian cardamom hills between 1978 and 2007 found significant changes in key climatic variables, including rising temperatures, declining monsoon rainfall, and variations in relative humidity. The researchers observed that increasing temperatures, coupled with irregular wet and dry spells, created favourable conditions for the proliferation of insect pests and disease-causing organisms, leading to greater dependence on pesticides. While small cardamom and coffee exhibited modest yield improvements during the study period, the findings highlighted growing climate-related challenges for plantation agriculture, particularly the increased risk of pest and disease outbreaks associated with changing weather patterns (Murugan et al, 2012).

A study conducted among 158 large cardamom farming households in Nepal found that while traditional adaptation measures such as tillering, weeding, and irrigation are widely practised, the adoption of scientifically recommended climate-resilient practices remains limited. The findings showed that higher levels of education, active participation in farmer groups, greater labour availability, and regular access to agricultural extension services significantly improve the adoption of climate-resilient practices. The study highlights the need for targeted policy interventions that strengthen farmer education, extension support, and institutional networks to enhance the resilience of cardamom farming systems under changing climatic conditions (Pandeya et al, 2025).

FGD findings: Cardamom farmers of Adimali, Idukki, Kerala

A summary of the FGD held in Adimali, Idukki, Kerala, is provided in **Table 4**.

The FGDs conducted by PAN India with six groups of small-scale cardamom farmers from Konnathady Grama Panchayat in Idukki district revealed that climate variability has emerged as a major challenge affecting agricultural productivity and rural livelihoods. Farmers consistently identified erratic rainfall patterns, including excessive rainfall, unpredictable precipitation, prolonged dry spells, low rainfall, drought conditions, and soil erosion, as the primary climate-related risks impacting cardamom cultivation. Farmers identified two major climate-related disasters that have had a profound impact on cardamom cultivation in the region: the

severe floods of 2018 and the prolonged drought experienced two years ago. These extreme weather events have caused substantial damage to agricultural systems, disrupted farming operations, and adversely affected the livelihoods of smallholder producers. Participants further reported that the most recent cropping season had the lowest

productivity and yield in their farming experience. They attributed this unprecedented decline to climate-induced factors, and these changing climatic conditions have significantly altered traditional cultivation cycles and intensified the vulnerability of cardamom production systems in the region.

Table 4. Overview of the FGD conducted in Adimali, Idukki, Kerala

Target group	Number of FGDs conducted	Total number of participants	Purpose
Small-scale cardamom farmers	6	118	Explored farmers' perceptions and experiences of climate-related changes, the impacts of climate variability on cardamom cultivation and livelihoods, associated socio-economic impacts, climate-resilient farming practices, and adaptation strategies

FGDs conducted in Adimali, Idukki, Kerala



According to the participants, these climatic stresses have resulted in reduced and delayed flowering, lower crop yields, and increased pest infestations and plant diseases, particularly fungal infections. Farmers also reported a growing incidence of plant rot, plant drying, and premature crop loss associated with inadequate rainfall and moisture stress. To sustain their plantations under these adverse conditions, farmers have been compelled to invest substantially more in crop management practices and protective measures. However, the combination of rising cultivation costs, declining production, and reduced market returns has significantly lowered farm incomes, placing considerable financial strain on farming households. The discussions further highlighted broader socio-economic concerns, with participants expressing that continued climate-induced losses could exacerbate poverty, weaken livelihood security, and potentially drive migration from farming communities in search of alternative sources of income. The discussions also underscored the growing impact of climate change on water availability across the region. Farmers consistently reported a noticeable decline in groundwater levels, with wells yielding significantly less water due to reduced soil moisture and inadequate rainfall. This has placed considerable pressure on farming households, particularly during prolonged dry spells, as they increasingly depend on irrigation to sustain cardamom plantations. Participants observed that water consumption for irrigation has risen substantially over the past two years, reflecting the increasing frequency of low-rainfall conditions and signalling a gradual transition towards water scarcity in the area.

To mitigate crop losses under these challenging conditions, many farmers have become heavily reliant on chemical fertilisers and other external inputs to maintain plant health and productivity. Despite these increased investments, yields have remained low, resulting in diminishing economic returns. Farmers expressed concerns that this growing dependence on chemical inputs not only increases production costs but may also contribute to long-term environmental degradation, including declining soil health and reduced carbon sequestration potential, and may increase greenhouse gas emissions associated with conventional agricultural practices. The economic burden arising from rising input costs, declining productivity, and unstable incomes has created significant financial stress for farming households. During the discussions, several participants highlighted instances where mounting debt and repeated crop losses had led to severe distress among farmers, with some referring to reports of

suicides linked to financial hardship and indebtedness. These accounts reflect the profound socio-economic challenges confronting vulnerable farming communities.

Participants also expressed dissatisfaction with the level of institutional support available during periods of climatic stress. Many farmers reported receiving limited technical guidance, advisories, or financial assistance during the severe drought two years ago. Concerns were raised regarding inadequate compensation mechanisms and the lack of timely interventions to help farmers cope with climate-induced losses. Furthermore, the discussions revealed significant communication gaps between farmers and extension agencies. A considerable proportion of participants reported being unaware of government schemes, training programmes, and support services offered by local agricultural institutions due to ineffective information dissemination. Limited digital access and low levels of digital engagement among many smallholder farmers have further widened this communication gap, restricting their ability to access weather advisories, extension services, and other critical agricultural information. Addressing these barriers will be essential for strengthening climate resilience and improving the adaptive capacity of farming communities in the region.

Field insights: The impact of climate change on paddy farmers in Thrissur, Kerala

Rice (*Oryza sativa*) is a major staple crop that feeds more than half of the world's population and plays a vital role in food security and rural livelihoods. However, climate change is increasingly threatening rice production through rising temperatures, erratic rainfall, and more frequent extreme weather events. These changes affect crop growth, reduce yields, and pose significant challenges to sustainable rice cultivation, particularly in regions that depend heavily on rice production (Fukuoka, 2024). The impacts of climate change on rice production extend beyond agriculture, affecting the social and economic well-being of farming communities. Smallholder farmers are particularly vulnerable due to limited financial resources, inadequate access to information and insurance, and weak institutional support. Climate-induced crop losses often lead to income instability, food insecurity, debt, and migration, while women farmers face additional challenges due to their significant role in rice cultivation and limited access to resources (Resmi et al., 2025). A field experiment was conducted during 2014-15 at the Regional Agricultural Research Station (RARS) in Pattambi,

Palakkad district, Kerala, using the popular rice varieties Aathira and Vaisakh. The DSSAT model was calibrated and validated with field observations to assess the impacts of projected climate change. The simulation results indicated a clear decline in rice yields under future climate scenarios (Subramanyam et al, 2019).

Reducing climate-related risks in rice cultivation requires a combination of policy and infrastructure interventions. Strengthening early warning systems, expanding crop insurance, promoting climate-resilient farming practices, and providing timely agro-advisories can enhance farmers' adaptive capacity. Improving drainage infrastructure, ensuring the availability of harvesting machinery, expanding storage facilities, and streamlining crop procurement are also essential to minimise post-harvest losses and improve the resilience of rice farming systems in Kerala (Kumar & Suresh, 2022). Agroecological approaches play an important role in improving the resilience of rice farming to climate change. Practices such as organic farming, crop diversification, intercropping, and integrated rice–livestock or rice–fish systems enhance soil health, conserve biodiversity, reduce dependence on synthetic inputs, and strengthen ecosystem services. These sustainable farming practices help minimise climate-related risks while supporting long-term productivity and farmers' livelihoods (Fukuoka, 2024).

Farmer interviews: Major insights

Farmer interviews conducted by PAN India indicate that climate change has significantly disrupted rice farming systems by altering seasonal calendars, making it increasingly difficult for farmers to plan sowing, irrigation, and harvesting. Farmers also reported that traditional environmental indicators, such as plant flowering and dragonfly abundance, once reliable predictors of seasonal changes, have become less dependable due to changing climatic conditions. This growing uncertainty has resulted in frequent crop losses and reduced farm productivity.

In addition to weather-related challenges, farmers observed an increasing incidence of pest infestations and fungal diseases, driven by rising temperatures, irregular rainfall, and prolonged humidity. Fruit farmers, in particular, reported being highly vulnerable to climate variability, as fluctuations in temperature and untimely rainfall during the flowering and fruit-development stages have led to substantial fruit drop, poor-quality produce, and significant reductions in yield and income. Overall, the findings highlight that climate change is not only affecting agricultural production but also increasing the economic risks and livelihood insecurity of farming communities. Mixed cropping emerged as one of the most widely adopted resilience practices among paddy farmers, contributing to both climate adaptation and improved economic stability.

Farmer interview held in Thrissur, Kerala



Case study 1

Climate change and the declining productivity of beekeeping

As part of the PAN India field study, interviews were conducted with two experienced beekeepers to understand how climate change is affecting bee populations and honey production. Both farmers consistently described a noticeable decline in honey yields over the past decade, emphasising that beekeeping has become increasingly difficult due to changing climatic conditions. Their experiences illustrate the close relationship between climate, flowering patterns, pollinator health, and rural livelihoods.

The beekeepers explained that honey production has reduced by nearly 50 per cent compared to ten years ago. They recalled that in the past, bee colonies were highly productive, often producing such large quantities of honey that harvesting became a frequent and labour-intensive task. According to one farmer, *"Earlier we used to get tired of harvesting honey because there was so much of it. Today, we get only about half of what we used to collect."*

This decline has directly affected household income and reduced the economic viability of beekeeping as a livelihood. The farmers identified climate change as the primary reason for this decline. Bees are highly sensitive to changes in temperature, rainfall, humidity, and seasonal cycles. Over the years, flowering seasons have become increasingly irregular, with many plants flowering either earlier, later, or for shorter durations than before. As a result, bees have less time and fewer opportunities to collect nectar and pollen, leading to lower honey production and weaker colonies. The unpredictability of weather has also disrupted the synchrony between bee activity and the flowering of important nectar-producing plants.

Another major concern raised by the beekeepers was the gradual decline in coconut cultivation, which has traditionally been an important source of nectar for honey bees. The decline in coconut plantations, coupled with the loss of forests and natural vegetation, has significantly reduced the availability of forage for pollinators. The disappearance of diverse flowering plants has forced bees to travel longer distances in search of food, increasing stress on colonies and reducing their productivity.

The respondents also highlighted that beekeeping is one of the agricultural activities most vulnerable to climate variability. Extreme weather events, prolonged dry spells, heavy rainfall, and unusually high temperatures not only affect the availability of floral resources but also influence bee behaviour, reproduction, and colony survival. Since bees play a critical role in pollinating both agricultural crops and wild plant species, their decline has implications that extend far beyond honey production, affecting biodiversity, crop yields, and ecosystem health.

This case study demonstrates that climate change is disrupting the ecological balance on which beekeeping depends. Declining honey yields, shrinking forage resources, and increasing climatic uncertainty are making beekeeping a more precarious livelihood. The experiences shared by the interviewed farmers underscore the urgent need for measures that protect pollinator habitats, conserve natural vegetation, promote climate-resilient farming landscapes, and strengthen adaptation strategies for beekeeping communities.

FGD findings: Climate change and adaptation challenges among kole farmers in the Thrissur–Ponnani Region, Kerala

Table 5 summarises the FGD carried out in Thrissur, Kerala.

Table 5. Overview of FGD conducted in Thrissur, Kerala

Target group	Number of FGDs conducted	Total number of participants	Purpose
Kole paddy farmers	1	10	Explored farmers' perceptions and experiences of climate-related changes, the impacts of climate variability and associated socio-economic impacts, climate-resilient farming practices, and adaptation strategies

The FGD conducted among kole farmers in the Thrissur–Ponnani region revealed that climate variability has significantly altered the traditional paddy cultivation system. Farmers unanimously reported that weather patterns have become increasingly unpredictable, with untimely rainfall, prolonged dry spells, and excessive heat affecting crop growth and farm management. According to the participants, although paddy production in terms of harvested quantity often appears satisfactory, grain weight has declined considerably, resulting in lower marketable yield and reduced income. They associated this decline with high temperatures during grain filling and erratic rainfall during critical crop growth stages.

Farmers observed a marked increase in the incidence of insect pests and crop diseases over the past decade. Consequently, pesticide dependence has risen substantially. While paddy cultivation previously required minimal chemical interventions, farmers now report applying pesticides seven to eight times during a single cropping season. They expressed concern that increasing climatic uncertainty has made crops more vulnerable to pest outbreaks, leading to higher production costs and greater environmental risks.

The discussion also highlighted significant changes in farming practices over time. Approximately ten years ago, farmers cultivated traditional paddy varieties such as Jeera, while relying extensively on green manures and organic fertilisers to maintain soil fertility. According to the participants, these practices involved lower production costs and contributed to healthier soils. In contrast, the present cultivation system is increasingly dependent on chemical

pesticides, fertilisers and external inputs. Farmers believed that the earlier organic-based production system was more effective in helping crops withstand climatic fluctuations and recover from weather-related stresses. Participants acknowledged that they currently do not practice any specific climate-resilient agricultural techniques. Instead, they described their approach as "going with the flow," adjusting sowing dates, input use, and field operations in response to prevailing weather conditions rather than following planned adaptation strategies. This reflects a largely reactive approach to climate variability rather than proactive climate adaptation.

Another major concern raised during the discussion was the limited institutional support available to farmers. Participants stated that compensation and financial assistance for climate-induced crop losses are often inadequate or delayed, leaving them vulnerable to recurring economic losses. They emphasised that stronger institutional mechanisms, including timely compensation, improved extension services, and technical guidance on climate-resilient farming, are essential for sustaining agriculture in the Kole wetlands. Farmers also expressed concern about the declining interest of younger generations in agriculture. They felt that attracting more youth to farming is critical to ensuring the long-term sustainability of Kole cultivation, particularly as climate change makes farming increasingly knowledge-intensive and management-oriented. A recurring issue discussed was the increasing acidity of both soil and field water. Farmers have observed that irrigation and standing water in paddy fields have made the fields more acidic over time, affecting crop performance.

FGD conducted in Ponnani, Kerala



AGROECOLOGY FOR CLIMATE RESILIENCE

Agroecology is a holistic approach to food production that integrates ecological, social, economic, and political dimensions. It promotes sustainable farming practices such as crop diversification, intercropping, crop rotation, organic soil management, cover cropping, and reduced reliance on synthetic inputs, while emphasising farmer participation, knowledge co-creation, collective resource management, and social equity (Kerr et al, 2023). Amid growing climate instability, environmental degradation, and widening socio-economic inequalities, agroecology has emerged as a transformative approach to building sustainable and resilient food systems. By integrating ecological principles with social and economic dimensions, it offers pathways to address the interconnected challenges facing agriculture. A key strength of agroecology lies in its ability to enhance soil health through practices such as applying organic inputs, crop diversification, crop–livestock integration, reduced tillage, and cover cropping.

These practices improve soil structure, promote beneficial microbial activity, increase water retention, and strengthen the resilience of farming systems to climate-related stresses. Water plays a crucial role in climate adaptation, and agroecological systems promote efficient water management through practices such as mulching, terracing, intercropping, agroforestry, and rainwater harvesting. These approaches reduce surface runoff and evaporation, improve soil infiltration and moisture retention, and enhance water-use efficiency, thereby increasing the resilience of farming systems to climate variability (Uckun, 2025). Evidence from different regions demonstrates the resilience benefits of agroecological farming systems. In Cuba, agroecological farms experienced 50–60% less crop damage than conventional farms following hurricanes and recovered more rapidly. Similarly, in Nicaragua, sustainable land management practices adopted under agroecology reduced soil erosion, conserved approximately 40% more topsoil, and lowered the incidence of landslides by nearly 48% compared to conventional farming systems. Beyond ecological benefits, agroecology also strengthens social resilience by promoting the sharing and co-creation of knowledge among farmers, researchers, communities, and other stakeholders, thereby enhancing local adaptive capacity to climate-related challenges (iPES).

In Andhra Pradesh, the Andhra Pradesh Community-Managed Natural Farming (APCNF) initiative has emerged as a significant example of

large-scale agroecological transformation, demonstrating the potential of natural farming to address interconnected challenges, including climate change, ecological degradation, water scarcity, and farmer distress. Implemented by the Government of Andhra Pradesh, APCNF is recognised as one of the world's largest women-led natural farming programmes. The initiative has contributed to reducing cultivation costs, restoring ecological health, enhancing farm resilience, and improving farmers' net incomes. Since its inception during 2015–16, the programme has expanded to cover over 8,168 Gram Panchayats, reaching more than 1.77 million farmers and approximately 0.92 million hectares of cultivated land. Evidence suggests that participating farmers have experienced income increases ranging from 38% to 66%, water savings of up to 50%, and greenhouse gas emission reductions of up to 46% per acre. The programme has also facilitated a transition from monoculture-based farming systems to more diversified and biodiverse agricultural practices, while strengthening climate resilience and promoting healthier, more diverse food systems. The success of APCNF has attracted attention beyond Andhra Pradesh, with its approaches and experiences being adapted and replicated in other Indian states and several countries.

A study conducted in the NICRA villages in the Kurnool and Anantapur districts of Andhra Pradesh examined the extent of adoption of climate-resilient agricultural technologies among 180 farmers and the factors influencing their adoption. The findings indicated that 74% of the respondents had fully adopted the recommended crop production technologies. Among the various practices, intercropping showed the highest adoption, followed by the use of drought-tolerant varieties, crop diversification, weather-based agro-advisory services, cultivation of short-duration crop varieties, and drought mitigation spraying. The study underscores the effectiveness of climate-resilient technologies in strengthening farmers' adaptive capacity to climate variability (Dhana Lakshmi et al, 2022). A comparative study evaluated the resilience of natural farming and conventional chemical farming to extreme climate events in Andhra Pradesh, focusing on the impacts of Cyclones Pethai and Titli (2018) and heavy rainfall in 2021.

The study surveyed paddy-growing regions severely affected by these events and employed multiple linear regression to assess factors such as crop damage, wind damage, submergence, and yield loss. The findings revealed that natural farming systems were significantly more resilient to climate-related

disturbances than conventional farming systems, with a statistically significant difference ($p < 0.001$) in the extent of climate-induced damage. The study highlights the potential of natural farming as an effective climate adaptation strategy to enhance agricultural resilience (Hussain et al., 2023). A study on natural farming in Andhra Pradesh examined its potential to address the challenges posed by climate change, rising cultivation costs, declining agricultural productivity, and natural resource degradation. Using secondary data from RySS, Indiatat, and the published literature, the study analysed the spatial distribution of natural farming using GIS and compared the yields and economic returns of natural and conventional farming systems. The findings indicated that natural farming reduced cultivation costs while improving crop yields, farm incomes, soil health, and environmental sustainability. The study also highlighted that natural farming minimises soil erosion, enhances the production of nutritious food, and reduces farmers' debt burden by reducing dependence on external inputs, demonstrating its potential as a sustainable and climate-resilient agricultural system (Kumar, 2022).

In Kerala, a study conducted among coffee growers in Wayanad assessed the adoption of climate-resilient agricultural practices in one of the state's most climate-vulnerable regions. The findings revealed that agronomic measures, including crop diversification and soil conservation, were widely adopted, whereas institutional measures, such as access to credit, market support, and water management interventions, were adopted at relatively low rates. The study identified farm size, farming experience, and institutional support as the key determinants influencing the adoption of climate-resilient practices. It emphasised that strengthening institutional support systems and promoting farmer groups and cooperatives can enhance the uptake of climate-resilient technologies and improve the adaptive capacity of smallholder farmers (AC, 2024).

A study on smallholder black pepper farmers in Kerala examined the adoption of climate-resilient strategies using a mixed-methods approach. The findings revealed that farmers preferred resilience strategies combining organic farming, diversified cropping systems with cardamom integration, and the conservation of traditional black pepper landraces. Organic farming was perceived as a sustainable long-term adaptation despite higher maintenance costs, while farmers showed mixed acceptance of grafted pepper plants due to the need for stronger institutional validation. The study also highlighted a growing shift

towards diversified farming systems to reduce market and climate risks, emphasising the importance of biodiversity conservation and institutional support in strengthening the resilience and sustainability of black pepper-based farming systems (Gopinath et al, 2026).

A study on sustainable agricultural practices in Kerala highlighted the importance of integrating traditional farming knowledge with modern scientific techniques to improve productivity, soil health, and environmental sustainability. The study reported that practices such as soil amelioration using lime and biochar, incorporation of legumes, application of biofertilisers, and biological pest management enhanced nutrient use efficiency, reduced chemical inputs, and increased crop yields. Integrated farming systems combining crops, livestock, fish, and agroforestry further improved farm income, carbon sequestration, and climate resilience. The study concluded that adopting Good Agricultural Practices (GAP), which integrate organic inputs, farm-generated resources, and limited use of chemicals, offers a sustainable pathway to enhance agricultural productivity while promoting environmental conservation and climate resilience (Bastin et al., 2025).

Another study on organic cardamom cultivation in Idukki district, Kerala, examined the adoption of recommended cultivation practices, technological innovations, supporting factors, constraints, and the socio-economic impacts of organic farming. The findings showed that organic farmers adopted innovations such as the Njallani variety, single-sucker planting, and minimum soil disturbance, driven by environmental concerns, consumer demand, and premium market opportunities. Compared with conventional farmers, organic growers exhibited greater risk-taking and entrepreneurial competence, while also generating higher profits and creating more employment opportunities. However, certification and marketing challenges emerged as major barriers to the wider adoption of organic farming. The study emphasised the need for stronger institutional support, including accessible extension services, group certification systems, and market promotion, to enhance the economic and ecological sustainability of organic cardamom cultivation (Gills, 2012).

The FGDs conducted among cardamom farmers in Adimali, Idukki district, Kerala, highlighted that the adoption of dedicated climate-resilient agricultural practices remains limited. While participants acknowledged the increasing impacts of climate variability, most reported relying on conventional cultivation methods rather than implementing structured adaptation strategies. One notable

practice currently employed is maintaining adequate shade, which is essential for the healthy growth and productivity of cardamom plants. To achieve this, farmers use green shade nets and cultivate shade-providing species such as hibiscus and other tree varieties within their plantations. These measures help reduce heat stress and create a more favourable microclimate for crop growth. Farmers also reflected on significant changes in the region's cropping patterns over time. Historically, the area supported the cultivation of crops such as coconut, coffee, ginger, pepper and various tubers. However, participants reported that many producers have gradually abandoned these crops due to recurring pest infestations and the comparatively higher economic returns associated with cardamom cultivation. As a result, farming systems in the region have become increasingly dependent on cardamom as the principal source of agricultural income, potentially increasing vulnerability to climate-related and market-driven risks.

A study on the Sarvathobhadram Organic Farmers' Cooperative in Kerala examined the role of the System of Rice Intensification (SRI) in promoting organic farming and enhancing climate resilience among small and marginal farmers. The findings showed that the cooperative successfully encouraged farmers to transition from conventional to organic cultivation through institutional support, convergence with government schemes, and collective action. The adoption of SRI improved rice productivity, strengthened food security and livelihoods, and enhanced farmers' resilience to climate-related risks through efficient water management practices. Although the transition to organic farming was initially gradual and constrained by several challenges, the study concluded that SRI is an effective and scalable cultivation method for improving the sustainability and climate resilience of paddy farming systems (Sreeni, 2022).

Cotton is one of India's major cash crops, cultivated on approximately 13 million hectares. It is the country's second-largest employment-generating agricultural sector, providing livelihoods to millions of people both directly and indirectly. A study on cotton-based Integrated Farming Systems (IFS) in India highlighted the need to diversify cotton production systems to improve sustainability and climate resilience. The expansion of hybrid and Bt cotton cultivation has led to widespread monocropping, reducing farm diversity and increasing production risks. The study found that integrating cotton with legumes, horticultural crops,

livestock, poultry, and vermicomposting significantly enhanced farm productivity, resource-use efficiency, and profitability across different agro-ecological regions. Intercropping cotton with pigeonpea improved water productivity and nutrient-use efficiency, while diversified IFS models generated substantially higher net returns than sole cotton cultivation. The study emphasised that promoting cotton-based IFS through improved market access, institutional credit, and farmer skill development can strengthen the resilience and sustainability of cotton farming systems (Venugopalan et al, 2021).

The FGDs conducted by PAN India identified various adaptation measures undertaken by the cotton farmers in Yavatmal, Maharashtra. These included changing sowing dates, adopting mixed cropping alongside monocropping, using natural pest management practices such as Jeevamrut, Dashparni, Nimboli Ark, and buttermilk sprays, constructing furrows and trenches for water management, and relying on irrigation during periods of extreme heat. Farmers also received weather advisories through mobile applications and increasingly used their own seeds during drought years to reduce production costs. The findings indicate that crop diversification, local knowledge, natural farming practices, and community-based resource sharing have strengthened resilience by improving food security, diversifying income sources, and enhancing farmers' ability to cope with climate variability.

However, expanding climate-resilient farming practices, strengthening farmer organisations, and improving institutional and policy support remain essential for enhancing the long-term resilience of farming communities. The study found that organic farming formed the foundation of climate resilience among the surveyed farmers. Unlike conventional systems, farmers did not use synthetic fertilisers or chemical pesticides, relying instead on compost, farmyard manure, crop residues, green manure, and locally prepared bio-inputs such as Jeevamrut, Dashparni Ark, and Gokrupa Amrut for soil fertility and pest management. Mixed cropping, practised by most respondents, emerged as a key adaptation strategy by reducing production risks, improving household food security, enhancing dietary diversity, and creating multiple sources of income. Cotton was commonly intercropped with soybean and pigeon pea, ensuring that the failure of one crop could be compensated by the others. Additional resilience practices included crop diversification, contour bunding, ridge-and-furrow systems, trenches, tree planting around farms, and

the conservation of farmer-saved seeds of crops such as pigeon pea, chickpea, wheat, and chia. Farmers also received weather advisories through mobile-based services and relied heavily on traditional knowledge, farmer-to-farmer learning, and collective community action to adapt to changing climatic conditions.

While farmers continue to rely on both traditional experience and modern sources such as mobile-based weather advisories, there remains a need to better integrate and facilitate the transfer of indigenous ecological knowledge across generations. The findings also emphasise that community-based approaches, including farmer-to-farmer learning, sharing of seeds, tools and labour, and stronger local organisations, play a crucial role in enhancing adaptive capacity and addressing both environmental and market-related challenges. Strengthening these knowledge-sharing networks and collective institutions can significantly improve the long-term resilience of farming communities to climate change. Research showed that when farmers had access to wage employment through India's Mahatma Gandhi National Rural Employment Guarantee Scheme, a social security and public works programme, alongside agroecological farming, suicide rates were dramatically lower, demonstrating that combining income diversification with sustainable farming creates resilient livelihoods in climate-stressed regions (Bharadwaj et al., 2023).

Agroecological systems have inherent climate adaptation features such as higher soil organic matter, which improves water retention and buffers against drought; crop diversity reduces catastrophic loss from a single pest, disease, or weather event; mulching reduces soil moisture evaporation by up to 40-50% in semi-arid conditions; and deeper root systems from healthy soil biology allow crops to access subsoil moisture.

Voices from the field: Farmer case studies

Case study 2

Sustainable income diversification and climate resilience through agroecological practices

Santosh Gophane is a 56-year-old organic farmer cultivating 4.5 acres of land and has been farming organically for the past 5 years. Agriculture serves as the sole source of livelihood for his family, meeting both household consumption needs and income requirements. His farming system reflects a diversified and sustainable approach, integrating traditional seed varieties, organic inputs, and climate-resilient

cultivation practices. The farm supports a diverse cropping system comprising cotton, soybean, wheat, green gram (moong), sesame, and pigeon pea (tur). Rather than depending on a single crop, Mr Gophane has adopted mixed cropping for the past ten years, enabling him to diversify production and reduce the risks associated with climate variability and market fluctuations. According to him, cultivating multiple crops provides several income streams and enhances the household's economic stability. Traditional seed varieties are used for wheat, sesame, and green gram, reflecting his preference for locally adapted crops. To maintain soil fertility and crop health, he follows sustainable nutrient management practices by applying farmyard manure and vermicompost while incorporating crop residues back into the soil. These practices help improve soil organic matter, nutrient cycling, and long-term soil productivity.

Mr Gophane also relies primarily on biological and non-chemical crop protection measures. The inputs used on his farm include Dashparni Ark, Neem Kernel Extract, Gokrupa Amrut, Egg Extract, Bhim Tonic, Trichogramma, Humic Acid, and Vermicompost. This integrated approach reduces dependence on synthetic agrochemicals while supporting healthier crop growth and ecological balance. Climate variability has prompted the adoption of several resilience-building measures on the farm. To minimise the impacts of drought and heavy rainfall, Mr Gophane has constructed trenches to improve water conservation and drainage. These structures help retain moisture during dry periods while preventing waterlogging during intense rainfall events, thereby improving crop performance under changing climatic conditions.

The diversified farming system has generated satisfactory production outcomes. On one acre each, pigeon pea and soybean produced approximately 5 quintals, while green gram yielded 4.5 quintals. With a total cultivation expenditure of approximately ₹20,000, the farm generated an annual income of around ₹1,00,000, demonstrating the economic viability of its low-input, diversified farming system. The household's average monthly expenditure is approximately ₹10,000, and the family meets a substantial portion of its food needs through its own agricultural production. Mr Gophane's farming experience demonstrates how diversification, the use of traditional seed varieties, organic nutrient management, and climate-resilient land management practices can strengthen both livelihood security and ecological sustainability. His case illustrates that integrating multiple crops with low external inputs not only reduces production risks but also enhances household self-sufficiency and resilience to changing climatic conditions.

Case study 3

Restoring soil health and water retention via deep tillage and composting

Santosh Golhar is a 44-year-old organic farmer cultivating six acres of land in Murali village. For the past five years, he has been engaged in organic farming as his primary occupation, with agriculture serving as the sole source of his family's livelihood. His farming system is characterised by crop diversification, organic nutrient management, traditional seed conservation, and climate-resilient cultivation practices. Mr Golhar follows a highly diversified farming system, cultivating soybean, pigeon pea (tur), groundnut, chickpea, wheat, green gram (moong), sesame, and a two-acre mango orchard comprising approximately 500 trees. By integrating annual field crops with perennial horticultural crops, he has developed multiple income sources that reduce dependence on a single crop and enhance his household's economic resilience.

The farmer continues to cultivate traditional seed varieties of wheat, sesame, green gram, chickpea, and pigeon pea. Rather than purchasing seeds each season, he preserves and stores his own seeds for future cultivation. This practice not only reduces cultivation costs but also helps conserve locally adapted genetic resources that are better suited to prevailing environmental conditions. To maintain soil fertility and improve long-term productivity, Mr Golhar applies farmyard manure and vermicompost while incorporating crop residues back into the soil after harvest. His crop management practices rely entirely on organic and biological inputs, including Jeevamrut, Go Krupa Amrut, Dashparni, Neem Seed Extract, Egg Extract, and Vermicompost. These preparations help improve soil biological activity, enhance nutrient availability, and provide natural protection against pests and diseases without relying on synthetic agrochemicals.

Over the past five years, Mr Golhar has consistently practised mixed cropping as a strategy to improve farm resilience. Recognising the increasing variability in weather patterns, he has adopted climate-resilient land management measures, such as trench construction and the ridge-and-furrow system, to improve drainage during heavy rainfall while conserving moisture during dry periods. In addition, irrigation facilities are used during periods of extreme heat to protect crops from moisture stress and maintain productivity. The diversified organic farming system has produced encouraging outcomes. The farm records yields of approximately

30 quintals of soybean, 6 quintals of pigeon pea, 21 quintals of groundnut, and 24 quintals of wheat, while cultivation costs remain comparatively low due to the extensive use of farm-produced organic inputs and seed conservation practices. The household's average monthly expenditure is approximately ₹15,000, and the family meets a substantial portion of its food requirements directly from crops grown on the farm, thereby enhancing household food security.

Mr Golhar's farming system demonstrates how organic agriculture, crop diversification, traditional seed conservation, and ecological land management can collectively strengthen climate resilience. His reliance on locally available resources, integrated farming practices, and multiple crop enterprises has reduced production costs, diversified income sources, and improved the sustainability of his farming system. The case highlights the potential of organic farming as a viable adaptation strategy for addressing the challenges posed by climate variability while simultaneously supporting household livelihoods and environmental conservation.

Case study 4

Micro-water management & livestock integration for household resilience

Gopal Nikam, aged 33, adopted pesticide-free farming three years ago and cultivates 15 acres of farmland. With a decade of farming experience, he relies on agriculture as the primary source of livelihood for his family, meeting both household consumption needs and income requirements. His farming system combines traditional agricultural knowledge with modern climate-informed decision-making, enabling him to better cope with the challenges posed by climate variability. Mr Nikam primarily cultivates soybean and pigeon pea (tur) under a mixed-cropping system, which he has consistently practised for the past ten years. He continues to use traditional varieties of pigeon pea and preserves his own seeds for future cultivation, reducing dependence on external seed sources while conserving locally adapted genetic resources. According to the farmer, cultivating multiple crops provides an important safety net, ensuring that if one crop fails due to adverse weather conditions, income can still be generated from the remaining crops.

The farmer follows sustainable crop management practices by applying farmyard manure (cow dung manure) to maintain soil fertility and improve soil health. For crop protection, he relies predominantly on biological and botanical formulations, including Neem oil, Karanja oil, Trichoderma, Dashparni,

Saptadhanya Ankur, and Seaweed extracts. These inputs help manage pests and diseases while reducing dependence on synthetic agrochemicals. Recognising the increasing frequency of extreme weather events, Mr Nikam has adopted several climate-resilient agricultural practices. To reduce the impacts of drought and heavy rainfall, he has developed trenches and uses the ridge-and-furrow method to improve water conservation and field drainage. During periods of intense heat, irrigation is used to protect crops from moisture stress. In addition, trees have been planted around the farm boundaries, contributing to soil conservation, microclimate regulation, and overall environmental sustainability.

A distinguishing feature of Mr Nikam's farming system is the integration of climate information into farm management. He regularly receives weather forecasts and climate advisories via the PDKV mobile application, enabling him to make informed decisions about agricultural operations. Based on these weather updates, he schedules sowing according to prevailing climatic conditions, thereby reducing the risks associated with erratic rainfall and delayed monsoons. Furthermore, the farmer is enrolled in the crop insurance scheme, providing an additional layer of financial protection against climate-induced crop losses. The diversified farming system has produced encouraging results, with yields of approximately 58 quintals of soybean and 34 quintals of pigeon pea. The average cultivation cost is approximately ₹8,000 per acre, while the household maintains an average monthly expenditure of ₹10,000. A significant portion of the family's food requirements is produced directly on the farm, contributing to household food security while reducing dependence on market purchases.

Mr Nikam's farming experience demonstrates how traditional farming knowledge can be effectively combined with climate-smart agricultural practices and digital weather advisory services to enhance resilience against climate change. His adoption of mixed cropping, traditional seed conservation, ecological crop management, climate-informed sowing decisions, crop insurance, and agroforestry illustrates a comprehensive adaptation strategy that strengthens livelihood security, reduces production risks, and promotes sustainable agricultural development under increasingly uncertain climatic conditions.

Case study 5

Risk reduction in cotton farming via mixed cropping and organic inputs

Digambar Bhoyar, a 39-year-old farmer, transitioned to non-chemical farming and currently manages a 20-acre farm. Having been engaged in

agriculture for more than a decade, farming as the sole source of livelihood for his family, supporting both household consumption and income generation. His farming system integrates traditional agricultural knowledge with climate-smart practices, enabling him to cope with the increasing challenges posed by climate variability while maintaining farm productivity. Mr Bhoyar cultivates a diversified cropping system comprising soybean, pigeon pea (tur), cotton, and chickpea. For the past ten years, he has consistently practised intercropping, recognising its benefits in reducing production risks, improving resource use efficiency, and enhancing farm resilience. According to the farmer, growing multiple crops provides an important safety net, ensuring that income can still be generated even if one crop is adversely affected by unfavourable weather conditions.

The farmer continues to cultivate traditional pigeon pea varieties and saves his own seeds for future seasons. This practice reduces dependence on purchased seeds while conserving locally adapted varieties that perform well under local agro-climatic conditions. A significant observation shared by Mr Bhoyar is the disappearance of the sunflower, a traditional crop once widely cultivated in the region, which has gradually become locally extinct due to changing climatic and farming conditions. To maintain soil fertility, Mr Bhoyar applies farmyard manure (cow dung manure) and follows sustainable soil management practices. As part of his climate adaptation strategy, he has adopted the ridge-and-furrow method, which helps conserve water during droughts and facilitates efficient drainage during periods of heavy rainfall. Irrigation facilities are also used during periods of intense heat to protect crops from moisture stress and sustain productivity.

Mr Bhoyar complements traditional farming knowledge with modern climate information services. He regularly receives weather forecasts and climate advisories via the PDKV mobile service, enabling him to schedule sowing operations based on prevailing conditions. Additionally, he is enrolled in the crop insurance scheme, which provides financial protection against climate-induced crop losses. The farmer has also adopted agroforestry practices by planting trees and hedges around the boundaries of his farm. These trees serve multiple functions by providing shade, supplying fodder for livestock, producing fruit, and improving the farm's microclimate. According to Mr Bhoyar, the integration of trees into the farming system has enhanced both ecological sustainability and farm resilience. An important benefit observed by the farmer is the reduction in pest infestation resulting

from intercropping. The diversified cropping system has created a more balanced farm ecosystem, reducing pest incidence while improving overall crop health and productivity.

The farm has achieved encouraging production levels, yielding approximately 60 quintals of pigeon pea from five acres, 25 quintals of soybean, 30 quintals of cotton from 2.5 acres, and 10 quintals of chickpea. The household's average monthly expenditure ranges from ₹10,000 to ₹15,000, while a substantial portion of the family's food requirements is produced directly on the farm, strengthening household food security. Mr Bhoyar's farming experience demonstrates how diversified agriculture, intercropping, traditional seed conservation, agroforestry, climate-informed decision-making, and sustainable land management can collectively enhance resilience to climate change. His integrated farming approach not only reduces climatic and economic risks but also improves biodiversity, lowers pest incidence, and supports long-term livelihood security. The case further illustrates the importance of combining indigenous farming practices with modern climate advisory services to build more resilient agricultural systems under changing environmental conditions.

Case study 6

Conserving traditional rice varieties under changing climatic conditions: The experience of a young woman farmer

Pavithra is a young rice farmer actively cultivating traditional rice varieties despite increasing climate uncertainty and declining economic returns. Her experiences illustrate how climate change is altering cropping patterns, reducing seed quality, affecting yields, and threatening the conservation of indigenous rice varieties. At the same time, her commitment to preserving traditional seeds highlights the important role of women farmers in safeguarding agricultural biodiversity and promoting climate resilience. Traditionally, the region followed three rice-cropping seasons. However, according to Pavithra, climatic variability has drastically altered this practice: *"We traditionally had three cropping seasons. However, now farmers cultivate only the first season, the Mundakan season."*

To adapt to changing climatic conditions, she experimented with cultivating rice during the first season. While the first year was successful, the practice soon became unsustainable. From the second year onwards, harvesting coincided with

periods of intense rainfall, resulting in severe crop losses and making timely harvesting difficult. She gradually shifted towards cultivating traditional rice varieties like Rakthashali and Kuruva that could better withstand climatic stress. However, Pavithra explained that climate resilience alone does not guarantee stable production. During the flowering stage, excessive rainfall often causes spikelets to become sterile ("pathiru"), leading to a significant reduction in grain formation and overall yield.

Another major consequence of climate change has been the delay in the agricultural calendar. The farming season now begins much later than before because prolonged rainfall prevents timely land preparation and sowing. This delay has serious implications for seed preservation. Traditionally, rice seeds remain viable for approximately six months under proper storage. However, the delayed planting season forces farmers to store seeds for an additional two months, reducing seed viability and germination rates. Consequently, many farmers are compelled to purchase seeds rather than rely on their own seed stock. Pavithra also discussed the challenges associated with conserving Rakthashali, one of the most preferred traditional rice varieties in the Vellangallur region due to its strong market demand and relatively short duration (approximately 100 days). She noted that preserving quality seed has become increasingly difficult under changing climatic conditions. Poor-quality seed not only reduces germination but also increases susceptibility to pest infestation, ultimately affecting crop productivity.

Another traditional variety she continues to cultivate is Kuruva, a long-duration, pest-resistant rice variety. During 2017–2018, Kuruva was widely cultivated because of its resistance to pests and adaptability to both drought and flooding. However, current rainfall patterns have made harvesting increasingly challenging. Heavy rains during crop maturity cause lodging, making harvesting difficult and increasing crop losses. Pavithra noted: *"Even though harvesting has become difficult because of heavy rain, I continue cultivating Kuruva to preserve the variety."*

Her statement reflects a strong commitment to conserving indigenous germplasm despite economic and production risks. Pavithra further observed that several traditional climate adaptation practices are gradually disappearing. Mulching, once widely adopted to conserve soil moisture and improve drought resilience, is no longer commonly practised. She attributed this decline to changes in farming systems and labour constraints. Comparing traditional and hybrid rice varieties, Pavithra believes

that traditional varieties exhibit greater resilience to climatic stress than hybrid varieties. Nevertheless, she acknowledged that this resilience comes with several trade-offs. As Pavithra said, *"Traditional varieties are climate-resilient to an extent, but they require more effort, are costlier to cultivate, and have less market demand."*

Thus, although traditional varieties possess adaptive characteristics that enable them to tolerate changing climatic conditions better than hybrids, economic constraints discourage their widespread cultivation. Beyond rice, Pavithra also highlighted the decline in the production of Kudampuli (Malabar tamarind), which she attributed to changing climatic conditions. According to her, production has reduced considerably over recent years, indicating that climate variability is affecting multiple traditional crops cultivated in the region.

Overall, Pavithra's experiences demonstrate that climate change affects agriculture not only through

declining yields but also by disrupting cropping calendars, reducing seed quality, increasing production risks, and threatening the conservation of traditional crop varieties. Her continued efforts to cultivate indigenous rice varieties despite these challenges underscore the significant role that young women farmers play in preserving agricultural biodiversity and strengthening community resilience. The case also highlights the need for targeted institutional support, including improved seed conservation systems, better market opportunities for traditional varieties, and climate-resilient agricultural interventions that encourage the continued cultivation of indigenous crops.

COMPARATIVE INSIGHTS

Table 6 summarises the insights gathered through the FGDs, case studies, and interviews carried out in this PAR.

Table 6. Comparative insights from FGDs, case studies, and farmer interviews

Aspect	Organic / Agroecological / Non-pesticidal farmers	Conventional farmers
Cropping system	Diversified farming through mixed cropping/ intercropping, reducing climate and market risks	Greater dependence on cotton monocropping or limited crop diversification
Seed use	Use of traditional, locally adapted varieties and farm-saved seeds, reducing seed costs and improving climate resilience	Dependence on purchased hybrid seeds, which are more vulnerable to erratic weather and require repeated purchase
Input costs	Lower cultivation costs due to use of farmyard manure, compost, botanical extracts, and on-farm inputs	Higher expenditure on fertilisers, pesticides, hybrid seeds, and external inputs
Soil health	Improved soil fertility, organic matter, microbial activity, moisture retention, and long-term soil productivity	Soil compaction, declining soil quality, reduced biological activity, and greater dependence on chemical fertilisers
Pest and disease management	Biological pest management and diversified farming reduced pest incidence and promoted ecological balance	Increasing pest outbreaks and fungal diseases, leading to higher pesticide use
Climate resilience	Better tolerance to droughts and heavy rainfall through ridge and furrow systems, trenches, agroforestry, mixed cropping, and soil conservation practices	Greater crop damage from waterlogging, drought, delayed sowing, and erratic rainfall
Water management	Improved water conservation and drainage through trenches, ridge and furrow systems, and increased soil moisture retention	More vulnerable to waterlogging and moisture stress due to poor soil structure

(Table 6 continued)

Aspect	Organic / Agroecological / Non-pesticidal farmers	Conventional farmers
Biodiversity	Conserved soil organisms, pollinators, beneficial insects, birds, and on-farm biodiversity through ecological farming practices	Declining biodiversity due to intensive chemical use and simplified farming systems
Yielded stability	More stable yields under variable climatic conditions because crop diversification spreads production risk, even if individual crop yields fluctuate	Larger yield fluctuations and greater crop failure during extreme weather events
Income security	Multiple crops and diversified enterprises provide several income sources, improving livelihood security	Income depends largely on the performance of one or two crops, increasing financial risk
Household food security	Greater self-sufficiency, with a significant share of household food produced on-farm	Greater dependence on market purchases for household consumption
Dependence on external inputs	Low dependence on purchased inputs due to seed saving and farm-produced bio-inputs	High dependence on commercial seeds, fertilisers, pesticides, and agrochemicals
Long-term sustainability	Builds ecological resilience by improving soil, conserving biodiversity, reducing environmental degradation, and strengthening adaptive capacity	More vulnerable to climate change due to declining soil health, increasing input dependency, and environmental degradation
Water management	Improved water conservation and drainage through trenches, ridge and furrow systems, and increased soil moisture retention	More vulnerable to waterlogging and moisture stress due to poor soil structure

CONCLUSION

The findings demonstrate that climate change has become a critical challenge affecting the sustainability of small-scale food-producing communities across Maharashtra, Telangana and Kerala. Increasing temperatures, erratic rainfall, prolonged droughts, floods, pest outbreaks, and declining soil and water resources have significantly disrupted agricultural production, reduced farm incomes, and heightened the socio-economic vulnerability of farming households. These impacts extend beyond crop productivity, affecting livelihood security, food security, health, and the overall resilience of rural communities.

Despite these challenges, the study highlights the considerable potential of agroecological approaches in enhancing climate resilience. Practices such as mixed cropping, crop diversification, organic soil management, natural pest control, biodiversity conservation, water management, and the use of

indigenous knowledge have enabled farmers to better cope with climatic uncertainties while reducing dependence on external inputs. The experiences documented across the study sites demonstrate that agroecology not only strengthens ecological resilience but also improves livelihood security and adaptive capacity.

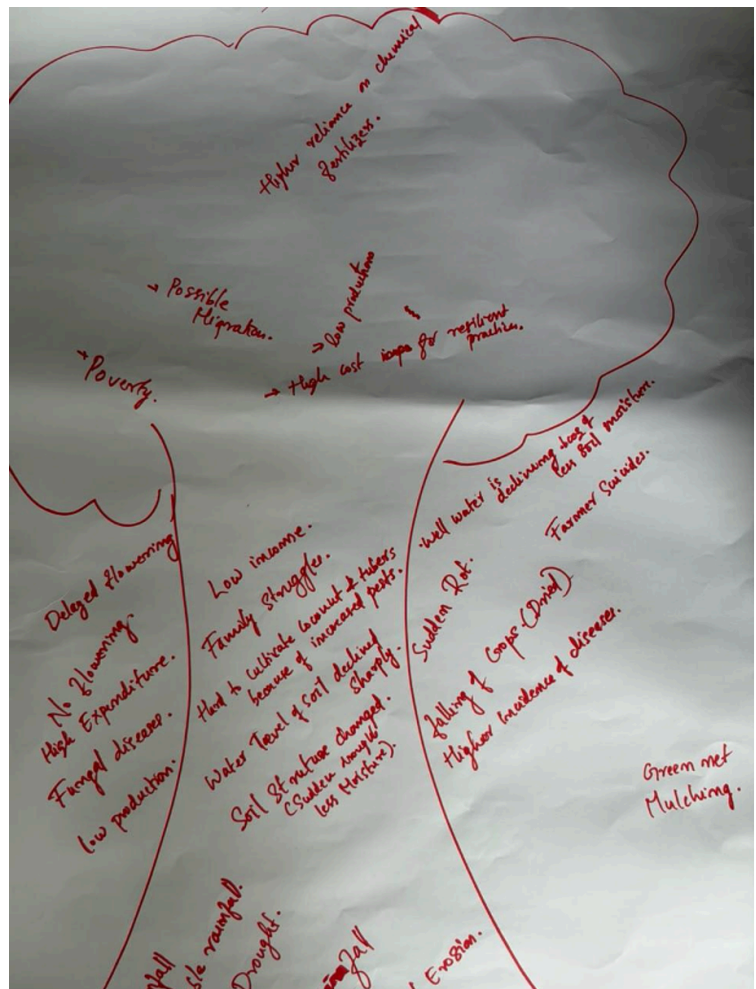
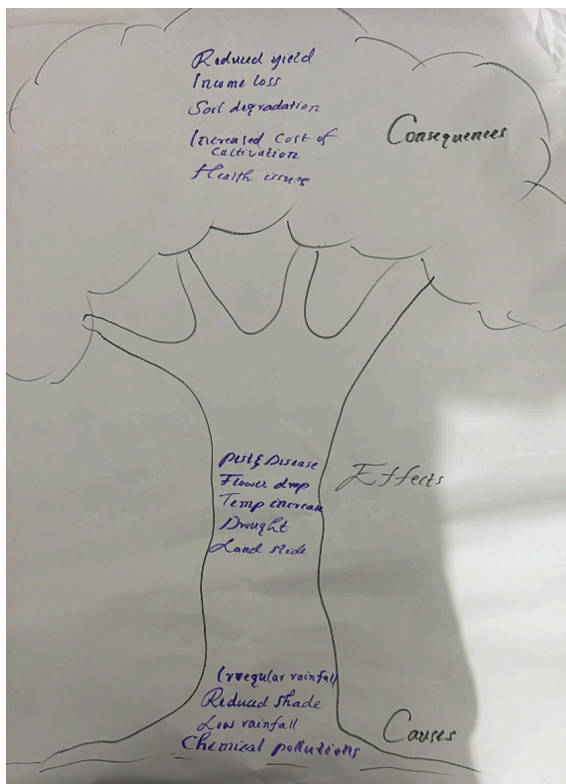
The study further underscores the importance of strengthening institutional support through improved extension services, timely climate information, accessible financial assistance, effective crop insurance, and policies that promote agroecological transitions. Investing in community-based learning, farmer organisations, and locally adapted climate-resilient practices will be essential for building sustainable and resilient agricultural systems. As climate risks continue to intensify, integrating agroecology into agricultural development and climate adaptation policies offers a viable pathway towards ensuring food security, environmental sustainability, and the long-term well-being of small-scale farming communities.

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Participatory rural appraisal tools: Problem Tree



India: Andhra Pradesh

SAHANIVASA

Executive summary

Climate change is increasingly threatening the livelihoods of farming and agricultural worker communities across the dryland region of Rayalaseema in southern Andhra Pradesh. This Participatory Action Research documents the lived experiences of communities across 20 villages in Nimmanapalle Mandal (Annamayya district) and Sodam Mandal (Chittoor district), where agriculture remains the primary source of livelihoods and food security.

The study covered 2,001 households representing approximately 6,003 people (2,931 women and 3,072 men), including 958 Dalit households and 220 Adivasi households. Data were generated through focus group discussions, semi-structured interviews, seasonal calendars, historical timelines, solution-tree analysis, village observations, community-led discussions, and follow-ups with local government offices, including the Local Panchayat Office, Primary Health Care Centre, and Agriculture Departments.

The study observed the following as among the impacts of climate change in the communities covered:

- Declining groundwater levels
- Delayed sowing
- Frequent crop failures
- Declining soil moisture
- Increased pest and disease outbreaks
- Reduced agricultural employment
- Increasing indebtedness
- Worsening food insecurity
- Growing distress migration

This research centres community knowledge and lived experiences to understand how climate change

is transforming agriculture, livelihoods and social well-being.

Communities consistently reported significant climatic changes over the past two decades. The annual rainfall of approximately 600-800 millimetres (mm) has become increasingly erratic, with delayed southwest monsoons, prolonged dry periods and short periods of intense rainfall causing severe runoff and soil erosion. Summer temperatures now frequently exceed 40-43°C, while winters have become shorter and less distinct than in previous decades.

The research centres community knowledge and lived experience to understand how climate change is transforming agriculture, livelihoods, and social well-being.

Despite increasing climatic uncertainty, communities continue adapting through diverse agroecological farming systems. The study documented widespread adoption of:

- Crop diversification - mixed cropping and intercropping
- Traditional drought-resistant seed varieties
- Mulching
- Composting
- Livestock integration
- Natural pest management
- Community seed conservation

While monocropped groundnut generated higher gross income during favourable seasons (approximately ₹70,000 per acre), diversified systems reduced cultivation costs from approximately ₹48,000 to ₹28,500 per acre, produced multiple food crops, and reduced the risk of complete crop failure. Even though net income is low in diversified cropping, farmers who adopt it say they have great hope of reaching yields like in olden times, as the soil is not exposed to toxic fertilisers or pesticides.

Similarly, diversified pearl millet, finger millet, sugarcane, and mango systems generated additional income from intercrops, including pulses, sesame, vegetables, marigold, and gongura, while improving household food availability.

These systems also reduced dependence on purchased fertilisers, pesticides and commercial seeds.

The study found that climate change is reinforcing existing social inequalities. The greatest impacts were experienced by:

- Landless agricultural labourers
- Tenant farmers
- Sharecroppers
- Small and marginal farmers
- Dalit communities
- Adivasi communities
- Rural youth
- Women from all of the above-mentioned communities were identified as particularly disadvantaged by the climate crisis

Crop failures reduce wage employment, increase indebtedness and force migration.

Food diversity has declined significantly, with many households reporting reduced consumption of millets, pulses and vegetables, while increasingly relying on subsidised ration rice.

Women frequently reduce their own food intake to prioritise children, contributing to widespread anaemia and poor maternal nutrition. The research also identified growing mental stress, occupational health risks and reduced educational opportunities among vulnerable households.

The findings demonstrate that climate adaptation should move beyond technological solutions alone. Strengthening climate resilience requires:

- Scaling up agroecological farming
- Expanding community seed banks and protecting farmers' seed rights
- Improving the implementation of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and increasing employment opportunities
- Investing in landscape-level water conservation

- Recognising women as farmers and supporting women-led organisations
- Securing land, tenancy and common property rights
- Supporting farmer-led knowledge systems and participatory extension services
- Strengthening village institutions, unions and community organisations

The study concludes that agroecology represents not only a strong farming system but also a pathway towards climate justice, food sovereignty, and resilient rural livelihoods.

Introduction

Background

Climate change has emerged as one of the greatest challenges facing rural food-producing communities across India. Dryland regions such as Rayalaseema are particularly vulnerable because agriculture depends heavily on seasonal rainfall and groundwater, and their ecosystems are fragile. Rising temperatures, erratic rainfall, prolonged droughts, and declining groundwater levels are increasingly threatening agricultural production, household incomes, and food security. Hence, 20 villages across Nimmanapalle Mandal in Annamayya district and Sodam Mandal in Chittoor district are selected for this study.

These climatic changes occur alongside existing social inequalities related to caste, land ownership, gender and access to natural resources. Consequently, climate impacts are experienced most severely by small and marginal farmers, tenant cultivators, landless agricultural workers, Dalit and Adivasi communities, and women engaged in agriculture.

The comparison of agroecological and monocropping systems demonstrated important differences. While monocropped groundnut generated higher gross income during favourable seasons (approximately ₹70,000 per acre), diversified systems reduced cultivation costs from approximately ₹48,000 to ₹28,500 per acre, produced multiple food crops, and reduced the risk of complete crop failure. Although net income is currently lower in some diversified systems, farmers practising them are confident that yields can recover as soil health improves, since the land is no longer exposed to toxic fertilisers and pesticides.

Despite their importance, these community-led adaptation practices remain inadequately documented within climate policy. This research therefore places farmers' knowledge, experiences and collective action at the centre of understanding climate resilience.

Objectives of the research

The objectives of this research are:

1. To understand how changing climatic conditions are affecting rural food-producing communities, particularly small and marginal farmers, sharecroppers, tenant cultivators, leased workers, and leased garden farmers
2. To document local experiences of environmental change and examine their effects on agriculture, livelihoods, food production, and everyday rural life
3. To explore the role of agroecological farming practices in helping communities adapt to climatic uncertainty and maintain agricultural sustainability
4. Similarly, diversified pearl millet, finger millet, sugarcane, and mango systems generated additional income from intercropping, including pulses, sesame, vegetables, marigold, and gongura, while improving household food availability

Research questions

The two central research questions were:

1. How is the climate crisis impacting rural communities?
2. The study found that climate change is reinforcing existing social inequalities. The greatest impacts were experienced by:

Methodology

Participatory Action Research (PAR) approach

This study used a Participatory Action Research (PAR) approach, which combines active engagement with communities and community-led analysis. Facilitators were village union members and leaders who worked closely with community members through structured discussions and collective reflection.

The research was conducted through open conversations based on people's memories, experiences,

and observations. Rather than beginning directly with the term "climate change," discussions started from people's everyday realities and lived experiences. Questions such as "Think back to when you first started farming. What were the rains like then? What are they like now?" were used to encourage reflection and discussion. Community members also explored changes in their environment by identifying the locations of water tanks, discussing when they dry up, and walking through these areas together. Charts with different indicators were used to make information gathering easier and more organised.

The marginalised communities were able to identify clear connections between their livelihood challenges, climate instability, and land encroachments. Their lived experiences, local observations, adaptation practices, and collective decision-making played an important role in understanding the situation. Data collection included Focus Group Discussions (FGDs) and individual interviews, which helped document people's experiences, beliefs, and knowledge passed down through generations. Village empowerment songs were also included during gatherings to create a comfortable environment and ensure that the process did not feel like a formal study.

After the FGDs, the facilitators collected additional details about the population across the 20 study areas to better understand farmers who practice agroecology and those who do not. Additionally, participatory mapping activities involved youth and elders working together, using Google Maps to identify geographical changes, land encroachments, and the locations of hills and water bodies that have dried over time.

Study locations

The study covers 20 villages: 10 in Nimmanapalle Mandal of Annamayya district and 10 in Sodam Mandal of Chittoor district in Andhra Pradesh, India. Both mandals are located in the semi-arid tropical Rayalaseema region, within the scarce rainfall zone of Andhra Pradesh. As predominantly dryland regions, farming mainly depends on seasonal rainfall, along with additional support from groundwater sources such as rainwater-harvested village tanks and deep irrigation bore wells. There are no perennial rivers in the area. The landscape is characterised by undulating plains, scattered rocky hillocks, and predominantly red ferruginous and black clay soils. Agriculture is largely centred on food grain production, including minor millets, pulses, vegetables, groundnut, and mango, the latter of which is a major commercial crop. The farming

system is predominantly rainfed, with mixed cropping and monocropping practices alongside livestock rearing.

Many farming households consist of small and marginal farmers or landless agricultural workers, including a significant number from Dalit, Adivasi, and Backward Caste communities. The region is highly vulnerable to recurrent droughts, erratic rainfall, groundwater depletion, and increasing climate variability, making agriculture and rural livelihoods highly climate-sensitive.

Participants

Across the 20 study villages, research participants included landless agricultural labourers, sharecroppers, tenant farmers, marginal farmers (0–2.5 acres), small farmers (2.5–5 acres), and medium farmers (5–10 acres). The study also included farmers practising agro-ecological methods under predominantly dryland conditions and farmers practising conventional monocropping, but excluded large farmers (10+ acres). The core discussions involved 47 participants, of whom 34 (72%) were women, while more than 10 farmers representing

the different livelihood categories participated in semi-structured individual interviews and narrative case stories. A few of these participants, along with new participants, also took part in other participatory exercises, including the seasonal calendar, historical timeline, solution tree, and community mapping activities. The participant groups comprised 70% women.

Of the total participants, 50% were elder farmers with 30 or more years of farming experience, while the remaining 50% were youth aged 18–35 and adults up to 50 years old, many of whom migrate when their households face financial difficulties.

Special emphasis was placed on ensuring that the voices of Dalit, Adivasi, and landless workers, especially women from these communities, were centred in the discussions, as they undertake much of the labour-intensive work in households and in agriculture.

Data collection methods

An overview of the methods used by the study to collect data is provided in **Table 1**.

Table 1. Summary of data collection methods used

Method	No. of conducted	Participants	Purpose
Focus Group Discussions (FGDs)	4	47 (34 women)	Observed climate changes, community-level impacts, and collective adaptive responses
Semi-structured Individual Interviews	10+ farmers (combining them in 2 videos) along with narrative case stories	Landless agricultural labourers, share croppers, and tenant farmers, small and marginal farmers, agro-ecological farmers/ dry land cultivation mono-cropping farmers (large farmers were not part of the study)	Captured differential vulnerability and personal livelihood impacts that were not expressed in group settings. In particular, the interviews captured the challenges faced by women, including nutritional problems, excessive workloads, wage disparities, and occupational health risks. Also helped document the experiences of farmers exposed to toxic chemicals while working without personal protective equipment (PPE) or appropriate tools under the government employment program (MGNREGA). On the other hand, the interviews provided detailed descriptions of the preparation and use of eco-friendly pest control systems

(Table 1 continued)

Method	No. of conducted	Participants	Purpose
Seasonal Calendar exercise	2	23 (18 women)	To identify shifts in agricultural seasons, crop calendars, pest patterns, and water availability by comparing seasonal patterns over the last three decades with the present
Historical Timeline / Oral History (Elders from the same group as the seasonal calendar)	2	12 (9 women)	To trace key climate events (droughts and floods), land-use changes along with encroachments, seed/ crop disappearances, and major policy changes over the past three decades through interviews and group discussions with long-standing community members
Solution Tree exercise (including some from the FGDs)	2	11 (9 women)	To co-develop community-led strategies for expanding agro-ecological practices, strengthening land and water rights, and empowering collective action to improve livelihoods, adapt to climate change, and sustain resilient agro-ecological farming systems
Community Mapping	2	Throughout the discussions, information was gathered with the active participation of elders and youth, who helped track environmental and land-use changes	To ground the research findings in the physical and social landscape of each village by facilitating participatory mapping of farm resources, water sources, vulnerable areas, and community solidarity networks using Google Maps and field visits to the major identified locations
Habitation-Wise Population	1 for each mandal or sub-district (see table below)	To ensure regular follow-ups, there was representation of periodically rotating union members across different geographical areas based on their availability (approximately 20 members)	To collect information on the population and different community categories by facilitating union members' engagement with local block government offices and visits to each village

Habitation-Wise population

Tables 2 and 3 provide a summary of the Habitation-Wise Population covered by the research.

Table 2. Habitation-Wise Population in the Annamayya district, Nimmanapalli mandal (sub-district)

Villages	No. of households	No. of Dalit		Total	No. of Adivasi		Total	No. of castes		Total	Total population		Total
		Female	Male		Female	Male		Female	Male		Female	Male	
Rachavetivari Palli	218	98	105	203	19	19	38	327	333	660	444	457	901
Reddivari Palli	222	82	86	168	72	80	152	329	331	660	483	497	980
Bandlapai	63	22	23	45	3	4	7	103	108	211	128	135	263
Mustur	168	29	34	63	15	20	35	298	303	601	342	357	699
Kondaiahgari Palli	125	56	65	121	8	12	20	178	182	360	242	259	501
Thavalam	155	47	52	99	35	38	73	226	233	459	308	323	631
Nimmana Palli	284	130	137	267	9	7	16	428	433	861	567	577	1,144
Agraharm	120	35	39	74	6	8	14	189	193	382	230	240	470
Sanakatavari Palli	72	13	15	28	0	0	0	113	118	231	126	133	259
Vengamvari Palli	246	12	15	27	12	17	29	458	464	922	482	496	978
Total	1,673	524	571	1,095	179	205	384	2,649	2,698	5,347	3,352	3,474	6,826

Table 3. Habitation-Wise Population in the Chittoor district, Sodam mandal (sub-district)

Villages	No. of households	No. of Dalit		Total	No. of Adivasi		Total	No. of castes		Total	Total population		Total
		Female	Male		Female	Male		Female	Male		Female	Male	
Cherukuvari Palli	126	148	154	302	99	103	202	99	105	204	346	362	708
Joggivari Palli	110	120	126	246	0	0	0	195	198	393	315	324	639
Gummadidoddi	17	25	29	54	0	0	0	27	29	56	52	58	110
Ramapuram	69	98	100	198	0	0	0	115	118	233	213	218	431
Nadigadda	124	156	160	316	0	0	0	185	187	372	341	347	688
Ambedkar Colony	21	58	60	118	0	0	0	0	0	0	58	60	118
Gandla Palli	105	0	0	0	0	0	0	274	280	554	274	280	554
Mitta Palli	54	59	64	122	35	38	73	45	52	97	138	154	292
Chintamakula Palli	42	112	118	230	0	0	0	0	0	0	112	118	230
Doddivari Palli	59	98	95	193	0	0	0	75	80	155	173	175	348
Total	727	873	906	1,779	134	141	275	1,015	1,049	2,064	2,022	2,096	4,118

Tables 4 and 5 summarise the total number of families and the population covered by the research.

Table 4. Total number of families covered by the research by category and land ownership

Category	Landless agricultural labourers	Sharecroppers and tenant farmers	Small, marginal, and medium farmers	Total families
Dalits	575	186	197	958
Adivasi	132	0	88	220
Other castes	494	160	169	823
Total	1,201	346	454	2,001

Table 5. Total population covered by the research by category and gender

Category	Female	Male	Total	Total families
Dalits	1,397	1,477	2,874	958
Adivasi	313	346	659	220
Small and marginal farmers of other castes	1,221	1,249	2,470	823
Total	2,931	3,072	6,003	2,001

A demographic assessment of 20 villages in Nimmanapalle and Sodam mandals (10,944 residents across 2,400 households) documented Scheduled Caste, Scheduled Tribe, and Other Caste compositions to guide participant selection.

From this, the study focused on 2,001 households—spanning landless laborers, sharecroppers, tenant farmers, and small-to-medium farmers practicing conventional monocropping, eco-friendly pest

management, or dryland agro-ecological farming. Large farmers (>10 acres) and non-agricultural households were excluded.

The findings and perspectives presented in this study are based on discussions with the participant groups listed in **Table 1**, which served as the primary source of information for understanding the realities and lived experiences of farming communities.

Community context

Socioeconomic profile

The farming communities across the study villages have different economic conditions, but they all face uncertainty and insecurity in their livelihoods. Farming is predominantly rainfed and depends on seasonal rainfall and limited water availability, which strongly influence agricultural production and household livelihoods. Among the 2,001 households (population 6,003) covered in the study, there are 1,201 landless agricultural labourers; 346 sharecroppers and tenant farmers; and 454 small, marginal, and medium farmers. Of these, 654 households practice agro-ecological farming under predominantly dryland conditions, while 146 households practice conventional, chemical-based monocropping. Few of the medium farmers (5–10 acres), who own relatively larger holdings than small and marginal farmers, generally have greater flexibility to experiment with eco-friendly pest management systems, especially for their own consumption.

The main crops cultivated include groundnut as the primary cash crop, along with sorghum, horse gram, finger millet, seasonal vegetables (tomato, brinjal,

ladies' finger, pumpkin, chillies, and drumstick), and fodder crops for livestock. Mango is the major commercial crop, while tamarind, neem, and wild date palm occur naturally across the landscape. Community members reported that sugarcane and paddy were the predominant crops until the first decade of the 21st century, accounting for nearly 40% of cultivation. Their cultivation has gradually declined to around 5% because of increasing water scarcity and climate variability. As a result, sugar factories operated by farmer cooperatives and private companies have closed down. This has swelled the ranks of agricultural workers.

Agriculture is the primary livelihood in the study villages, but climate impacts and falling yields have heightened income insecurity. Due to the agrarian crisis, agricultural laborers find work for only ~60 days annually, earning Rs. 250–350 per day, well below Andhra Pradesh's statutory minimum wage of Rs. 400–500, with women facing gender wage gaps. Trade unions demand a National Minimum Wage of Rs. 920 per day, but it remains unadopted by the Government of India, while the 8th Central Pay Commission excludes agricultural labor from its wage revisions.

Group exercise with community members



Although MGNREGA promises up to 100 days of supplementary employment, villagers report incomplete implementation and inadequate earnings. Consequently, families face distress migration and child labor, with girls disproportionately forced out of school due to economic hardship, domestic duties, and safety risks.

Milk production is another important source of livelihood across all sections of the farming community. While farmers with land generally maintain grazing areas on their own land, many landless agricultural labourers and marginal farmers own one or two cattle and depend on common property resources, including grazing lands, hillocks, canal bunds, and tank foreshore lands. Community members reported that increasing land encroachments have reduced access to these common resources, affecting livestock rearing and household incomes.

Land ownership patterns vary considerably across households. Where 575 Dalits are landless agricultural labourer households, 186 Dalits are sharecropper and tenant farmer households, and 197 Dalits are small, marginal, and medium farmer households. While 132 landless agricultural labourer households and 88 small, marginal, and medium farmer households belonged to Adivasi communities. And, 494 landless agricultural labourer households, 160 sharecropper and tenant farmer households, and 169 small, marginal, and medium farmer households belonged to other caste groups. There are farmers who own 10+ acres who are not included in the study, as well as individuals in other occupations.

Although some households own agricultural land, many lack reliable irrigation and therefore supplement their income through agricultural wage labour. Landless households depend entirely on daily-wage employment while also cultivating land through informal tenant-farming and sharecropping arrangements with larger landowners. These agreements are generally based on verbal understandings regarding crop sharing or land rent, leaving cultivators highly vulnerable when crops fail.

Caste continues to strongly influence economic life in these villages. Although some households have received up to 5 acres of government-allocated dry land or wasteland through a land distribution programme, community members reported that these allocations have largely remained unproductive due to a lack of irrigation and other

essential infrastructure. In many cases, the land allocated to Dalit and Adivasi communities is in inaccessible areas such as hillocks or on highly degraded, drought-prone land, making cultivation difficult. Also, a few of them got land in high-radiation areas. Of the 958 Dalit households, 220 Adivasi households, and 823 households from other castes (predominantly Backward Castes) represented in the study, the majority were landless agricultural labourers (1201) and tenant farming households (346), reflecting historical inequalities in land ownership and access to livelihood opportunities.

Encroachment on common grazing lands and water tank beds has disrupted natural water flows and reduced resource access for marginalized Dalit and Adivasi households, heightening overall climate vulnerability. Simultaneously, chronic unemployment forces agricultural laborers into hazardous work, such as spraying toxic pesticides without personal protective equipment. This exposes resource-poor households to severe physical, mental, and financial shocks with little safety net for recovery.

Agroecological practices in the community

Crop diversification is already widely practised across the study villages. Instead of cultivating a single crop, farmers combine a main cash crop with food crops and seasonal intercrops, reducing dependence on one crop and spreading production risks under rainfed conditions. For example, one acre of groundnut is intercropped with pearl millet (sorghum), red gram, Bengal gram, hyacinth beans, green gram, black-eyed peas, and sunflower, yielding an estimated combined gross income of Rs. 48,225 and a net income of approximately Rs. 19,725. Similarly, finger millet is cultivated together with sorghum, black gram, green gram, sunflower, and marigold, while pearl millet is intercropped with sesame, hyacinth beans, green gram, black-eyed peas, and black gram. These diversified cropping systems provide food, fodder, and income from the same field while reducing the risks associated with crop failure.

Farmers explained that crop diversification supports household food requirements for nearly three months and reduces dependence on purchasing food from markets. However, due to climate change, erratic rainfall, and repeated failures of seasonal rains, many small landholders cannot afford investments in groundwater borewells and continue to depend entirely on rain-fed cultivation. Despite

these challenges, many farmers continue to cultivate multiple crops on the same land.

Tree-based farming systems are practised by a section of farmers through mango cultivation. A one-acre mango-based farming system is commonly integrated with seasonal vegetables, green gram, black gram, and horse gram. In addition, naturally growing tamarind, neem, and wild date palm trees contribute supplementary food, fodder, and seasonal income.

Eco-friendly farming and traditional seed saving persist as key climate adaptation strategies in the study area:

- Medium Farmers (5-10 acres): Grow organic food crops for household use using bullock

ploughing, vermicomposting, and local pest control, reducing input costs and soil degradation.

- Small Farmers (0-5 acres): Avoid costly toxic pesticides by relying on multi-cropping to protect yields and maintain soil fertility.
- Seed Conservation: Reusing traditional, climate-resilient seed varieties preserves diversity and cuts dependence on commercial markets.

These informal practices are further sustained by community resource management and MGNREGA-funded water conservation initiatives, such as tank restoration and rainwater harvesting.

Group exercise with community members



FINDINGS: IMPACTS OF CLIMATE CHANGE

Observed changes in climate and weather

Farmers across the study villages reported noticeable increases in temperatures over the last 10-20 years. According to elder farmers, summers were previously limited mainly to March-May, whereas extreme heat is now experienced from February until June, exceeding 42-43°C with warmer conditions extending into the post-monsoon season. Community members observed that heat conditions once considered exceptional have become common, affecting crops, livestock, and human health.

One elder farmer explained: *"Earlier, we could work in the fields throughout the day. Now, by afternoon, the heat becomes unbearable, and many workers suffer from sunstroke."*

Agricultural workers were identified as among the most affected because they continue to work outdoors with limited access to drinking water, shade, first-aid facilities, toilets, and breastfeeding spaces. Women workers experience additional hardships due to the absence of these basic facilities.

Historically, the study area received around 700-750 mm of rainfall that was relatively well distributed throughout the monsoon season. Farmers explained that the Southwest Monsoon previously arrived from early to mid-June till September, and the Northeast Monsoon (October-December) followed, allowing timely land preparation and sowing. Today, the monsoon often arrives late, and rainfall is concentrated in a few heavy events of 600-800 mm, separated by long dry periods.

As one farmer described: *"The annual rainfall now is all in one week instead of over several months."*

Community members emphasised that the problem is not only a reduction in total rainfall but also its uneven distribution. Heavy rainfall within a short period causes runoff, flooding, and topsoil erosion, while prolonged dry months reduce groundwater recharge and create moisture stress during crop growth.

Historical timeline discussions showed that droughts have become more frequent and prolonged over the past 2 decades. Elder farmers recalled that during the 1990s and early 2000s, consecutive crop failures due to drought were relatively uncommon, whereas they now experience repeated years of delayed monsoon onset,

prolonged dry spells, and declining groundwater availability.

One elder farmer reflected: *"Earlier, rain-fed crops, especially rice, grew over 5 feet and followed predictable seasons. Now, rains come late or all at once, crops remain short in height and fragile, and sudden rainfall washes them away, forcing many of us to stop cultivating them."*

Farmers also observed that winters have become noticeably shorter. Earlier, cooler conditions generally lasted from October to mid-January, whereas they are now shorter, less distinct, and interrupted by prolonged periods of heat.

Historical timeline discussions consistently showed that farming communities perceive climate change through a combination of rising temperatures, delayed monsoons, prolonged droughts, shorter winters and more intense rainfall events. Together, these changes have reduced the reliability of traditional farming calendars and increased the vulnerability of rainfed agriculture across both Nimmanapalle and Sodam mandals.

Impacts on agricultural production

Climate change has had direct effects on agricultural production across the study villages. Farmers consistently reported that variations in climate, the use of toxic pesticides and fertilisers, and limited land encroachments have reduced crop productivity, increased production costs, and intensified production risks. The impacts were found to differ between agroecological diversified farming systems and conventional chemical-based monocropping systems, particularly in terms of production costs, resilience, and household food security.

Groundnut, the principal cash crop, was repeatedly identified as the crop most affected by irregular rainfall and increasing temperatures. Although conventional monocropping farms currently produce around 1,400 kg per acre, farmers explained that this is achieved only through higher investments in irrigation, chemical fertilisers, pesticides, and improved seed varieties, resulting in a cultivation cost of approximately Rs. 48,000 per acre. In contrast, agroecological farms produce about 650 kg of groundnut per acre, along with 365 kg of intercrops, including sorghum, pulses, sunflower, and legumes, for a combined yield of about 1,015 kg per acre and a substantially lower cultivation cost of Rs. 28,500 per acre. While monocropping generates higher gross returns, diversified farming provides

food crops, fodder, and multiple income sources, reducing production risks and improving soil and household food security.

Community members also observed long-term changes in the productivity of several crops. Under conventional monocropping systems, pearl millet (sorghum/jowar) declined from around 1,400 kg per acre (1995-2004) to 800 kg per acre (2015-2025). Red gram, Bengal gram, and hyacinth beans declined from 650-750 kg to about 600 kg per acre, while green gram reduced from 800 kg to 750 kg, black-eyed peas from 600 kg to 500 kg, and black gram from 550-600 kg to 550 kg per acre. Finger millet declined slightly from 1,100-1,200 kg to around 1,100 kg per acre, while rice reduced from 3,600-3,750 kg to 3,500 kg per acre. Sugarcane yields declined from 58-60 tonnes to 55 tonnes per acre, and mango production reduced from about 7 tonnes to 5 tonnes per acre. Farmers associated these changes primarily with increasing temperatures, irregular rainfall, declining soil moisture, and reduced groundwater availability.

Participants further explained that while crop yields have fluctuated by only 5-10% in recent years, the actual cost of cultivation has increased by approximately 10-15% annually, mainly due to rising prices of seeds, fertilisers, pesticides, irrigation, fuel, machinery, and labour. In comparison, the real increase in farm income has remained only 2-3%, substantially reducing farm profitability.

Farmers explained that changing rainfall patterns have shortened cultivation periods and made agricultural production increasingly unreliable. Delayed monsoon onset, followed by intense rainfall over a short period, often results in poor germination, moisture stress during crop growth, and crop losses before harvest. In several years, complete crop failures were reported, particularly for rainfed groundnut and pulse crops.

Food crops such as finger millet, sorghum, pearl millet, and horse gram have also become increasingly vulnerable. Community members reported that traditional food production, once relatively stable under rainfed conditions, has become far less predictable.

Market failures further compound production risks. Farmers described situations where tomato cultivation became economically unviable, with transportation and production costs exceeding market prices. One participant explained that 10 kg of tomatoes cost approximately Rs. 35 to produce, while market prices fell to around Rs. 25, forcing farmers to dispose of their

harvest. Some also reported increased post-harvest decay associated with repeated chemical applications.

By comparison, farmers practising agroecological diversified farming explained that cultivating several crops within the same field reduces the risk of complete crop failure. Even if one crop performs poorly, other crops continue to provide food, fodder, or marketable produce, strengthening household resilience.

Farmers consistently reported increasing pest infestations over the past two decades. They associated these outbreaks with rising temperatures, irregular rainfall, and greater dependence on conventional chemical farming systems.

The most commonly reported pests included the red hairy caterpillar, tobacco caterpillar (*Spodoptera litura*), leaf miner, aphids, thrips, whiteflies, stem borers, pod borers (*Helicoverpa armigera*), and sucking pests, which particularly affect groundnut, pigeon pea, chickpea, vegetables, finger millet, and mango. Farmers also reported an increasing incidence of leaf spot, rust, collar rot, wilt, and viral diseases across several crops.

Participants explained that conventional farming often requires repeated pesticide applications to control these outbreaks, increasing production costs while exposing both farmers and agricultural workers to toxic chemicals. Community members noted that pest outbreaks frequently recur despite repeated spraying, creating a cycle of increasing chemical dependence.

In contrast, agroecological farmers reported greater reliance on traditional pest control preparations, crop diversification, biological control, local seed varieties, and vermicomposting. These practices reduced dependence on purchased pesticides and enabled farmers to manage pest attacks with lower financial risk.

Communities observed increasing signs of soil degradation across the study villages. Farmers reported declining soil fertility, reduced soil moisture retention, hardening of agricultural land, and increasing dependence on irrigation to maintain crop production.

Participants explained that heat waves followed by short-duration, high-intensity rainfall frequently wash away fertile topsoil, accelerating soil erosion and reducing soil nutrients. Community members also attributed the decline in soil quality to prolonged use of chemical fertilisers, intensive mechanised ploughing, groundwater over-extraction, and reduced application of organic manure.

Several participants noted that plastic mulch is increasingly used to conserve soil moisture because soils dry rapidly after rainfall.

One marginal farmer, who also works as an agricultural labourer, explained: *"Earlier, the land would hold moisture for longer. Now, even after rain, the soil dries quickly, and crops struggle. So we use plastic sheets to retain the moisture. It is a one-time use, and we burn it after each use."*

Although plastic mulch temporarily conserves moisture, farmers acknowledged that disposing of it after each use increases the cost of the plastic sheets. Community members further explained that replacing animal-drawn cultivation with heavy machinery has reduced the natural incorporation of organic matter into soils, contributing to declining soil health.

Participants also expressed concern about the wider social and health impacts of conventional agriculture. High capital investments in hybrid seeds, chemical fertilisers, pesticides, irrigation motors, and machinery have increased farmers' indebtedness. According to the National Alliance of Agriculture Allied Workers Union (NAAWU) community study, approximately 25% of agricultural workers' household income is spent on health care, largely because of prolonged exposure to agrochemicals. Women were identified as the most affected, as they spend longer hours working in agricultural fields and are more frequently exposed to pesticides during cultivation, weeding, harvesting, and post-harvest activities.

Impacts on household well-being

Climate impacts have directly reduced household income by lowering agricultural production and limiting employment opportunities. The impacts were most severe among the 1,201 landless agricultural labourer households, 346 sharecropper and tenant farmer households, and 454 small, marginal and medium farmer households included in the study. Agricultural labourers reported receiving only around 60 days of agricultural employment annually, while repeated crop failures reduced earnings for farming households. Consequently, many families increasingly depend on MGNREGA (despite its poor implementation), livestock rearing, seasonal migration, and other informal work to supplement their incomes, which are unsustainable.

Repeated crop failures have also increased household indebtedness. Small, marginal, and tenant farmers

generally invest their own savings or borrow money before each agricultural season to purchase seeds, fertilisers, pesticides, and other farm expenditures. When crops fail, these investments cannot always be recovered. Community members reported borrowing from private moneylenders at interest rates ranging from 25% to 60% per year, creating long-term debt and forcing many households to reduce cultivation or abandon farming altogether.

According to the study, a few small, marginal, and medium farmers have stopped cultivating their land over the past two decades due to repeated crop failures under rainfed conditions.

Food security has deteriorated considerably across the study villages. Earlier, farming households produced enough food on their own farms to meet approximately 9 months of pulse requirements and 6 months of minor millet consumption. Today, this has declined to around 4 months of pulses and 3 months of minor millets, largely because many households have stopped cultivating these traditional food crops. As a result, families increasingly depend on the Public Distribution System (PDS) for rice and on purchased food from local markets, which has very low nutritional value. In a few families, children increasingly ask for packaged foods, such as Rs. 5 to 10 instant noodles, contributing to poorer nutritional outcomes.

Health impacts were also reported. Rising temperatures, pesticide exposure, nutritional stress, and difficulties accessing water all affect physical and mental well-being. Few villages had concerns about hospitals being out of reach during an emergency.

School education was another area of concern. Some families described situations where children, especially girls, stopped attending school due to economic pressure, safety concerns, or to support household income through labour.

One woman agricultural worker shared: *"When there is no crop, education becomes difficult. My daughter gave up her education so that her brother could continue studying. It is not safe for her to travel to school, and we also hope to marry her into a family with a better income."*

Differential impacts across social groups

Climate change has affected all households across the study villages, but its impacts are experienced unequally. Communities consistently explained that households with fewer resources, insecure livelihoods, and limited social protection are the most vulnerable. Among the 2,001 households

included in the study, the greatest impacts were experienced by the 1,201 landless agricultural labourer households, followed by 346 sharecropper and tenant farmer households, and 454 small, marginal, and medium farmer households.

These vulnerabilities are further intensified by long-standing social inequalities, particularly among Dalit and Adivasi communities. The study included 958 Dalit households and 220 Adivasi households, representing a combined population of 3,533 people (2,874 Dalits and 659 Adivasis). A large proportion of these households are concentrated within the most vulnerable livelihood groups. Of the 1,201 landless agricultural labourer households, 575 were Dalit, and 132 were Adivasi households.

Women farmers and women agricultural workers were identified as the worst affected. Besides participating in agricultural work, 2,931 women in the research area continue to shoulder unpaid household responsibilities, including collecting water, preparing food, caring for livestock, children, and elderly family members. During droughts and crop failures, these responsibilities increase further, while many men migrate in search of employment to repay debts and support their families.

Women are disproportionately affected by these changes. Participants explained that women often reduce their own food intake so that children and other family members can eat first. According to records from the Primary Health Centre (PHC), approximately 40% of Dalit and Adivasi women across the 20 study villages were reported to be anaemic. Community members linked this to declining access to pulses, millets, vegetables, and other nutritious foods, particularly during pregnancy and periods of prolonged livelihood stress.

Landless agricultural labourers were identified as one of the most vulnerable groups because their livelihoods depend entirely on the availability of farm work. Of the 2,001 households included in the study, 1,201 households (about 60%) were landless agricultural labourers. When poor rainfall reduces cultivation, employment opportunities decline immediately. Community members explained that the increasing number of workers competing for fewer jobs forces wages downward, creating a cycle of poverty and indebtedness.

Participants reported that agricultural employment has declined from approximately 120 working days per year three decades ago to around 60 days annually. The limited implementation of MGNREGA has further reduced livelihood security,

forcing many households to migrate to towns and cities, where they often work in low-paid, informal employment while living in poor conditions. Community members also reported that 68 farmer and agricultural worker suicides occurred across the 20 study villages over the past three decades due to debt-related pressures.

Community members explained that compensation provided after natural disasters generally goes to landowners rather than to tenant farmers or sharecroppers. As a result, tenant farmers often bear the risks of production without receiving government support, which increases indebtedness and discourages continued cultivation.

Young people have become increasingly vulnerable as agriculture becomes less reliable. Participants explained that declining agricultural incomes, climate-related crop failures, land grabbing, and increasing corporate control over agriculture have reduced livelihood opportunities in rural areas. As a result, an estimated 70% of rural youth in distress migrate to urban centres in search of employment, where many work in unorganised sectors for wages below the statutory minimum. This migration weakens community support systems and reduces young people's involvement in farming and local institutions.

Community members explained that historical exclusion from land ownership, limited access to irrigation, dependence on wage labour, and continued encroachment on common property resources have increased their vulnerability to climate change. They also highlighted an important equity concern. Many Dalit and Adivasi households own land on hillocks, rocky terrain, or in locations distant from restored tanks and water-harvesting structures.

Consequently, despite participating in MGNREGA works, they often receive fewer direct benefits from improved soil moisture and groundwater recharge than farmers whose land is closer to these interventions. This unequal access limits their ability to fully benefit from water conservation measures and reinforces existing social and livelihood inequalities.

Overall, the study shows that climate change does not affect everyone equally. Existing inequalities related to intensified differences in land ownership, access to resources, labour conditions, gender roles, and social inequality all determine who bears the greatest burden, making women, landless labourers, tenant farmers, smallholders, youth, and particularly Dalit and Adivasi communities the most vulnerable to climate change impacts.

FGD with participants
of the study



FINDINGS: AGROECOLOGY AND CLIMATE RESILIENCE

Farmers' responses to climate stress

Farmers across both mandals have developed different strategies to respond to increasing climate uncertainty, particularly changing rainfall patterns, rising temperatures, and declining groundwater levels. In the dryland (rainfed) farming systems of Nimmanapalle Mandal (Annamayya district) and Sodam Mandal (Chittoor district), farmers are increasingly cultivating crops better adapted to low rainfall and drought conditions.

Crop diversification has become one of the most important adaptation strategies. Of the 2,001 households included in the study, 654 practised diversified farming, compared with 146 practising conventional monocropping. Among the multi-cropping households were 306 Dalit households, 88 Adivasi households, and 260 households from other caste groups, while 77 Dalit households and 69 households from other caste groups practised mono-cropping. Instead of relying solely on groundnut, agroecological farmers cultivate a combination of finger millet, sorghum, pearl millet, red gram, green gram, black gram, horse gram, chickpea, sunflower, seasonal vegetables, and fodder crops. Mixed cropping reduces the risk of complete crop failure, improves household food security, and provides multiple sources of income under uncertain climatic conditions. Periodically, the 1,202 landless labourers practice agro-ecology depending on whose land they work on.

Some farmers with access to land have returned to cultivating traditional and local seed varieties because they are better adapted to dry conditions, irregular rainfall, and local soils than hybrid varieties, which generally require higher water availability and greater pesticide use.

In addition, groundwater restoration and rainwater conservation activities implemented since 2005 under the MGNREGA have contributed to improving groundwater recharge and retaining soil moisture, helping support crop growth during dry periods.

Agroecological practices observed

Crop diversity. Crop diversity was one of the most widely observed agroecological practices across the study villages. Rather than relying on a single crop, farmers cultivated a range of cereals, pulses, oilseeds, vegetables, fruit trees, and fodder crops according to rainfall, soil conditions, and household food needs.

Many households also reported that growing a variety of pulses reduced the need to purchase protein-rich food from markets.

Mixed cropping. Mixed cropping is commonly practised to minimise climate-related production risks. Instead of cultivating only groundnut, farmers combined it with several food and cash crops in the same field.

- A typical groundnut-based diversified system included pearl millet (jowar), red gram, Bengal gram, hyacinth beans, green gram, black-eyed peas (alasanda/cowpea), and sunflower.
- Similarly, finger millet was cultivated together with pearl millet, black gram, green gram, sunflower, and marigold.
- While pearl millet was mixed with sesame, hyacinth beans, green gram, black-eyed peas, and black gram.

Intercropping. Intercropping was another important agroecological practice observed across the study villages.

- Pulses such as red gram, green gram, black gram, and cowpea were commonly intercropped with groundnut because they improve soil fertility through biological nitrogen fixation while providing additional food and marketable produce.
- Sesame is intercropped with pearl millet in rainfed fields because of its low water requirement.
- While gongura (sour spinach) is grown between sugarcane rows to increase income and make better use of available land.
- Mango orchards also followed an intercropping system, particularly during the early years (4 to 5 years) before full canopy development. Farmers cultivated fruits like jamun, guava, sapota, and lemon, along with seasonal vegetables, and planted moringa, green gram, black gram, and horse gram between mango trees to generate annual income while the orchards matured. Horse gram was especially valued because it could be sown during August and September when the southwest monsoon failed, surviving prolonged dry conditions better than many other crops.

Community members explained that intercropping improved land-use efficiency, reduced pest incidence, diversified production, enhanced soil fertility, and provided multiple harvests from the same field, making it an important strategy for adapting to increasing climate variability.

One woman farmer said, *"Earlier we depended only on groundnut, but now we grow different crops because when one fails, another survives."*

Soil health practices. Several farmers reported moving away from chemical-intensive farming and adopting composting practices to improve soil health and reduce dependence on synthetic fertilisers. The most common practices included returning crop residues to the soil instead of burning them and applying farmyard manure from cows, goats, and poultry. Farmers explained that these organic inputs improve soil structure, increase earthworm populations, enhance microbial activity, and enable the soil to retain moisture for longer periods after rainfall.

Farmers also prepared and applied natural microbial formulations such as Jeeva Amrutham, Ghana Jeeva Amrutham, and Vana Jeeva Amrutham as part of natural farming and Non-Pesticide Management (NPM) practices. Rather than acting as fertilisers,

these preparations function as soil microbial stimulants by increasing beneficial microorganisms, improving nutrient cycling, enhancing soil structure and moisture-holding capacity, and reducing dependence on chemical fertilisers.

The farmers described Jeeva Amrutham as “feeding the soil so the soil feeds the plants”. Similarly, Ghana Jeeva Amrutham is the solid form of Jeeva Amrutham stored for 6 months and used when needed. Vana Jeeva Amrutham is a natural farming input prepared using forest materials and naturally occurring microorganisms, rather than relying mainly on cow-based ingredients, as in Jeeva Amrutham. The word “Vana” means forest, and “Jeeva Amrutham” means life-giving microbial solution.

See **Box 1** for the ingredients, preparation process, and application of Jeeva Amrutham and Vana Jeeva Amrutham.

Box 1. Ingredients, preparation process, and application of Jeeva Amrutham and Vana Jeeva Amrutham

Jeeva Amrutham

Ingredients:

10 kg fresh cow dung (preferably from indigenous/local cows)
10 litres of cow urine
2 kg jaggery (acts as food for microorganisms)

2 kg pulse flour (commonly gram flour/besan)
A handful of local soil (taken from farm bunds or under trees to introduce local microorganisms)
200 litres of water

Preparation process:

Take a large container or cement tank
Add 200 litres of water
Mix in the cow dung thoroughly until it dissolves
Add cow urine and stir well
Add jaggery and dissolve it completely
Add pulse flour and mix evenly

Add a handful of local soil
Stir the mixture well in one direction for a few minutes
Cover loosely with cloth or a lid (do not seal tightly)
Leave it to ferment for 5- 8 days in the shade. Stir once or twice daily

How to apply:

Poured around plants directly (usually 100 litres of it can be used for 1 acre of land), or
Diluted and used at intervals during crop growth around the roots

Vana Jeeva Amrutham

Ingredients:

Green leaves from different tree species
2 to 5 litres of cow urine
2 kg jaggery
Cow dung (sometimes used)

100 litres of water
2 kg Pulse flour or flour mixture
Few cases of leaf litter, compost, or fermented plant extracts

Preparation

Collect soil with rich organic matter
Add chopped green leaves
Mix with water in a large container
Add jaggery and pulse flour

Stir well and leave for fermentation for a few days
Stir daily and keep in the shade

How to apply:

Pour around the roots

Green manure. Green manuring remains an important agroecological practice for naturally improving soil fertility. Farmers cultivate Sunn Hemp (*Janumu*), Dhaincha (*Jeeluga*), and Pillipesara (*Vigna trilobata*) specifically to return their biomass to the soil as organic manure. These fast-growing legumes enrich the soil by fixing atmospheric nitrogen, increasing organic carbon, suppressing weeds, and improving soil fertility without relying on chemical fertilisers.

For fruit orchards, green manure crops are generally sown after the first monsoon rains in June and incorporated into the soil 45–55 days later, usually during August or September, before they become woody. In annual cropping systems such as groundnut, green manure seeds are sown after harvest (September–October) and ploughed back into the soil during late December or early January before the next cropping season.

Among the commonly used species:

- Sunn Hemp (*Janumu*) grows well in well-drained sandy loam soils, produces high biomass, and contributes approximately 50–60 kg of nitrogen per hectare. It is incorporated into the soil at the flowering stage, about 45–50 days after sowing
- Dhaincha (*Jeeluga*) performs well in heavy clay, waterlogged, and alkaline soils, fixes up to 75–80 kg of nitrogen per hectare, and is incorporated 50–55 days after sowing, before the stems become woody
- Pillipesara (*Vigna trilobata*) is suitable for rice fallows and black cotton soils with residual moisture. Besides serving as green manure, it is also valued as nutritious cattle fodder, although farmers noted that it establishes more slowly than Sunn Hemp

Mulching. Mulching was commonly practised using crop residues left after harvest. Instead of burning these residues, farmers spread them across the soil surface to conserve moisture, reduce evaporation, suppress weed growth, moderate soil temperature, and protect the topsoil from erosion caused by intense rainfall. Farmers explained that mulching helps maintain soil moisture for longer periods during dry seasons, particularly under rainfed conditions, while gradually adding organic matter to the soil as the residues decompose. These benefits were considered especially important under increasingly erratic rainfall and prolonged dry periods associated with climate change.

Water Management. Water conservation was identified as one of the most important climate adaptation practices across the study villages, particularly because agriculture is predominantly rainfed.

The major water conservation practices observed included:

- Soil moisture conservation through mulching
- Construction and strengthening of contour bunds and field bunds to slow surface runoff
- Percolation pits for groundwater recharge
- Restoration and clearing of natural drainage contours
- Field bunding and trenches to improve water infiltration
- Desilting of irrigation tanks and village ponds
- Application of the nutrient-rich tank silt removed during desilting to agricultural fields to improve soil fertility and moisture retention

Most of these interventions were undertaken through the MGNREGA, enabling community participation in restoring local water resources while generating rural employment. Community members explained that these measures have increased rainwater retention, improved groundwater recharge, reduced soil erosion and runoff, enhanced irrigation availability, and strengthened the resilience of rainfed farming systems during prolonged dry periods.

Pest management. Agroecological natural pest management practices were adopted by approximately 130 households, primarily among farmers practising mixed and multi-cropping systems. These households were part of the 654 agroecological farming households in the study (306 Dalit, 88 Adivasi, and 260 small and marginal farmers from other caste groups). Adoption was highest among the 454 farmers who cultivated their own land, suggesting that secure land access encouraged the adoption of agroecological pest management practices.

These approaches focused on strengthening ecological balance by conserving beneficial insects, maintaining crop diversity, and enhancing natural predator populations to suppress pests rather than relying on external chemical inputs.

The majority of agroecological farmers relied on locally prepared biological inputs, including neem-based pest preparations, Jeeva Amrutham, Gana Jeeva Amrutham, and Vana Jeeva Amrutham.

Farmers prepared different formulations of Jeeva Amrutham according to the crop growth stage. For plants approximately one month old, 5 litres of Jeeva Amrutham were mixed with 200 litres of water. For plants around three months old, 10 litres of Jeeva Amrutham were mixed with 100 litres of water. The same formulation was also sprayed during the flowering stage of mango trees to reduce pest incidence. Before application, the mixture was filtered to prevent clogging and ensure uniform spraying.

Local seeds. Traditional seed saving was identified as an important agroecological practice that strengthened farmers' resilience to climate variability and reduced dependence on external agricultural inputs. Very few farmers routinely save seeds from previous harvests, maintain locally adapted crop varieties, and exchange seeds with relatives, neighbours, and other community

members. This practice was common with crops such as groundnut, sorghum, red gram, Bengal gram, hyacinth bean, green gram, black gram, black-eyed peas, finger millet, rice, and locally propagated mango varieties.

Small and marginal farmers emphasised that purchasing commercial seeds every season has become increasingly expensive. Depending on the crop, the cost of purchasing market seeds ranges from approximately ₹500 to ₹10,000 per acre, whereas using saved or exchanged seeds generally involves only minimal costs associated with cleaning, drying, storage, and seed treatment (approximately ₹50 to ₹1,000 per acre) for the crops that are listed. As a result, farmers estimated that seed saving can reduce cultivation costs by ₹400 to ₹9,000 per acre, depending on the crop, as shown in **Table 6**.

Table 6. Approximate seed cost savings using local community seeds

Crop	Approximate cost of purchased seed (Rs./acre)	Cost when using saved/ exchanged seed (Rs./acre)	Approximate saving (Rs./acre)
Groundnut	8,000-10,000	500-1,000	7,000-9,000
Sorghum (Jowar)	800-1,200	100-300	700-1,000
Red Gram	2,000-3,000	200-500	1,800-2,500
Bengal Gram	2,000-2,800	200-500	1,800-2,300
Hyacinth Bean	1,500-2,000	200-400	1,300-1,600
Green Gram	2,000-2,500	200-500	1,800-2,000
Black-eyed Pea	1,500-2,000	200-400	1,300-1,600
Black Gram	2,000-2,500	200-500	1,800-2,000
Finger Millet (Ragi)	500-800	50-100	400-700
Rice	1,500-2,500	200-500	1,300-2,000
Mango	Nursery saplings: ₹80-200 per plant	Farmers use grafts/scions from existing trees	Significant long-term savings

Traditional seed saving was identified as an important agroecological practice that strengthened farmers' resilience to climate variability and reduced dependence on external agricultural inputs. Very few farmers routinely save seeds from previous harvests, maintain locally adapted crop varieties, and exchange seeds with relatives, neighbours, and other community members. This practice was common with crops such as groundnut, sorghum, red gram, Bengal gram, hyacinth bean, green gram, black gram, black-eyed peas, finger millet, rice, and locally propagated mango varieties.

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Beyond the financial benefits, farmers expressed limited confidence in commercially available hybrid seeds. They reported that these varieties often require higher applications of chemical fertilisers and pesticides, perform poorly under prolonged drought and erratic rainfall, and cannot be reliably saved for replanting in subsequent seasons. In contrast, locally conserved seed varieties have been selected over generations under the dryland conditions of southern Andhra Pradesh and are perceived to be more drought-tolerant, better adapted to local soils, and more reliable under changing climatic conditions.

Community seed exchange further strengthened local seed sovereignty by enabling farmers to access locally adapted seed varieties without having to purchase them on the market. This informal system not only reduced production costs but also conserved agricultural biodiversity, maintained traditional crop varieties, and enhanced the adaptive capacity of farming households facing increasing climatic uncertainty.

Agroforestry. Trees continue to play an important role in the agroecological farming systems of the study villages, providing multiple ecological, nutritional, and economic benefits while strengthening resilience to climate variability.

Farmers integrate a diversity of tree species within and around their farms, including:

- Mango (*Mangifera indica*) for seasonal fruit production and household income;
- Tamarind (*Tamarindus indica*), commonly found in common lands or naturally established over many years, provides fruit for household consumption and sale;
- Neem (*Azadirachta indica*) for shade, natural pest management, medicinal uses, and organic pest preparations;
- Drumstick/Moringa (*Moringa oleifera*) for year-round household consumption and supplementary income;
- Avisa (*Sesbania grandiflora*) is used as fodder for livestock and as an edible leafy vegetable;
- Bamboo (*Bambusa spp.*) for minimal household construction, fencing, agricultural supports, and other livelihood needs;
- Teak (*Tectona grandis*) and other timber species planted along farm boundaries to reduce wind erosion, minimise soil loss during heavy rainfall, and serve as long-term household assets; and
- Jamun (*Syzygium cumini*) for seasonal fruit, shade, biodiversity conservation, and soil and moisture conservation.

Farmers explained that integrating trees into their farming systems diversifies livelihood sources and reduces vulnerability to crop failures caused by droughts and erratic rainfall. Tree-based products provide food, fodder, fuelwood, timber, and additional household income during periods when annual crops perform poorly. Seasonal harvesting patterns further distribute income throughout the year. Tamarind is generally harvested from the beginning of the year until around April, after which the mango harvesting season provides an additional source of income. Neem and drumstick are available for household use throughout much of the year, with harvesting often determined by household needs and market demand.

Beyond their economic value, trees contribute important ecosystem services by improving soil fertility through leaf litter, conserving soil moisture, reducing wind and water erosion, providing shade for crops and livestock, supporting pollinators and beneficial insects, and enhancing on-farm biodiversity. Farmers regarded agroforestry as an important strategy for strengthening climate

resilience, particularly under increasingly unpredictable weather conditions.

As one farmer explained: *"Even if the groundnut fails, the mango tree and tamarind trees still survive."* This observation highlights how agroforestry functions as a livelihood safety net, enabling households to maintain food availability and generate income even when annual crops are adversely affected by climate-related shocks.

Livestock integration. Livestock husbandry remains an integral component of the agroecological farming systems in the study villages, contributing to nutrient cycling, household food security, livelihood diversification, and resilience to climate-related shocks. The most commonly reared livestock include cattle (cows), goats, sheep, and backyard poultry (hens).

Livestock contributes to farming systems in several ways. Cattle provide farmyard manure, which is widely used to improve soil fertility and organic matter content. Cow dung and cow urine are also primary ingredients in traditional natural farming preparations such as Jeeva Amrutham, Gana Jeeva Amrutham, and Vana Jeeva Amrutham, reducing farmers' dependence on synthetic fertilisers and pesticides.

Livestock also enhances household nutrition. Milk, eggs, and meat are primarily consumed within the household, while poultry meat is generally reserved for festivals, family gatherings, and other special occasions. Surplus milk is sold regularly through local milk collection centres, providing households with a steady source of income throughout the year. Farmers explained that payments from dairy cooperatives or milk collection centres are typically made on a 15-day payment cycle, helping families meet routine household expenses and reducing dependence on seasonal crop income.

Beyond their productive role, livestock functions as an important household financial asset. Many farmers described cows, goats, and sheep as a form of living savings, which can be sold during periods of financial distress, crop failure, health emergencies, educational expenses, or social obligations. This provides an important safety net, particularly for small and marginal farming households facing increasing climatic and economic uncertainties.

However, farmers also reported that changing environmental conditions are affecting livestock production. The encroachment of common lands has

reduced the availability of grazing areas, making it increasingly difficult to rear sheep and goats. In addition, declining water availability has negatively affected duck rearing in several villages, reducing populations and limiting an important supplementary livelihood for some households.

Evidence of resilience outcomes

The agroecological practices observed across both mandals demonstrated several outcomes that strengthened farmers' and agricultural workers' ability to continue cultivating amid increasing climate variability and growing pressures from land grabbing. Although these practices cannot eliminate climate risks, they have helped farming households reduce production losses, diversify income sources, improve soil and water resources, and recover more quickly after climate shocks.

Yield stability. Farmers across both mandals explained that maintaining agricultural production has become increasingly difficult due to irregular and unpredictable rainfall, rising temperatures, prolonged dry spells, and declining groundwater levels. In response, many farmers adopted diversified farming systems that reduced dependence on a single crop and improved their capacity to cope with climatic uncertainty.

Tables 7 and 8 provide a comparison between diversified and monocropping systems.

Diversified dryland farming systems were built around drought-tolerant crops such as groundnut, finger millet (ragi), pearl millet (bajra), sorghum (jowar), horse gram, red gram, sesame, sunflower, green gram, black gram, and Bengal gram, depending on soil moisture and rainfall conditions. Instead of relying solely on a single commercial crop, farmers combined cereals, pulses, oilseeds, vegetables, and fodder crops to spread production risks throughout the season.

The economic comparison between diversified and monocropping systems illustrates this resilience. Under monocropping, groundnut produced about 1,400 kg per acre, generating an estimated gross income of ₹70,000 and net income of ₹22,000, but required a much higher cultivation cost of ₹48,000 per acre. In contrast, the diversified groundnut system produced only 650 kg of groundnut, but the additional harvest of 365 kg from pearl millet, red gram, Bengal gram, hyacinth beans, green gram, black-eyed peas, and sunflower increased the total production to 1,015 kg, with a gross income of

₹48,225 and a net income of ₹19,725, while reducing cultivation costs substantially to ₹28,500 per acre. Farmers explained that although diversified systems

generated slightly lower monetary returns in favourable years, they were less risky because crop failure rarely affected all crops simultaneously.

Table 7. Climate change adaptation: Agroecological / Diversified farms' yield

	2025				Yield in kg / acre		
Groundnut (Main Crop)	Cost per acre (Rs.)	Crop yield (Kg)	Rs. per Kg	Estimated Gross Income (Rs)	1995-2004	2005-2014	2015-2025
Groundnut		650	50	32,500	900-1,000	850-950	850-950
Pearl Millet (Sorghum, Jowar)		75	35	2,625			
Red Gram (Pigeon Pea/Kandulu)		50	55	2,750			
Bengal Gram (Chickpea)		40	50	2,000			
Hyacinth Beans (Anapa)	1,500-2,000	40	35	1,400			
Green Gram	2,000-2,500	40	45	1,800			
Black Eyed Peas (Alasanda/Cowpea)	1,500-2,000	50	40	2,000			
Sunflower	2,000-2,500	70	45	3,150			
Total Yield in (Kgs)	1,015						
Total Gross Income (Rs.)	48,225						
Total Expenditure (Rs.)	28,500						
Total Net Income (Rs.)	19,725						

	2025				Yield in kg / acre		
Sugarcane (Main Crop)	Cost per acre (Rs.)	Crop yield	Rs.	Estimated Gross Income (Rs)	1995-2004	2005-2014	2015-2025
Sugarcane (Tonne)	1,05,000	45	3200	1,44,000	65	50	45
Sour Spinach (Gongura)-Fibre in Kgs		300	15	4,500	350	350	300
Total Gross Income	1,48,500						
Total Expenditure	1,05,000						
Total Net Income	43500						

	2025				Yield in kg / acre		
Finger Millet (Main Crop)	Cost per acre (Rs.)	Crop yield (Kg)	Rs. per Kg	Estimated Gross Income (Rs)	1995-2004	2005-2014	2015-2025
Finger Millet (Ragi)	26,000	600	35	21,000	1,400-1,500	1,300-1,400	1,200-1,300
Pearl Millet (Sorghum, Jowar)		75	35	2,625			
Black Gram		30	45	1,350			
Green Gram		30	45	1,350			
Sunflower		50	45	2,250			
Marygold		500	25	12,500			
Total Yield in Kgs	1,285						
Total Gross Income	41,075						
Total Expenditure	26,000						
Total Net Income	15,075						

	2025				Yield in kg / acre		
Pearl Millet (Main Crop)	Cost per acre (Rs.)	Crop yield (Kg)	Rs. per Kg	Estimated Gross Income (Rs)	1995-2004	2005-2014	2015-2025
Pearl Millet (Bajra / Sajjalu)	25,000	650	28	18,200	1,000-1,200	1,000	950-1,000
Sesame (Nuvvulu)		150	120	18,000			
Hyacinth Beans (Anapa)		40	35	1,400			
Green Gram		40	45	1,800			
Black Eyed Peas (Alasanda/Cowpea)		50	40	2,000			
Black Gram		40	45	1,800			
Total Yield in Kgs	970						
Total Gross Income	43,200						
Total Expenditure	25,000						
Total Net Income	18,200						

	2025				Yield in kg / acre		
Mango (Main Crop)	Cost per acre (Rs.)	Crop yield (Kg)	Rs. per Kg	Estimated Gross Income (Rs)	1995-2004	2005-2014	2015-2025
Mango (Tonne)	48,000	5	15,000	75,000	6-7	5-6	5-6
Seasonal Vegetables - Depends (Kg)		300	25	7,500			
Green Gram (Kg)		40	45	1,800			
Black Gram (Kg)		40	45	1,800			
Horse Gram (Kg)		40	48	1,920			
Total Yield (except for mango)	420				500	400-450	400-450
Total Gross Income	88,020						
Total Expenditure	48,000						
Total Net Income	40,020						

Table 8. Conventional / chemical / monocropping farms' yield

	2025				Yield in kg / acre			
Crop/ acre	Cost of Cultivation (Rs/ acre)	Average Yield	Rs.	Estimated Gross Income (Rs/ acre)	Estimated Net Income (Rs/ acre)	1995-2004	2005-2014	2015-2025
Groundnut (Kg)	48,000	1400	50	70,000	22,000	1,000-1,400	1,000-1,400	1,000-1,400
Pearl Millet (Sorghum, Jowar)	17,000	800	35	28,000	11,000	1,400	1000-1,400	800
Red Gram (Pigeon Pea/Kandulu)	20,000	600	55	33,000	13,000	650-750	600-700	600
Bengal Gram (Chickpea)	17,000	600	50	30,000	13,000	650-750	600-700	600
Hyacinth Beans (Anapa)	16,000	600	35	21,000	5,000	650-750	600-700	600
Green Gram	18,000	750	45	33,750	15,750	800	750-800	750
Black Eyed Peas (Alasanda/Cowpea)	16,000	500	40	20,000	4,000	600	550	500
Sunflower	25,000	1000	45	45,000	20,000	1,000-1,100	1,000-1,500	1,000
Black Gram	17,000	550	45	24,750	7,750	550-600	550-600	550
Finger Millet (Ragi)	27,000	1100	35	38,500	11,500	1,100-1,200	1,100-1,200	1100
Rice	30,000	3,500	16	56,000	26,000	3,600-3,750	3,500-3,600	3,500
Sugarcane (Tonne)	130000	55	3,200	1,76,000	46,000	58-60	55	55
Mango (Tonne)	45,000	5	15,000	75,000	30,000	7	5	5

A similar trend was observed in other diversified systems. The finger millet-based system generated a total yield of 1,285 kg and a net income of ₹15,075 per acre by including sunflower, black gram, green gram, pearl millet, and marigold. Likewise, the pearl millet-based system combined sesame and pulses to achieve a net income of ₹18,200 per acre, while the mango-based agroforestry system, supported by intercrops such as vegetables, horse gram, green gram, and black gram, generated approximately ₹40,020 per acre in net income. Farmers explained that these diversified systems ensured at least some harvest even when one crop failed. They also relied on minimal or no toxic pesticides, allowing the soil to maintain healthy microbial activity, improve long-term fertility, and support future crop production. In contrast, farmers observed that continuous chemical-intensive cultivation gradually degrades soil quality, reducing its productivity and, over time, making the land less suitable for cultivation.

Historical comparisons also suggest that diversified systems have maintained relatively stable production over time. For example, diversified groundnut yields declined only modestly from around 900–1,000 kg per acre during 1995–2004 to approximately 850–950 kg per acre during 2015–2025, while finger millet declined from about 1,400–1,500 kg to 1,200–1,300 kg per acre, and pearl millet from 1,000–1,200 kg to around 950–1,000 kg per acre. Although yields have decreased due to changing climatic conditions, farmers reported greater hope for future crop production.

One important observation from Nimmanapalle Mandal was the revival of the traditional Pancha Vari system, where farmers cultivate sorghum, pearl millet, finger millet, horse gram, and sesame together in the same field. Farmers explained that this traditional mixed cropping practice has provided more stable household income and food security over the past five years than neighbouring farms cultivating only single commercial crops.

Beyond crop diversity, farmers also reported significant improvements from soil restoration practices, including mulching, incorporation of crop residues, application of farmyard manure, green manuring, and the use of Jeeva Amrutham, Ghana Jeeva Amrutham, and Vana Jeeva Amrutham. These practices improved soil structure, increased earthworm populations, enhanced soil moisture retention, and reduced crop stress during prolonged dry periods. Farmers further explained that replacing toxic pesticides with natural pest management preparations reduced production costs and improved both soil and human health.

Water conservation measures also contributed to resilience. Since 2005, groundwater recharge activities implemented through MGNREGA, including desilting irrigation tanks, constructing contour bunds, percolation pits, trenches, and field bunds, have improved rainwater retention and groundwater recharge in several villages. Farmers cultivating land near these restored water bodies reported improved moisture availability, enabling cultivation even during years of below-average rainfall.

Food security. Agroecological practices strengthened household food security by increasing both the diversity and availability of food produced on farms. Of the 2,001 households included in the study, 654 agroecological farming households practised diversified cropping systems, enabling them to produce cereals, pulses, vegetables, fruits, and fodder from the same land rather than relying totally on a single commercial crop. Farmers explained that this diversity ensured that at least some crops could be harvested even when irregular rainfall or pests affected others, thereby improving food availability at least now and then.

Farmers reported that, over the past two decades, declining rainfall and repeated crop failures have reduced household food production. Earlier, many families produced enough pulses for approximately 9 months and enough millets for about 6 months each year. Today, this has declined to around four months of pulses and three months of millets, increasing dependence on purchased food and the Public Distribution System (PDS). Under the PDS, eligible households generally receive 5 kg of rice per person per month, but many participants expressed concern that a rice-only ration does not provide adequate nutritional diversity.

Also, it becomes unusually sticky and clumps together after cooking. In contrast, households practising agro-ecological farming explained that crop diversity reduced their dependence on ration rice and market purchases by enabling them to consume a wider range of home-produced foods.

Traditional seed saving further strengthened food security. Farmers saved seeds from previous harvests and maintained local crop varieties that were better adapted to dry conditions, irregular rainfall, and local soils. This reduced dependence on purchasing expensive commercial seeds every season and enabled cultivation to continue even during financially difficult years.

Tree-based farming systems also contributed to household nutrition and resilience. Mango,

tamarind, drumstick (moringa), neem, and other locally available trees provided fruits, edible leaves, and seasonal income throughout the year. Livestock further strengthened household food systems by supplying milk, eggs, and occasional meat, while surplus milk sold through village collection centres generated regular income, helping households purchase other essential food items.

Overall, farmers emphasised that diversified agroecological farming not only improved food availability but also promoted more diverse and nutritious diets, reduced dependence on markets and low-quality ration food, and increased household resilience during periods of climate stress and economic hardship.

Economic resilience. The findings indicate that agroecological farming strengthened household economic resilience by reducing cultivation costs and dependence on external agricultural inputs. Of the 2,001 households studied, 654 practised agroecological or diversified farming and 146 practised conventional chemical-based monocropping. The remaining 1,347 landless or wage-dependent households experienced economic instability, relying on variable landlord labour or mixed cropping opportunities. Farmers practising agroecology consistently reported lower expenditure on purchased seeds, chemical fertilisers, pesticides, and irrigation, as they relied more on locally saved seeds, farmyard manure, green manures, Jeeva Amrutham, Ghana Jeeva Amrutham, Vana Jeeva Amrutham, mulching, and water conservation practices.

The comparison of cultivation costs clearly demonstrates this difference. A diversified groundnut-based farming system required an investment of approximately ₹28,500 per acre, compared with ₹48,000 per acre under conventional monocropping—a reduction of ₹19,500 (around 41%) in production costs. Similarly, diversified sugarcane cultivation required ₹1,05,000 per acre, compared with ₹1,30,000 per acre under conventional cultivation, reducing costs by ₹25,000 per acre. Pearl millet-based diversified farming reduced cultivation costs from ₹17,000 to ₹25,000 per acre, depending on the associated intercrops, while finger millet-based systems required approximately ₹26,000 per acre, slightly lower than the ₹27,000 required under conventional farming.

Although monocropping often generated higher yields for a single crop, for example, 1,400 kg of groundnut per acre compared with 650 kg in diversified farming, it also required substantially

higher capital investment and greater dependence on borewell irrigation, hybrid seeds, chemical fertilisers, pesticides, and mechanisation. Farmers explained that these investments increased their financial risk because crop failure meant losing both the harvest and the large amount of money borrowed for cultivation. In contrast, diversified farming reduced seasonal expenditure and lowered dependence on loans, enabling households to continue cultivation even during years of irregular rainfall.

Participants also noted that the cost of chemical cultivation has continued to increase over time. While cultivation expenses have risen by an estimated 10–15% annually, increases in farm income have remained much lower, at approximately 2–3% per year, reducing profit margins and increasing indebtedness among conventional farmers. Community members further observed that excessive use of chemicals has contributed to soil degradation, declining groundwater levels, and rising household health expenditures. As mentioned, a NAAWU community study found that nearly 25% of agricultural workers' income is spent on health-related expenses, many of which are linked to prolonged exposure to toxic pesticides.

Agroecological farming also strengthened household resilience by diversifying livelihoods and income sources. Instead of depending entirely on a single commercial crop, households combined crop production with livestock, horticulture, seasonal wage labour, and government support programmes. This reduced the risk of complete loss of income when a crop failed due to drought, heat stress, or pest outbreaks.

Diversified farms combined major crops such as groundnut, finger millet, pearl millet, sugarcane, or mango with intercrops including red gram, green gram, black gram, black-eyed peas, chickpea, sesame, sunflower, hyacinth bean, vegetables, and fodder crops. For example, while a mango-based farming system generated approximately Rs. 88,020 per acre in diversified farming, mono-cropping gives Rs. 75,000 as gross income, including income from mangoes, seasonal vegetables, green gram, black gram, and horse gram.

Livestock formed another important component of household resilience across all livelihood groups. Milk production provided regular cash income throughout the year, while livestock also supplied manure for crop production, reducing expenditure on chemical fertilisers. Many landless agricultural labourers and marginal farmers owned one or two cattle despite having no grazing land of their own, relying instead on common property resources.

Households also diversified their livelihoods through employment under MGNREGA, providing up to 100 days of wage employment during periods of agricultural unemployment.

Overall, the findings suggest that agroecological farming strengthened economic resilience not because it always produced the highest yield from a single crop, but because it reduced production costs, lowered dependence on external inputs and debt, diversified income throughout the year, and spread climate-related risks across multiple crops and livelihood activities. This enabled farming households to recover more quickly from climate shocks than households dependent on a single high-input commercial crop.

Community resilience and collective action. Beyond individual farming practices, resilience was also strengthened through collective action at the village level, with the formation of groups such as agricultural workers, women workers, and a youth committee, facilitated by the Andhra Pradesh Vyavsaaya Vruthidarula Union (APVVU).

Village groups and local village associations played an important role in identifying common challenges and collectively demanding public works to improve water availability, farming conditions, and land ownership rights for landless farmers through the government land distribution programme. There is also a government scheme that supports the installation of community borewells for Dalit and Adivasi farmers who have contiguous land. However, only a small number of farmers benefited from this opportunity. Many others could not access the scheme mainly due to administrative delays, slow approval processes, and limited response from government departments.

Farmers explained that water conservation efforts became possible largely through MGNREGA labour-intensive works such as desilting water tanks, digging percolation pits, bunding, trenching, clearing natural contours, constructing groundwater recharge structures, and desilting rainwater-feeding channels.

These works created local employment while restoring agricultural landscapes. Village associations continued to organise collectively to demand:

- Expansion of water conservation works
- Better access to employment opportunities with fair and equal wages for men and women

- Protection of common lands and water bodies
- Restoration of tanks and local water systems
- Providing working tools and PPEs
- Extension of 100 days of employment to 200 days in a year

Farmers described collective action as an important part of climate resilience because it supports their livelihoods through agricultural production and provides social support during periods of uncertainty. One farmer explained: *“If we work together on land and water, everyone benefits. The government or the landlords can only respond positively to our demands when we approach collectively.”*

COMPARATIVE INSIGHTS

Figure 1 summarises the differences observed between farmers practising agro-ecological approaches and those depending more heavily on input-intensive or conventional farming systems. It also compares diversified farming systems with monocropping practices. The comparison is based on farmers' observations and experiences over the past 5 years, including changes noticed across seasons and recent years, which reflected similar patterns over time.

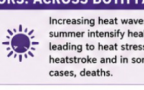
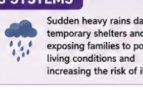
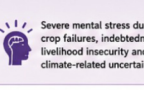
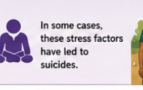
COMMUNITY SOLUTIONS AND COLLECTIVE ACTION

This section presents the solutions identified by community members through the Solution Tree exercise conducted during participatory workshops with two groups in each mandal. Farmers and agricultural workers emphasised that climate resilience cannot be achieved through individual farm-level changes alone, but requires collective action, local knowledge, and stronger public support systems. (See **Annex 3**)

Vision (Tree Trunk)

Building collective rural resilience through agroecology, land rights, and water justice. The community's central vision was to build farming systems that are less dependent on external inputs and better able to sustain livelihoods under changing climate conditions. Farmers described a future in which agriculture is supported through agroecological practices, better access to water, secure land ownership, stronger community cooperation, and greater government accountability.

Figure 1. Comparing agroecological farming and conventional farming

COMPARATIVE OF FARMING SYSTEMS OVER 5 YEARS	
Agro-ecological / Diversified Farms vs Conventional / Chemical / Mono-cropping Farms	
INDICATORS (5 YEARS)	AGRO-ECOLOGICAL / DIVERSIFIED FARMS
 Crop diversity	High diversity with mixed cropping and intercropping systems
 Yield stability	Stable income in average - More stable production during irregular rainfall and dry periods due to crop diversity and local adaptation.
 Input costs	Lower spending through seed saving, natural manure, tank silt application, mulching, and practice of traditional pest control. So labour get more employment.
 Climate resilience	Stronger ability to adjust to rainfall changes and moisture stress.
 Soil health	Improved soil health as moisture and softer soils increased organic matter and biological activity conducive to the local climatic conditions.
 Water management	Better water conservation through mulching, bunding, contour works, percolation pits, tank restoration and decentralized micro-water management systems adapted.
 Pest management	Higher pest control with care for bio-diversity using of chemical free pesticides of neem-based preparations, nature based vermicomposting, Jeeva Amrutham, Ghana Jeeva Amrutham and Vana Jeeva Amrutham.
 Food security	Better nutritious food access through chemical free climate resilient mixed crops, vegetables, fruit & fodder trees, and healthy livestock
 Economic resilience	Stable income in comparison to other farmers as they have multiple income sources including crops, trees, livestock, animal husbandry seed saving and wage work
 Recovery after climate shocks	Faster recovery because of diversified production and lower seasonal investment. Also, the land is fertile over years to yield better after any uncertainty.
 Dependence on markets	Lower dependence due to local inputs and household food production.
 Use of common resources	Greater use of local ecological knowledge and community resource management.
 Livelihood flexibility	Better livelihood as diverse support is taken by livestock, seasonal harvesting, mixed crops and public employment schemes
 Health	Balanced health - Consumption of nutritious and non-chemical based food practices keep them with better health conditions. The preventive curative health care dependent on use of traditional knowledge nature-based local remedies, Ayurveda medical care. They also depend on Govt health departments for serious ailments using health cards with low health expenditure.
INDICATORS (5 YEARS)	CONVENTIONAL / CHEMICAL / MONO-CROPPING FARMS
 Crop diversity	Low diversity as focused mainly on single cash crops/ mono-crops
 Yield stability	Unstable & low income in average - Common phenomena of mono cropping is complete crop loss or partially with low quality production, due to volatile climate situation-acute drought, uncertain heavy rainfall, failure of seasonal rainfall etc.,
 Input costs	Higher spending - Buy the hybrid seeds from market with high cost; 25% increase of chemical fertilizers usage; costlier toxic pesticides increase the quantity every year; capital intensive irrigation; and plastic sheets to cover the land during cultivation.
 Climate resilience	Weaker ability - adapting due to dependency on corporate driven agro-tech based inputs and external skills that can't adapt to unstable weather conditions overtime.
 Soil health	Degenerated soil health - Farmers reported that declining of moisture and retention due to excessive unnatural chemicals and pesticides killed the regenerative capacity of the soil.
 Water management	Water depletion due to over exploitation of water over ground (water irrigation tanks, lakes) and underground water (deep bore wells) extraction with high capital-intensive technology.
 Pest management	Lower pest control with high risk of damage to the bio-diversity by fully dependent on chemical pesticides and purchased inputs. Hence, loss of crops is observed.
 Food security	Insecure food due to food shortage and toxic chemical based food available in the market and government ration rice during crop loss (which is most likely every time)
 Economic resilience	Unstable income as concentrated in fewer sources of income and more sensitive to production and market failure. Hence, few youth distress migrate to near by towns for construction allied work and return when work leads to horrible conditions there.
 Recovery after climate shocks	Slower recovery due to debt accumulation along with higher interest rate. Also, higher crop production and transport costs have been difficult to recover. Many are unemployed and underemployed.
 Dependence on markets	Higher dependence for seeds, chemicals, food, and agricultural inputs
 Use of common resources	Less dependence on community-managed ecological practices
 Livelihood flexibility	Weakened livelihood More dependent on agricultural market returns and crop success.
 Health	Volatile health conditions - many reported, even in villages due to consumption of chemical-based food and direct exposure to usage of toxic pesticides, developed health conditions such as cancer, heart problems, high blood pressure, and diabetes. They have more emergencies to the hospitals but with limited access, they find it difficult. Additionally, corporate driven medicines are unaffordable.
MAIN HEALTH RISK FACTORS: ACROSS BOTH FARMING SYSTEMS  Lack of appropriate tools, safety equipment and PPE leading to frequent work-related injuries.  Increasing heat waves in summer intensify health risks leading to heat stress, heatstroke and in some cases, deaths.  Sudden heavy rains damage temporary shelters and huts, exposing families to poor living conditions and increasing the risk of illness.  Severe mental stress due to crop failures, indebtedness, livelihood insecurity and climate-related uncertainties.  In some cases, these stress factors have led to suicides.	

Strategies (Roots)

Community-led actions and enabling support systems.

The roots of the Solution Tree represented the actions that communities believe are necessary to further strengthen resilience. These include organising village-level awareness meetings, rallies, and peaceful protests, as well as submitting memoranda to government authorities to advocate for policy changes that support farming communities and promote agroecological agriculture.

Farmer learning and knowledge sharing. To build rural resilience, communities actively engage in farmer-to-farmer exchanges focused on traditional practices and the revival of local agroecological methods. These initiatives involve documenting and providing practical training on natural farming preparations, such as Jeeva Amrutham, Ghana Jeeva Amrutham, and Vana Jeeva Amrutham, while developing model agroecological farms to demonstrate their tangible benefits and encourage policy-level support from the government.

Seed saving and local seed networks. To strengthen local seed networks, communities focus on the collective selection and preservation of quality traditional and drought-tolerant crop varieties. By maintaining village-level seed banks, farmers can easily exchange seeds while significantly reducing their reliance on commercial markets. Additionally, these initiatives prioritise strengthening women's skills in collecting, processing, selecting, and preserving high-quality seeds to ensure long-term agricultural sustainability.

Water restoration and conservation. Communities enhance water resilience by implementing various soil and water conservation practices. These efforts include conserving soil moisture through mulching, constructing bunds and contour works, and developing percolation pits and trenches to capture runoff. To restore local water resources and boost groundwater recharge, local initiatives also focus on desilting tanks—reusing the rich sediment in agricultural fields—and actively recharging dried or depleted bore wells.

Government support and public investment. To strengthen rural livelihoods, government support and public investment must prioritise the expansion of public employment schemes for water conservation and land regeneration. This includes strengthening the implementation of MGNREGA and ensuring its continuation under the proposed Viksit Bharat-Guarantee for Rozgar and Ajeevika

Mission (Gramin) (VB-G RAM G) programme, while addressing concerns that it may offer fewer employment opportunities than MGNREGA. Additionally, these initiatives should focus on ensuring faster administrative responses for borewell and irrigation support schemes, alongside securing land access and land rights for landless farming households and smallholders cultivating less than five acres.

Collective action and village associations. To drive systematic change, communities mobilise through village groups to raise common demands, monitor local land and water resources, and engage collectively with government institutions rather than as isolated individuals. A key priority is securing tenancy cards and legal support for tenant farmers and sharecroppers, enabling them to access drought relief, crop insurance, and government benefits from which they are typically excluded. Furthermore, these associations actively advocate for reversing land encroachments on Dalit and Adivasi commons to restore community land rights, the foundation of local food security, while strengthening media advocacy and collaborating with like-minded organisations and unions to influence broader policy decisions.

Expected outcomes (Branches)

Climate resilience. Enhancing climate resilience empowers farmers to sustain agricultural operations through periods of irregular rainfall and prolonged drought. Implementing these practices improves soil-water retention and reduces overall climate-related losses, ultimately enabling communities to adapt more effectively to changing seasonal conditions.

Food sovereignty and nutrition. Enhancing local food sovereignty involves increasing crop diversity to expand the year-round availability of nutritious food. By growing a wider variety of crops locally, communities improve overall household food security while significantly reducing their dependency on external commercial markets.

Biodiversity restoration. Restoring local biodiversity relies on reviving mixed-cropping systems and increasing the use of traditional, locally adapted seed varieties. Additionally, these efforts focus on protecting trees and promoting broader ecological farming practices to enhance overall environmental resilience.

Improved livelihoods. Adopting diversified farming creates better livelihood opportunities while significantly reducing farming costs by using natural

inputs. By integrating livestock rearing with multiple cropping, households achieve greater income stability, which ultimately strengthens livelihood security and helps retain youth in rural villages.

Improved access to irrigation and water. Adopting sustainable water management practices enhances groundwater recharge, significantly reduces surface runoff, and improves soil moisture retention. Together, these conservation measures build water resilience and drive higher agricultural productivity across dryland areas.

Education and future opportunities. Strengthening agricultural security and rural livelihoods directly contributes to eliminating child labour, enabling all children in the community to enrol in and remain in school.

Better health. Transitioning to safer farming practices improves overall community health by implementing preventive measures that minimise direct exposure to toxic pesticides. Consequently, health-related issues are significantly reduced while nutritional outcomes, particularly for women, are substantially improved.

Overall, communities described resilience not simply as the ability to survive climate change, but as the process of rebuilding agriculture through cooperation, local knowledge, ecological farming practices, secure land and water rights, and stronger public support systems.

KEY INSIGHTS

The Participatory Action Research conducted across 20 villages in Nimmanapalle Mandal (Annamayya District) and Sodam Mandal (Chittoor District) documented the experiences of 2,001 households (6,003 people, 2,931 women and 3,072 men), including 1,201 landless agricultural labour households, 346 tenant and sharecropper households, and 454 small and marginal farmer households. The study also documented agroecological practices among 654 diversified farming households and compared them with 146 monocropping households, generating evidence on climate impacts and locally developed adaptation strategies.

Climate change is transforming dryland agriculture

Communities consistently reported that the climate has become increasingly unpredictable over the last two decades. Delayed monsoons, prolonged dry spells, rising temperatures, declining groundwater,

and short periods of intense rainfall have disrupted traditional farming calendars.

Historical timelines and seasonal calendar exercises showed that crops once cultivated according to predictable seasonal cycles now face uncertain sowing periods, increased moisture stress, and greater production risks. Farmers explained that annual rainfall is increasingly concentrated into a few heavy rainfall events rather than being distributed across the cropping season, resulting in runoff, soil erosion, and reduced groundwater recharge.

Heatwaves have become more frequent, with temperatures regularly exceeding 40°C, increasing heat stress for agricultural workers and reducing crop productivity.

Climate change is deepening the agrarian crisis

Climate variability has reduced agricultural productivity while increasing production costs.

Across conventional monocropping systems, farmers reported increasing dependence on hybrid seeds, chemical fertilisers, pesticides, plastic mulching, mechanisation, and deep borewells, resulting in steadily rising cultivation costs.

Although the market value of crops has increased slowly, farmers estimated that actual production costs increase by approximately 10-15% annually; the real increase in farm income has remained only 2-3%, substantially reducing farm profitability.

The study documented declining long-term yields in several traditional crops:

- Pearl millet declined from approximately 1,400 kg/acre during 1995-2004 to around 800 kg/acre today under monocropping
- Finger millet declined from 1,100-1,200 kg to around 1,100 kg/acre
- Mango production reduced from approximately 7 tonnes to 5 tonnes per acre
- Sugarcane yields declined from 58-60 tonnes to about 55 tonnes per acre

Communities associated these with rising temperatures, irregular rainfall, declining soil fertility, groundwater depletion, and increasing dependence on external agricultural inputs.

Agroecological farming improves climate resilience

The study documented 654 agroecological/diversified farming households, compared with 146 households practising conventional monocropping.

Rather than relying on a single crop, diversified farms combined crops such as groundnut, finger millet, pearl millet, sorghum, red gram, green gram, black gram, horse gram, sesame, sunflower, vegetables, and fruit trees.

These systems spread climate risks across multiple crops.

Although monocropped groundnut generated higher gross returns during good rainfall years (₹70,000/acre) compared with diversified groundnut systems (₹48,225/acre), diversified farms required substantially lower investment (₹28,500 compared with ₹48,000 per acre) and reduced the risk of complete crop failure.

Similarly, diversified mango systems generated additional income from vegetables and pulses, increasing gross returns to approximately ₹88,020/acre. Sugarcane intercropped with gongura increased total gross income to approximately ₹148,500/acre.

Farmers explained that diversified systems ensured that even if one crop failed, other crops continued producing food and income.

Agroecology reduces production costs

One of the strongest findings was the reduction in dependence on external agricultural inputs. Agroecological farmers reduced expenditure by using local seed saving, farmyard manure, tank silt, green manure, mulching, Jeeva Amrutham, Ghana Jeeva Amrutham, Vana Jeeva Amrutham, neem-based pest management, and Non-Pesticide Management (NPM).

Compared with monocropping systems, agroecological farms avoided much of the recurring expenditure on hybrid seeds, chemical fertilisers, toxic pesticides, and plastic cover mulching.

Communities reported that these practices improved soil moisture, earthworm populations, soil softness, and biological activity while reducing dependence on purchased inputs.

Agroecology strengthens household food security

Unlike monocropping systems that produce mainly one commercial crop, diversified farms supplied

households with cereals, pulses, vegetables, fruits, fodder, milk, eggs, and livestock products throughout the year.

The 654 agroecological households reported greater dietary diversity and reduced dependence on purchased food and government-ration rice.

By contrast, many households practising conventional farming reported increasing dependence on the Public Distribution System after repeated crop failures. Communities reported that food security has declined considerably over the past two decades. Previously, many households produced enough pulses for approximately 9 months and millets for around 6 months each year.

Today, this has reduced to approximately four months of pulses and three months of millets, leading to greater dependence on purchased food and government-ration rice.

Climate change is increasing household indebtedness

Crop failures directly translated into debt accumulation. Small farmers, tenant farmers, and sharecroppers often borrowed money before every cultivation season.

When crops failed, loans accumulated, with reported annual interest rates ranging from 25% to 60%. Communities reported that a few small and marginal farmers had stopped cultivating portions of their land during the last two decades because repeated crop failures made cultivation financially unviable.

High production costs, crop losses, and unstable market prices created a cycle of indebtedness that many households struggled to escape.

Climate impacts are socially unequal

Climate change does not affect all households equally.

Among the 2,001 households covered: 1,201 were landless agricultural labour households; 346 were tenant and sharecropper households; and 454 were small and marginal farming households. By population, they are divided as follows: 958 Dalit households (2,874 people); 220 Adivasi households (659 people); and 823 households from other communities (2,470 people).

Dalit and Adivasi households represent the majority of agricultural labour households and face structural inequalities. These households experienced multiple

overlapping vulnerabilities arising from insecure employment, limited land ownership, reduced access to irrigation, and dependence on seasonal wage labour.

Women bear a disproportionate climate burden

Women were identified as the most affected group across nearly every research method.

Women simultaneously undertake agricultural labour, unpaid domestic work, livestock care, fuelwood collection, water collection, childcare, and food preparation.

During droughts and crop failures, women commonly reduced their own food intake to prioritise children and other family members. Community health records indicated that approximately 40% of Dalit and Adivasi women across the study villages were anaemic, reflecting long-term nutritional stress.

Women also reported greater exposure to pesticide-related health risks because they spend longer hours undertaking manual agricultural work.

Water conservation has strengthened resilience where implemented

Communities identified water restoration as one of the most effective climate adaptation measures. Through MGNREGA-supported activities introduced since approximately 2005, villages implemented contour bunding, trenches, percolation pits, desilting of tanks, field bunds, and groundwater recharge structures.

Farmers explained that these interventions improved soil moisture, groundwater recharge, and irrigation availability. However, Dalit and Adivasi farmers often owned land located away from restored water systems and therefore benefited less from these investments.

Community knowledge is central to climate adaptation

The research demonstrated that many of the most effective adaptation strategies originated within farming communities rather than external technical programmes.

Communities continue to maintain traditional seed systems, mixed cropping, pancha vari cultivation, green manure, natural pest management, livestock

integration, community seed exchange, and local weather knowledge. These practices have evolved over generations and continue to provide practical solutions for adapting to increasingly uncertain climatic conditions.

Collective action strengthens resilience

Village organisations, women's associations, unions, and community institutions played an important role in strengthening resilience. Their collective action pushed for the following:

- Restoration of village tanks
- Implementation of MGNREGA
- Community seed conservation
- Legal awareness
- Government accountability
- Access to welfare programmes
- Protection of common property resources,
- Promotion of agro-ecological farming.

The findings suggest that resilience is not built only through agricultural technologies but also through stronger community institutions, collective decision-making, and public investment.

Overall key insight

The evidence demonstrates that agroecology is not only an alternative farming method but a comprehensive climate resilience strategy. While conventional monocropping can generate higher yields and gross income in favourable seasons, it requires significantly higher financial investment and exposes farmers to greater risks from climate variability, debt, and market fluctuations. In contrast, diversified agroecological systems reduce production costs, strengthen household food security, improve soil and water resources, diversify income sources, and enable faster recovery from climate shocks. However, the benefits of agroecology alone cannot overcome structural inequalities. Strengthening climate resilience in dryland Andhra Pradesh requires complementary investments in land rights, water conservation, community seed systems, women's leadership, secure livelihoods, and policies that prioritise smallholders, tenant farmers, landless agricultural workers, and Dalit and Adivasi communities.

POLICY AND ADVOCACY IMPLICATIONS

This research shows that climate change in southern Andhra Pradesh is not only an environmental challenge but also a question of land, water, livelihoods, labour rights, and social justice. Farmers are already living with climate impacts, and responses therefore need to move beyond technical agricultural solutions and strengthen community resilience, public support systems, and collective action.

Policy recommendations

Public support for agroecology

- Expand government support for agroecological and natural farming practices that reduce dependence on external inputs and strengthen climate resilience. Develop dedicated agroecology policies and support programmes in line with the principles and recommendations of the UN Convention on Biological Diversity (CBD), to which India is a Party, and the Food and Agriculture Organisation (FAO) agroecology framework
- Expand MGNREGA from 100 to 200 days of guaranteed employment per household per year and revise the minimum wage to ₹920 per day, as demanded by workers' organisations, under the 8th Pay Commission, to reduce distress migration and strengthen rural livelihoods
- Increase government support schemes for low-cost ecological farming methods, including mixed cropping, agroforestry, soil restoration, and natural pest management
- Introduce and develop agroecology and biodiversity education in universities to encourage young people to acquire skills for agriculture-based livelihoods

Seed sovereignty policies

- Support community seed systems and local seed conservation initiatives, including establishing and promoting community seed banks. Encourage the conservation and use of locally adapted, drought-tolerant seed varieties that are better suited to changing rainfall patterns and dryland conditions
- Protect farmers' rights to save, exchange, reuse, and sell traditional seeds. Farmers should also have the right to reject seed packages that require

the mandatory use of chemical fertilisers and pesticides

- Reduce dependence on commercial seed systems that increase production costs, promote dependence on external inputs, and heighten farmers' vulnerability to climate change

Climate adaptation programs

- Design climate adaptation programs which address social inequalities and prioritise vulnerable groups, including landless labourers, women, Dalit and Adivasi households, tenant farmers, and smallholders
- Integrate agroecology into district and state climate adaptation planning
- Strengthen community-based water restoration and groundwater recharge systems with a decentralised managed system under the control of the committees formed with the local communities. For example, a water management committee, with members from the local community, may be set up with proper responsibilities assigned by the government
- Expand access to climate information and locally relevant adaptation support at the panchayat level, disseminating updates through local FM radio and other accessible communication channels

Land and water rights

- Improve the implementation of land distribution programs for landless women workers, providing essential infrastructure for water sources, electricity, subsidised seeds, and organic input preparation facilities
- Strengthen legal protections to safeguard common lands, grazing areas, tank beds, and water bodies from encroachment
- Enhance access to irrigation and ensure the equitable implementation of schemes for artificial groundwater recharge and water source restoration
- Reduce administrative delays to ensure smallholders can efficiently access and benefit from government land and water support programs

Development programme recommendations

Support village-level training that will:

- Promote crop diversification through community-based planning and collective decision-making processes
- Support soil restoration practices across contiguous landscapes so that soil and water conservation measures, including erosion control, can be implemented collectively
- Recognise and strengthen community-managed local seed conservation systems, while protecting and respecting traditional knowledge and community seed governance
- Strengthen community capacities in water conservation skills and techniques
- Promote natural pest management systems and agroecological farming practices
- Provide capacities on the preparation and use of Jeeva Amrutham, Ghana Jeeva Amrutham, and Vana Jeeva Amrutham
- Encourage participatory, farmer-to-farmer, and community-led training approaches rather than top-down agricultural extension services
- Strengthen and support village women's associations to assist families during crises and address issues such as domestic violence, sexual abuse, malnutrition, unequal wages, and challenges faced by women in agricultural work

Promote and strengthen field schools and organise farmer-to-farmer learning through exchange visits that:

- Provide platforms for farmers to exchange experiences and demonstrate successful practices
- Facilitate inter-village learning visits to observe agroecological methods in practice
- Recognise senior farmers and experienced community members as key local knowledge holders
- Document and produce instructional videos to support better comprehension and application

Strengthen rural employment for climate resilience by expanding public employment programs that support tank desilting, bunding and contour works, percolation pits, soil moisture conservation, water harvesting structures, and groundwater recharge.

Ensure these programs remain accessible to landless workers and smallholders, even after they receive government-distributed land. Water conservation

and livelihood support initiatives should also be implemented near their land. Furthermore, MGNREGA and similar programs should issue individual, worker-based job cards rather than family-based ones to ensure equal access to employment for every eligible worker.

Guarantee health and labour protection through programs that will:

- Improve access to rural healthcare facilities and promote proper sanitation
- Increase occupational safety support for agricultural workers, including the provision of proper tools and protective equipment
- Address mental health challenges linked to climate stress, debt, and livelihood insecurity
- Strengthen measures to prevent child labour and support continued education

Movement building and collective action

Farmers' organisations must be strengthened through initiatives that will:

- Support village associations, farmer collectives, and worker unions as key actors in climate adaptation and rural development
- Build collective negotiation power around land, water, wages, access to public programs and common property resources such as common grazing lands, hillocks, canal bunds, tank foreshore lands, and local water bodies
- Encourage local leadership among women, youth, tenant farmers and agricultural workers

Solidarity networks must be promoted to:

- Build stronger links between farming communities, like-minded workers' organisations, agroecology networks, and civil society groups
- Create spaces for shared learning across regions facing similar climate challenges
- Strengthen collective advocacy for equitable climate policies and resource access

The people's movement for climate justice must be advanced to:

- Shift climate responses from individual responsibility to collective public action

- Recognise climate resilience that depends not only on changing farming practices but also on addressing structural inequalities related to land ownership, labour conditions, caste, gender, and access to natural resources

Overall, long-term resilience requires strengthening agroecology alongside collective rural action, secure land and water rights, public investment, and stronger community unions/committees.

CONCLUSION

This study demonstrates that climate change is already reshaping agriculture and rural livelihoods across the dryland landscapes of Annamayya and Chittoor districts. Rising temperatures, erratic rainfall, groundwater depletion, soil degradation and increasing production risks have combined with existing inequalities to deepen poverty, indebtedness, food insecurity and migration, particularly among landless labourers, tenant farmers, Dalit and Adivasi communities, women and rural youth.

At the same time, the research provides strong evidence that agroecological farming offers a practical and locally grounded pathway for climate resilience. Crop diversification, mixed cropping, traditional seed conservation, organic soil management, natural pest control, livestock

integration and water conservation have enabled farming households to reduce production risks, lower cultivation costs, improve food security and strengthen ecological sustainability.

The findings also demonstrate that resilience extends beyond farming practices. Collective action through village organisations, women's groups, farmers' unions, and public programmes such as MGNREGA plays a crucial role in restoring natural resources, protecting livelihoods, and strengthening community capacity to respond to climate shocks.

Scaling up agroecological transitions therefore requires supportive public policies that recognise farmers' knowledge, secure land and seed rights, strengthen water conservation, expand social protection and place vulnerable rural communities at the centre of climate action. Such an approach offers not only a pathway to climate adaptation but also to greater social justice, food sovereignty and sustainable rural development.

ANNEXES

Annex 1

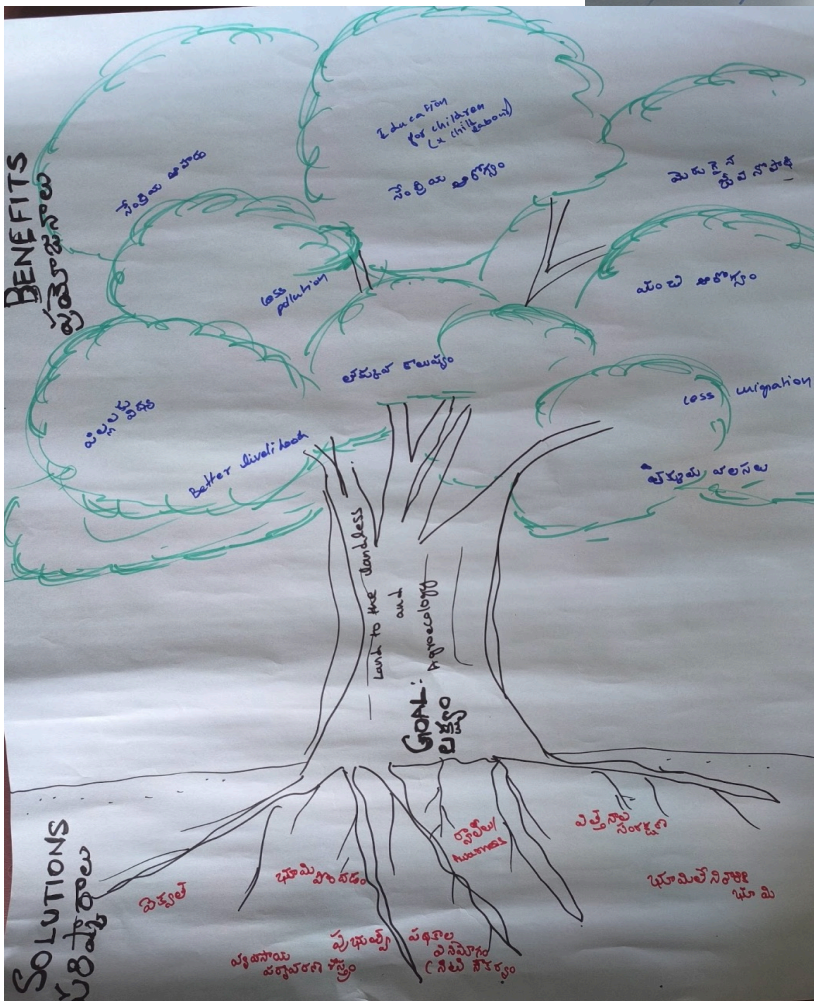
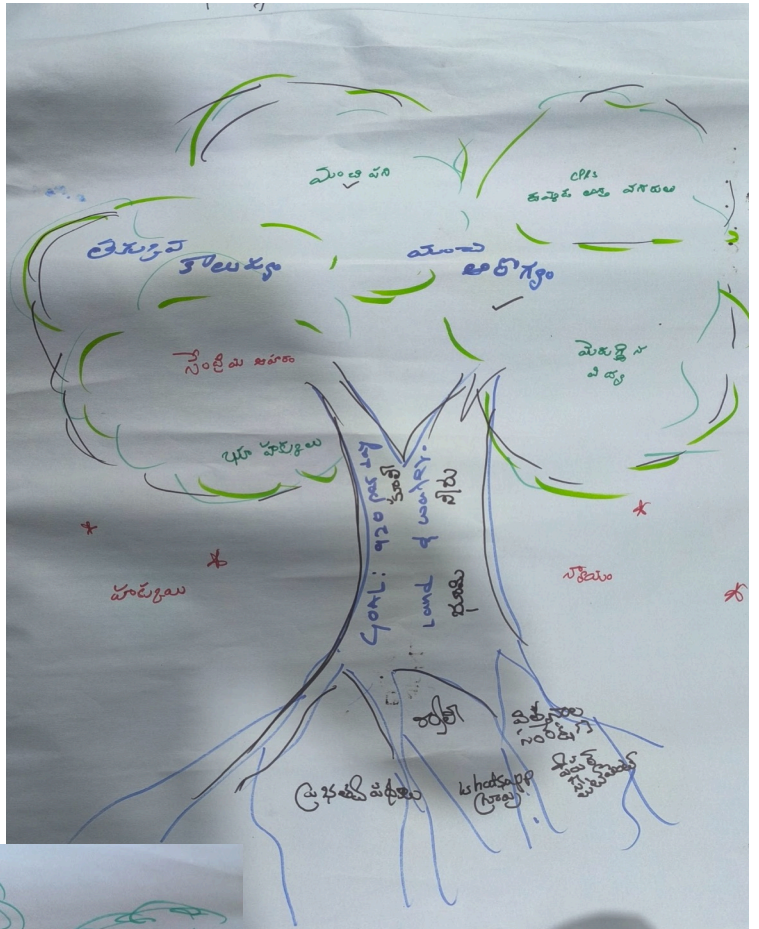
Historical Timeline

[illegible]

Annex 2

Seasonal Calendar

	JAN-FEB	MARCH-APR	MAY-JUNE	JULY-AUG	SEPT-OCT	NOV-DEC
RAINFALL	↓	↓	=	↑	↑	=
TEMPERATURE	పల్లెగా	వేడిగా	బలం వేడిగా	వెచ్చగా	వెచ్చగా	pleasant / వల్లగా
WATER	మధ్యస్థం	low low లో ఉన్నది	↓ బలం లో ఉన్నది	మెరుగుపడుతుంది (Improving)	ఎంతగా ఉంటుంది	"
CROP PATTERNS	aroundnut, vegetables కూరగాయలు	land preparation	sowing preparation పంట నాట సిద్ధం	croasnut, millets sowing	వంట పంటలు	కొల పంటలు
CROP DIVERSITY	=	↓	↓	↑	↑	=
PEST	↓	=	=	↑	↑	=
SOIL FERTILITY	— స్థిరంగా	వేల పొడిగా	వేల లో ఉన్నది	మెరుగుపడుతుంది	యంతే	యంతే
LABOUR DEMAND	=	↓	↑ కొంతమంది ఎక్కువ	↑	↑	↑
FOOD AVAILABILITY	=	↓	↓	↑	↑	=
FOREST FOODS	↓ కొంత ఎక్కువ	↓	↓ (వనం లో ఉన్నది)	↑	↑	↑
LIVESTOCK CONDITIONS	↑	నీటి కొరత and water stress	↓	Improving	↑	↑
PASTURE AVAILABILITY	↑	=	=	=	↑	↑
MIGRATION	↓	=	↑	↓	↓	↓
HEALTH ISSUES	↓ cal. క్షయం	↓ Heat stress	↓ Heat stroke risk	↓	↓	↓



Nepal: Surkhet District

Social Work Institute (SWI)

Executive summary

Climate change poses a serious threat to rural livelihoods and agricultural systems in Nepal, particularly for smallholder farmers who depend on rainfed agriculture. This Participatory Action Research (PAR) study, conducted in Chaukune and Chingad Rural Municipalities of Surkhet District, examines the impacts of climate change and the role of agroecology in building resilience. Through focus group discussions (FGDs), farmer interviews and other participatory methods, the study engaged marginalised communities, including Dalit and Raji farmers.

The findings show that climate change has contributed to declining agricultural productivity, water scarcity, soil degradation, crop failures, and more frequent pest and disease outbreaks. Staple crops such as rice, maize and wheat are increasingly affected by erratic rainfall, droughts and floods. These pressures have reduced household incomes, increased vulnerability and contributed to migration, particularly among young people, while women and landless farmers face disproportionate impacts.

Despite these challenges, farmers are adopting agroecological practices including crop diversification, intercropping, composting, agroforestry and local seed conservation. The study concludes that agroecology, combined with traditional and local knowledge, offers a sustainable pathway to strengthen climate resilience, improve food security and support rural development in Nepal.

Introduction

Climate change has emerged as a major challenge for rural livelihoods and agricultural systems in Nepal. Rising temperatures, erratic rainfall, prolonged droughts, floods and landslides, together with the spread of pests and diseases, are affecting

farming communities, particularly smallholder farmers who depend heavily on natural resources. Nepal is highly vulnerable to climate change, with more than 60% of its population relying directly on agriculture for their livelihoods (MoALD, 2020). The country has experienced an average temperature increase of about 0.056°C per year since the 1970s, accompanied by increasingly irregular precipitation patterns (DHM, 2017). Because most farming systems are rainfed and climate-sensitive, even modest changes in weather conditions can significantly affect agricultural productivity.

Rural communities are particularly vulnerable because of their dependence on rainfed agriculture, limited access to irrigation and fragile socio-economic conditions. Agriculture remains a key sector in Nepal, contributing around one-quarter of GDP and supporting a majority of rural households (Economic Survey, 2023). Climate variability has already reduced yields of major staple crops such as rice, maize, and wheat, with some areas experiencing up to a 20% decline in rice production due to delayed monsoons and drought (MoALD, 2021). These changes threaten food security, biodiversity, traditional farming practices and overall community resilience.

The impacts are particularly severe in Karnali Province, one of the most remote and least developed regions of Nepal. Although it accounts for only about 6% of the national population, nearly 28.9% of its people live below the poverty line and more than 51% experience multidimensional poverty (Karnali Province Planning Commission, 2020). Agriculture is the primary livelihood in the region, yet it is constrained by poor infrastructure, limited irrigation and weak market access. Climate-related risks such as droughts and floods are increasing, with studies showing rising drought frequency and declining soil moisture in the Karnali River Basin (Aryal et al., 2025). Many parts of Karnali also face chronic food insecurity and malnutrition, further increasing vulnerability to climate change (Chaudhary & Maharjan, 2023).

Agroecology has gained recognition as a sustainable and climate-resilient approach to agriculture. It applies ecological principles alongside traditional and local knowledge to promote diversified farming systems, improve soil health, conserve biodiversity and manage natural resources sustainably. By reducing dependence on external chemical inputs and strengthening local food systems, agroecology can enhance resilience while supporting environmental sustainability.

This report presents findings from a PAR study examining the impacts of climate change and exploring agroecology as a climate solution in rural Nepal. The research engaged farmers through participatory methods, including focus group discussions (FGDs) and interviews, enabling participants to share their experiences, identify climate-related challenges and discuss locally adapted agroecological practices.

The participatory approach enabled communities to reflect collectively on environmental change, agricultural challenges and locally driven solutions. The findings highlight the importance of combining community knowledge and traditional practices with agroecological approaches to strengthen climate resilience and support sustainable rural development, particularly in vulnerable regions such as Karnali Province.

Objectives

The research has three main objectives, namely:

- To assess the impacts of climate change on the livelihoods, food security, and farming systems of rural communities
- To examine the role of agroecological practices in strengthening climate resilience and sustaining food production.
- To compare the vulnerabilities and adaptation capacities of agroecological and input-intensive farming communities under climate stress.

Methodology

This study used a Participatory Action Research (PAR) approach at two sites in the Inner Terai and Mid-Hill regions of Nepal where agroecological practices are present. Data were collected through two focus group discussions (FGDs), involving 34

participants in total, and 18 individual farmer interviews. The study included marginalised communities such as Dalit and Raji farmers, including small and limited landholders. Participants represented three generations of farmers, allowing the research to capture diverse experiences and knowledge of climate change and agroecology.

The PAR framework emphasised active community participation throughout the research process. Farmers were not only research participants but also contributed to identifying issues, sharing experiences and discussing local adaptation practices. The approach supported the co-generation of knowledge by integrating farmers' indigenous knowledge and lived realities into the research process. Through FGDs and interviews, the study centred on the experiences of rural farming communities, including marginalised groups and different generations, to understand climate impacts and the role of agroecology in building resilience.

Research site and location

The research was conducted in two rural municipalities of Surkhet District: Chaukune and Chingad. In Chaukune Rural Municipality, Ward No. 9 was selected for its mixed communities and broader adoption of agroecological practices. In Chingad Rural Municipality, Wards No. 3 and 5 were selected to examine local farming systems, climate impacts and community adaptation practices. See **Figures 1 and 2** for the research sites' locations.

Participants and data collection

Tables 1 and 2 list the names of the study's participants from the two municipalities.

The study collected data from the participants through FGDs and semi-structured interviews. **Table 3** summarises these data collection methods.

Community context

Socioeconomic profile

The rural communities have very little land, much of it fragmented and scattered. Agricultural production is declining. In the past, people made agricultural tools for their livelihoods and worked on landowners' farms, but the use of local farming tools has declined. Many people have stopped farming, and livestock rearing has also declined.

Figure 1. Map of Chingad Rural Municipality of Surkhet District of Nepal



Figure 2. Map of Chaukune Rural Municipality of Surkhet District of Nepal

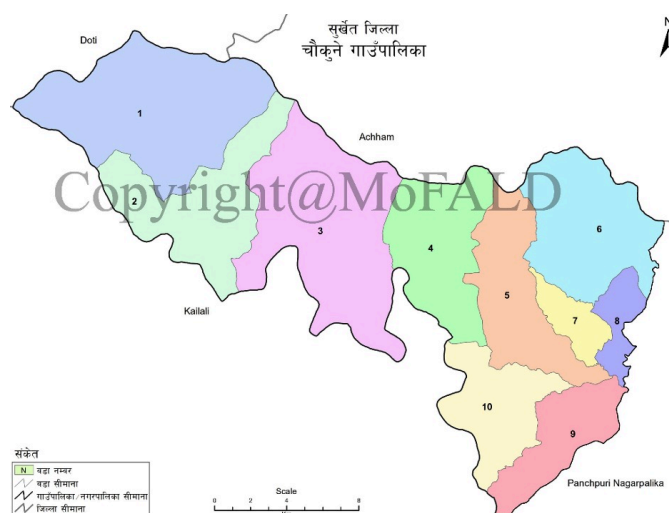


Table 1. Interview respondents

Name	Address	Gender	Age
Binod Khanal	Chaukune RM, Ghatgaun	Male	34
Kamala Raji	Chaukune RM, Ghatgaun	Female	41
Deurupa Rawat	Chaukune RM, Ghatgaun	Female	43
Jeet Bahadur Kami	Chaukune RM, Ghatgaun	Male	41
Ratan Raji	Chaukune RM, Ghatgaun	Male	41
Prem Raji	Chaukune RM, Ghatgaun	Male	27
Dipendra Raji	Chaukune RM, Ghatgaun	Male	24
Yam Raji	Chaukune RM, Ghatgaun	Male	55
Nabin Acharya	Chaukune RM, Ghatgaun	Male	29
Dharma B. K.	Chaukune RM, Ghatgaun	Female	62
Ganesh B. K.	Chingad RM, Tule	Male	45
Nara Bahadur Rokaya	Chingad RM, Tule	Female	39
Mahima Rokaya	Chingad RM, Tule	Female	40
Bhumisara Rokaya	Chingad RM, Tule	Female	30
Top Bhadhur Rokaya	Chingad RM, Tule	Male	35
Sita Saud	Chingad RM, Aulching	Female	26
Krishna Kumar Rokaya	Chingad RM, Tule	Male	31
Pathe Khadka	Chingad RM, Tule	Male	59

Table 2. FGD participants

S. N.	Name	Address	Gender
1	Nabin Prasad Acharya	Chaukune RM-9	Male
2	Padam Rawat	Chaukune RM-9	Male
3	Ratan Tamata	Chaukune RM-9	Male
4	Karna B. K.	Chaukune RM-9	Male
5	Jay Bahadur Bayak	Chaukune RM-9	Male
6	Amar B. K.	Chaukune RM-9	Male
7	Rana Budha	Chaukune RM-9	Male
8	Mansara B. K.	Chaukune RM-9	Female
9	Thebu B. K.	Chaukune RM-9	Female
10	Jayakala B. K.	Chaukune RM-9	Female
11	Jaisara Nepali	Chaukune RM-9	Female
12	Padma Devi Dhamala	Chaukune RM-9	Female
13	Hima Devi Shahi	Chaukune RM-9	Female
14	Nanna Kala B. K.	Chaukune RM-9	Female
15	Mina Shahi	Chaukune RM-9	Female
16	Nirmala Tamata	Chaukune RM-9	Female
17	Akendra Prasad Devkota	Chaukune RM-10	Male
18	Kabiram Dhungana	Chaukune RM-9	Male
19	Laxmi Prasad Dhakal	Chaukune RM-9	Male
20	Dil Maya Nepali	Chingad RM	Female
21	Dil Maya B. K.	Chingad RM	Female
22	Mina B. K.	Chingad RM	Female
23	Devisara B. K.	Chingad RM	Female
24	Bhim Bahadur Khadka	Chingad RM	Male
25	Haikali Khatri	Chingad RM	Female
26	Karna Bahadur Thapa	Chingad RM	Male
27	Top Bahadur Rokaya	Chingad RM	Male
28	Bikhali Gharti	Chingad RM	Female
29	Krishni Kumari Rokaya	Chingad RM	Female
30	Bhakta Bahadur Khatri	Chingad RM	Male
31	Til Bahadur Khadka	Chingad RM	Male
32	Karna Bahadur Rokaya	Chingad RM	Male
33	Pathe Khadka	Chingad RM	Male
34	Sita Saud	Chingad RM	Female
35	Laxmi Prasad Dhakal	Chingad RM	Male

Table 3. Overview of data collection methods used

Method	Number conducted	Participants	Purpose
Focus Group Discussion	2	34	Agroecology and the solution to climate change effects
Individual Interview	2	18	Agroecology and the solution to climate change effects
Solution Tree	1	10	Agroecology and the solution to climate change effects

Farming systems

Farming is mainly based on mixed systems in which crops and livestock are raised together. Farmers grow rice, maize, wheat and millet according to the seasonal cycle. Cows, buffaloes, goats and chickens provide manure, milk, meat and income. Farming depends largely on family labour, traditional knowledge and monsoon rainfall. In recent years, migration, climate change and the declining use of local resources have affected traditional farming systems.

Main crops and livelihood sources

The communities' livelihoods depend mainly on agriculture and natural resources. Most households rely on farming, livestock rearing, daily-wage labour, and small businesses for income. Many also depend on remittances from family members working in cities or abroad. Forest products, local crafts and traditional occupations provide additional support. More recently, some people have engaged in small enterprises, vegetable farming and other off-farm activities to supplement household income. Their main crops include rice, maize, wheat, barley, millet, potato and lentil.

Land ownership patterns

Land ownership in rural Nepal is unequal and fragmented. Some households own relatively large areas of fertile land, while many small farmers and marginalised communities, including Dalits, have little or no land. Inheritance has further divided land into small, scattered plots.

Although most rural people depend on agriculture, limited land ownership constrains food production and income. In some areas, farmers also practise sharecropping or work on other people's land for their livelihoods.

Agroecological practices in the community

The following are the documented agroecological practices in the research sites.

Crop diversification

Crop diversification is gradually increasing in rural Nepal, with farmers cultivating a wider range of

cereals, vegetables, fruits and cash crops. However, many households continue to depend on traditional staples such as rice, maize and wheat. The extent of diversification is influenced by climate change, market access, irrigation and agricultural support services. In some areas, farmers have adopted vegetable farming and high-value crops to generate income, while diversification remains more limited in remote areas.

Agroforestry

Agroforestry integrates trees, crops and livestock on the same land. Farmers commonly grow fodder, fruit and timber trees around fields and homesteads. These systems provide fodder, firewood, fruits and organic manure while supporting soil conservation, biodiversity and moisture retention.

Composting

Compost is commonly prepared by mixing kitchen waste, farmyard manure, crop residues and other vegetation. Farmers collect organic materials from households and farms and allow them to decompose in pits or heaps. This traditional practice improves soil fertility and organic matter while reducing dependence on chemical fertilisers.

Local seed use

Local seeds remain widely used. Many seasonal vegetable seeds are sourced locally and saved from previous harvests, while cereal crops such as rice, maize, wheat and millet are mainly represented by locally adapted varieties. These seeds are well suited to the local climate, soils and traditional farming practices.

Impacts of climate change

The documented impacts of climate change in the communities are as follows:

Rising temperatures. Rising temperatures are affecting agriculture and rural livelihoods by reducing

crop productivity, increasing soil moisture loss, and making growing conditions for rice, wheat, maize, and millet less predictable. Higher temperatures also contribute to drought, drying water sources and water scarcity, affecting irrigation and household water supplies. Warmer conditions can favour the spread of pests and crop diseases, increasing production losses and reliance on chemical pesticides. Livestock are also affected by heat stress, reduced fodder availability, and lower productivity. Together, these pressures weaken food security, reduce household income and encourage migration, while also threatening local biodiversity, indigenous crop varieties and traditional farming knowledge.

Irregular rainfall. Rainfall has become increasingly erratic, with delayed monsoons, untimely heavy rain, prolonged dry periods and reduced winter rainfall disrupting traditional farming calendars. Rice, wheat, maize and vegetables are increasingly affected by moisture stress, flooding and crop failure. Heavy rainfall can cause floods, landslides and soil erosion, damaging farmland, irrigation systems and rural infrastructure, while prolonged dry periods create water shortages for irrigation and household use. These changes also favour pest and disease outbreaks, threatening food security and household incomes.

More frequent droughts. More frequent and prolonged droughts have reduced soil moisture, dried water sources and created severe shortages for irrigation and household use. Drought conditions reduce the productivity of rice, wheat, maize and vegetables, contributing to crop failure, food insecurity and income loss. Livestock production is also affected by reduced fodder and drinking water. Frequent droughts increase poverty, migration and dependence on external support, particularly among smallholder and marginalised farmers.

Floods and storms. Floods and storms are causing increasing damage to agriculture and rural livelihoods. Heavy rainfall and extreme weather events can lead to river overflow, landslides, soil erosion and the destruction of standing crops, farmland, irrigation systems and infrastructure such as roads and bridges. Livestock and stored food supplies may also be damaged, compounding losses.

Smallholder farmers are particularly vulnerable because they have fewer resources with which to recover, increasing the risks of poverty, debt and migration.

Impacts on agricultural production

Crop yield changes. Climate change has altered crop yields through rising temperatures, irregular rainfall, droughts, floods and increased pest and disease outbreaks. Staple crops such as rice, wheat, maize and millet have experienced reduced or less stable productivity due to heat stress, moisture imbalances and extreme weather. Although some high-altitude areas may experience changes in crop suitability as temperatures rise, overall productivity has become more unstable and unpredictable. These fluctuations directly affect food security, household income and rural livelihoods, particularly for smallholders who depend on subsistence agriculture.

Crop failures. Crop failures are becoming more common as rising temperatures, irregular rainfall, prolonged droughts, floods and storms disrupt planting and harvesting cycles, reduce soil moisture and damage crops at critical growth stages. Rice, maize, wheat and vegetables are particularly vulnerable. Crop losses reduce food availability and income, increase farmers' debt and can force households to seek alternative livelihoods or migrate for work. Smallholder and marginalised farmers are especially vulnerable due to limited access to irrigation, technology, and financial support.

Pest and disease outbreaks. Climate-related changes in temperature and rainfall can favour the survival and spread of insects, fungi and crop pathogens. Warmer and more humid conditions may contribute to the emergence of new pests and the expansion of existing ones into previously unaffected areas, resulting in greater crop damage and reduced productivity. Farmers may respond by increasing pesticide use, raising production costs and creating additional risks for soil health, biodiversity and human health.

Soil degradation. Soil degradation is intensified by irregular rainfall, floods, droughts and rising temperatures. Heavy rainfall and floods cause erosion, nutrient loss and landslides, while prolonged dry periods reduce soil moisture and organic matter, weakening soil structure and fertility.

Continuous use of chemical fertilisers and pesticides, together with reduced organic inputs, can further degrade soil health. Declining soil quality reduces productivity and increases vulnerability to drought and climate variability by lowering the soil's water-holding capacity.

Impacts on household well-being

Food security. Climate change threatens food security by reducing agricultural productivity and increasing crop losses. Rising temperatures, irregular rainfall, droughts, floods, storms, pest outbreaks and soil degradation disrupt food production and reduce the availability and stability of staple foods such as rice, maize, wheat and millet. Households may experience food shortages, seasonal hunger and reduced dietary diversity. Lower farm incomes also make it harder for smallholders to obtain sufficient, nutritious food from markets, while price instability and supply disruptions can further exacerbate food insecurity among vulnerable communities.

Household income. Climate change reduces household income by lowering agricultural productivity and increasing the risk and cost of crop losses. Because many rural households depend on agriculture, lower yields and repeated production losses reduce farm income while increasing expenditure on irrigation, pesticides and recovery. Livestock losses, reduced fodder availability, and declining productivity further affect incomes. Climate shocks can therefore increase debt, food insecurity and seasonal unemployment, encouraging households to seek alternative livelihoods or migrate.

Debt levels. Climate-related production losses can increase household debt by making farming more uncertain and costly. Crop failures, droughts, floods, irregular rainfall and pest outbreaks may force farmers to borrow for seeds, fertilisers, pesticides, irrigation and recovery. When harvests are poor, households struggle to repay loans, while rising input costs and declining farm incomes deepen dependence on informal or high-interest credit. Livestock losses and reduced alternative income opportunities further weaken repayment capacity, potentially leading to reduced food consumption, asset sales and migration.

Health and education. Climate change affects health and education through its impacts on agriculture, livelihoods and living conditions. Rising temperatures, floods, droughts, irregular rainfall, and disease outbreaks can contribute to malnutrition, waterborne diseases, heat stress, and other health problems, particularly among children, women, and older people. Poor health reduces people's ability to work and attend school regularly. Climate-related income losses also constrain spending on health care and education, while extreme events may damage or close schools. Migration linked to climate stress can further disrupt children's access to education.

Differential impacts across social groups

Women farmers. Women farmers face disproportionate impacts because they combine agricultural work with responsibility for food production, water collection and household management. Droughts, floods and irregular rainfall can increase their workload while reducing crop yields and household food security. Limited access to land, credit, resources and climate information further increases their vulnerability.

Landless labourers. Landless labourers depend heavily on seasonal agricultural employment, which declines when crop failures, reduced farm activity and climate-related disasters disrupt production. Reduced employment leads to unstable incomes and greater poverty, often forcing workers to migrate or take low-paid informal jobs.

Smallholders. Smallholder farmers are particularly vulnerable because they rely heavily on rainfed agriculture and have limited access to irrigation, technology and financial support. Climate variability causes crop losses, unstable yields and higher production costs, reducing incomes and increasing exposure to food insecurity and debt.

Youth. Rural youth face declining agricultural opportunities, income instability and increasing risks of climate-induced migration. As farming becomes less attractive or profitable, many young people leave agriculture to seek work in cities or abroad, contributing to labour shortages and weakening long-term rural development.

Agroecology and climate resilience

Farmers' responses to climate stress

Adjusting planting dates. Farmers adjust sowing and transplanting dates in response to changing rainfall and temperature patterns. For example, in some areas, farmers delay rice transplantation until the monsoon is established to reduce exposure to drought or early dry spells.

Crop diversification. Farmers grow multiple crops together or in rotation to spread production risk and improve resilience to climate shocks. For example, maize may be grown with beans and millet so that at least some crops can be harvested when conditions are unfavourable.

Changing crop varieties. Farmers adopt varieties that are more tolerant of drought, heat or pests. For example, early-maturing and drought-resistant rice and maize varieties introduced by local agriculture offices are being used in response to unpredictable rainfall.

Agroecological practices observed

Crop diversity

Mixed cropping. Mixed cropping is a common agroecological practice that helps reduce climate risk and improve food security. Farmers cultivate combinations such as maize with cowpea and soybean, rice with black gram, wheat with pea, chickpea and rayo, lentil with mustard, and potato with rayo and radish. These systems improve the use of land and moisture, support soil fertility and can reduce pest and disease pressure. Leguminous crops such as cowpea, soybean, pea, chickpea and lentil also contribute nitrogen to the soil

Intercropping. Farmers cultivate cauliflower, broccoli and cabbage together as intercrops, while onion, tomato, fennel, garlic and coriander are also grown in mixed systems. Wheat and barley are cultivated together in some areas to increase production stability and reduce the risk of crop failure. Intercropping can improve soil fertility, suppress weeds, reduce pest and disease incidence and help maintain soil moisture.

Soil health practices

Composting. Composting is a traditional agroecological method for maintaining soil fertility and reducing dependence on chemical fertilisers. Dry leaves, forest litter, animal manure and other organic materials are collected from forests and farms and decomposed in compost pits. Kitchen waste, weeds, grasses and crop residues can also be layered in pits and allowed to decompose, producing nutrient-rich compost for agricultural use.

Green manuring. Green manuring is practised in some parts of Nepal, particularly using dhaicha in rice fields. Farmers grow dhaicha before rice cultivation and incorporate it into the soil while it is still green, increasing organic matter and natural nitrogen. The practice improves soil structure, moisture retention and nutrient availability while reducing dependence on chemical fertilisers.

Mulching. Both organic and plastic mulching are used in vegetable production and nursery management. Plastic mulch is commonly used for

crops such as potatoes, chilli and strawberries to conserve soil moisture, control weeds, regulate soil temperature and support productivity. Organic mulch includes rice, maize, and wheat straw, as well as locally available plant materials such as asuro.

Water management

Soil moisture conservation. Soil-moisture conservation involves practices that retain water in the soil for longer, particularly during dry spells. Farmers use mulching, organic matter, minimum tillage, and crop residue retention to reduce evaporation and improve water-holding capacity. For example, rice or maize straw is used as mulch in vegetable fields to maintain soil moisture and reduce irrigation needs.

Water harvesting. Water harvesting involves collecting and storing rainwater for agricultural and household use. Farmers construct ponds, tanks and small reservoirs or collect runoff during the monsoon for use during dry periods. Rainwater may be stored in plastic-lined ponds or traditional ghatta ponds and used for irrigation during droughts, improving water availability and resilience.

Pest management

Natural pest control. Natural pest control uses biological and locally available methods to manage pests without relying solely on harmful chemicals. Farmers use botanical preparations such as neem and asuro extracts, ash or cow-urine sprays, Jholmol and apichi, while also encouraging natural predators such as birds and beneficial insects.

Biodiversity-based approaches. Biodiversity-based pest management uses ecological diversity and trap crops to control pests. In cabbage fields, marigolds are used as trap crops to help reduce cabbage butterfly infestations. In tomato fields, chickpea and marigold are used to manage the fruit borer, while mustard is used in wheat fields to attract aphids away from the main crop. These approaches can support natural pest regulation while reducing pressure on the main crop.

Local seeds

Traditional seed varieties. Farmers continue to cultivate traditional varieties of rice, maize, millet, wheat and vegetables that have been conserved over generations. These varieties are adapted to rainfed, low-input conditions and are valued for their resilience to local climate stresses. For example, local rice varieties may tolerate drought and irregular rainfall better in marginal areas.

Seed saving practices. Seed saving takes place at the household level and through community seed banks. Farmers select, store and preserve seed from their own harvests for future planting, helping maintain seed availability during climate shocks or market disruptions. Community seed banks also conserve diverse local varieties, strengthen seed sovereignty and maintain agrobiodiversity for long-term resilience.

Agroforestry. Agroforestry integrates trees with crops to improve soil fertility, moisture retention, biodiversity and climate resilience. Farmers commonly grow fruit trees such as litchi and mango alongside crops to provide food, income and shade. Turmeric and ginger may be cultivated under tree

shade, while leafy vegetables such as broadleaf mustard benefit from organic matter and improved microclimatic conditions.

Livestock integration. Livestock provides farmyard manure that improves soil fertility and structure. Farmers use cow dung and composted animal waste in crop fields to increase organic matter, improve moisture retention and reduce dependence on chemical fertilisers.

Table 4 summarises the comparison between agroecological farming and conventional or input-intensive farming based on four indicators (yield stability, input costs, crop diversity, and climate resilience).

Table 4. Agroecological farming vs conventional/Input-intensive farming: Selected indicators

Indicator	Agroecological farms (diversified systems)	Conventional farms (Monocropping)
Yield stability	Higher (more stable over seasons)	Lower (more affected by climate and pests)
Input costs	Lower (uses local inputs, fewer chemicals)	Higher (depends on fertilisers and pesticides)
Crop diversity	High (mixed crops, rotation, intercropping)	Low (single crop systems)
Climate resilience	Stronger (adaptable to shocks & variability)	Weaker (vulnerable to droughts & floods)

Interviews in Chaukune Rural Municipality, Ward No. 9, Ghatgaun



FOCUS GROUP DISCUSSIONS: SUMMARY OF FINDINGS

The Participatory Action Research (PAR) undertaken in Chingad and Chaukune Rural Municipalities of Surkhet, Nepal, provides a detailed account of how rural farming communities are experiencing and responding to changes in climate, agriculture, food systems, natural resources and livelihoods. The findings presented in **Annex 1** (Focus Group Discussion at Chingad Rural Municipality, Surkhet) and **Annex 2** (Focus Group Discussion at Chaukune Rural Municipality, Surkhet) are particularly valuable because they are grounded in the observations and experiences of community members themselves. Participants were asked to compare conditions approximately ten years ago with the situation at present, allowing the research to document changes over time from the perspective of people directly engaged in farming and other rural livelihood activities.

The FGDs present a consistent picture of a rural agricultural system undergoing profound transformation. Farmers describe a past in which agricultural production was closely integrated with livestock, forests, local seed systems, community labour and locally available organic materials. Seeds were selected and conserved within households; agricultural knowledge was transmitted between generations; neighbours exchanged seed and labour; livestock provided manure and food; crop residues and other organic materials were returned to the soil; and diverse cultivated and wild foods contributed to household food security.

The present situation is considerably more difficult. Farmers in both communities report increasingly irregular and untimely rainfall, more frequent droughts, shifting crop calendars, declining water availability, increased pest and disease incidence, deteriorating soil health, loss of biodiversity, declining livestock numbers, increasing dependence on purchased inputs and food, and growing abandonment or underuse of agricultural land. At the same time, the availability of agricultural labour has declined as young people migrate in search of employment. The weakening of agriculture has consequently become both an environmental and a social problem.

The findings also show that climate change cannot be separated from other changes taking place in rural communities. Changes in farming practices, market dependence, mechanisation, migration, declining livestock rearing, deforestation and the

weakening of traditional systems of collective labour and knowledge-sharing interact with climatic pressures. In many cases, these factors reinforce one another. For example, migration reduces the availability of agricultural labour; labour shortages encourage mechanisation and changes in farming practices; changing farming practices increase dependence on purchased inputs; and declining agricultural production further reduces the attractiveness of farming to young people.

Yet the findings do not present rural communities simply as victims of climate change. Both Chingad and Chaukune retain substantial knowledge and practices that can contribute to climate resilience. These include local seed conservation, mixed cropping, intercropping, crop rotation, mulching, composting, use of farmyard manure, rainwater harvesting, conservation farming, organic pest management, food preservation, and use of locally available materials. In this respect, the PAR findings indicate that agroecology is not an entirely new concept for these communities. Many of its principles are already embedded in their traditional agricultural knowledge and practices.

The central message emerging from FGDs is therefore twofold. First, climate change is placing increasing pressure on the ecological, economic and social foundations of rural agriculture. Secondly, communities retain important knowledge, practices and capacities that can be strengthened as part of an agroecological response. The challenge is to protect and revitalise these capacities while adapting them to changing climatic and socioeconomic conditions.

Chingad FGD

Changing farming systems

The FGD in Chingad begins with changes in how farmers select, preserve, and obtain seeds. Ten years ago, seed selection was largely based on farmers' own knowledge and direct observation of crops. For food crops, farmers selected healthy panicles and carefully examined grain quality. The selected seeds were mixed with ash and properly stored for future use. Vegetable seeds were collected from large, healthy fruits after they reached full maturity and were dried in the sun before storage. Fruit crops were propagated through grafting, with seedlings prepared and transplanted. Seeds of spices and cash crops were also carefully selected and stored. Some were placed underground in pits lined with straw and rice husks. Seeds were therefore primarily preserved within the household.

This system placed considerable responsibility and knowledge in the hands of farmers. Seed was not simply an agricultural commodity purchased before each planting season. It was part of the household production cycle. Farmers observed the quality of their crops, selected suitable plants, processed the seed and stored it for future use. When a household did not have sufficient seed, it could exchange or borrow seed from neighbours and relatives.

The situation today is markedly different. Seeds are mainly purchased from agro-vets, while indigenous seed varieties are gradually disappearing. Participants also observed that agricultural production is increasingly dependent on chemical fertilisers and that hand tractors are being used more extensively. Agricultural subsidies have become more accessible, while modern practices are considered less time- and labour-intensive than traditional methods.

The transition in the seed system is particularly significant because it represents a change in the relationship between farmers and agricultural biodiversity. The former system enabled farmers to reproduce seed from their own harvests and to maintain varieties through household and community knowledge. The increasing reliance on purchased seed provides access to external varieties but can also weaken local seed conservation. The disappearance of indigenous varieties consequently represents not only a change in agricultural inputs but also a potential loss of locally accumulated knowledge.

This change is accompanied by changing perceptions of agricultural productivity. Farmers increasingly depend on commercial inputs and market sources. At the same time, climate change makes local production more uncertain. The result is a system in which farmers face a combination of declining control over seed resources and increasing uncertainty over whether crops will perform successfully under changing environmental conditions.

Climate change and the changing agricultural calendar

Climate change is particularly evident in the Chingad participants' description of the agricultural calendar. Ten years ago, farmers followed relatively predictable seasonal patterns. Rice seed was prepared in Baisakh, transplanted from Jestha 12 to Asar 15 and harvested in Kartik. Wheat was sown in Ashoj/Kartik and harvested between Baisakh and Jestha. Maize was planted in Baisakh and harvested in Bhadra, while finger millet was sown in Jestha

and subsequently weeded and harvested later in the season. Finger millet was also intercropped with black gram, demonstrating mixed cropping within the traditional production system.

The present calendar has shifted. Rice seed is prepared in Jestha; transplantation occurs from Asar to approximately mid-Shrawan, and harvesting is completed by the end of Kartik. Wheat is sown later, from Kartik to Mangsir, and harvested from Baisakh to Jestha. Maize is harvested in Asoj rather than Bhadra, while finger millet is harvested in Kartik. Participants attributed these changes to irregular rainfall, insufficient precipitation at the appropriate time, increasing severity of climate change, increased deforestation and rising temperatures. Frequent droughts have become an additional challenge.

These observations illustrate an important dimension of climate change for rain-dependent farmers: the loss of predictability. The problem is not simply that there is less rainfall. Rather, rainfall no longer arrives consistently when crops need it. A planting calendar that was once based on relatively stable seasonal patterns must now be continually adjusted.

Such changes can affect the whole agricultural production cycle. Seed preparation, planting, transplanting, weeding and harvesting all depend on the availability of sufficient water at appropriate times. When rainfall is delayed or insufficient, farmers may be forced to postpone activities, accept reduced yields or invest in additional inputs. In a community where irrigation facilities are already inadequate or unavailable, this vulnerability becomes particularly serious.

The Chingad participants' observations consequently show that climate change is experienced as a disruption of agricultural rhythms. Farmers have not simply lost production because of isolated disasters; they are operating in a climate where the seasonal conditions on which traditional farming practices were based have become less reliable.

From organic nutrient cycles to increased chemical input use

The traditional farming system in Chingad was closely connected to livestock and locally available organic materials. Farmers used straw, crop residues and green leaves as mulching materials. Organic fertilisers included cow, buffalo and goat urine as well as dung-based compost. Cow urine was traditionally applied to fields during Shrawan.

This system created a close relationship between crops, livestock and soil. Animal manure provided nutrients, while crop residues and plant materials could be returned to the land. The use of mulch also helped protect the soil and retain moisture. Such practices reduced the need to purchase agricultural inputs and made use of materials that were already available within the farming system.

Today, the number of cattle, buffaloes and goats being reared has decreased. Livestock rearing is declining, and there is a shortage of people available to collect traditional resources such as leaf litter, crop residues and mulch. At the same time, chemical fertilisers are widely used because they are readily available on the market and supported by subsidies. Organic fertilisers continue to be used, but some are now purchased from the market.

This change has implications beyond fertiliser choice. The decline of livestock weakens one of the foundations of the traditional farming system. When fewer households keep cattle, buffaloes or goats, less manure is available. When fewer people remain in farming, there is also less labour for collecting organic materials and maintaining labour-intensive practices.

The increasing use of chemical fertilisers should therefore be understood as part of a broader transformation of the farming system. Farmers are responding to labour shortages, changing climatic conditions and the availability of commercial inputs. The transition may reduce the time and labour required for some agricultural activities, but it can also increase dependence on external inputs.

The Chingad participants later identify declining soil health, loss of organic matter and deterioration of soil properties as major agricultural problems. This creates an important link between the decline of traditional organic practices and the present condition of agricultural soils.

Mechanisation and the transformation of agricultural labour

Agricultural tools and technologies have undergone a major transformation in Chingad. Traditional farming relied on tools such as the plough, yoke, wooden leveller, hoe and spade. Agricultural products and seeds were stored in traditional structures, including Bhakari, Thahara, Thun, Doko and Doilo.

Today, mini tillers and power tillers are widely used. Iron ploughs have replaced traditional wooden ploughs, while plastic sacks, drums and containers are increasingly used for storing and transporting agricultural products. Participants noted that farming has become less labour-intensive and more convenient.

The transformation is particularly evident in crop processing. Traditional tools such as Dhikki, Jato, and water mills (Pani Ghat) were previously used for grinding, husking, and processing grains. Today, combined mills, diesel mills and electric mills are commonly used.

The participants' observations suggest that mechanisation is both a consequence of and a response to rural labour shortages. There are fewer people available for agricultural work, while modern technologies reduce the amount of labour required. Migration has therefore contributed to technological change, while technological change is simultaneously altering the nature of agricultural work.

This does not mean that mechanisation is viewed negatively by the communities. The participants recognise that modern technologies save time and reduce physical labour. The challenge lies in ensuring that the adoption of modern machinery does not lead to the abandonment of ecological practices that remain important for soil, water, and biodiversity.

Declining livestock and changing rural production

Livestock once occupied a central position in Chingad households. Cows, buffaloes, goats and local chickens were commonly reared, with cows and buffaloes traditionally kept in sheds. Today, traditional cattle rearing has declined, while broiler and layer poultry farming has become more common. Improved breeds of goats, pigs and poultry are increasingly replacing indigenous animals.

This shift reflects the broader movement from diversified household production towards more specialised forms of livestock production. Indigenous livestock were integrated into household agriculture and contributed manure, food and income. Commercial poultry and improved breeds may provide opportunities for income generation, but they also represent a greater orientation towards market-based production.

The decline of livestock has consequences for crop production as well. Traditional manure systems become harder to sustain as fewer households keep animals. At the same time, declining livestock numbers reduce the diversity of household livelihood sources.

The Chaukune FGD reinforces this trend, reporting that households now keep fewer livestock than before and that livestock rearing has declined alongside migration and shortages of human resources. Participants explicitly associated the decline of livestock with lower income generation.

Bees, forests and ecological change

The decline of bees provides a particularly visible example of broader ecological change. In Chingad, beehives were once commonly found in households, and wild bees naturally settled in them. Bees were also abundant in forests and other natural environments. Today, however, bees have become increasingly rare.

The disappearance of bees is significant, as participants also report increasing deforestation and environmental degradation. Deforestation has increased in rural areas, while development and construction are sometimes undertaken in what participants describe as an unscientific manner.

The relationship between forests, pollinators and farming is consequently changing. The loss of forests and natural habitats affects biodiversity and can also disrupt agricultural processes that depend on ecological relationships.

The participants' observations on forest foods reinforce this concern. Chingad communities have traditionally used a wide variety of forest products, including Kaapro, bamboo shoots, Jibre saag, Dungre saag, Koiralo, Nigalo, wild garlic, Asuro, Rakta chandan, various wild fruits and mushrooms.

These foods are not merely supplementary resources. They form part of the community's wider food system and represent an important reserve of nutritional and ecological diversity. Their continued availability depends on the health of forests and water systems.

Land abandonment, water scarcity and disaster vulnerability in Chingad

The agricultural landscape itself is changing. Participants reported that almost all available land was cultivated in the past. Today, a large portion of land is becoming barren due to abandonment. Many

people have migrated abroad for employment, creating a shortage of agricultural labour.

Land abandonment is therefore connected to both economic and environmental pressures. Agriculture becomes less attractive when production is uncertain, labour is scarce and farming costs increase. Migration provides an alternative source of livelihood but simultaneously reduces the number of people available to cultivate land.

Participants also observed an increase in natural disasters. Floods, landslides, earthquakes, storms and soil erosion occurred less frequently in the past, while deforestation and forest fires have increased significantly in recent times.

Water availability has deteriorated alongside these changes. Previously, rivers, streams, traditional water wells and ponds provided abundant water, while springs remained available. Today, rainfall is no longer arriving in its proper season, and snowfall in the mountains has decreased or become irregular. Ponds and springs are gradually drying up.

The connection between rainfall, groundwater and water sources is particularly important. Participants recalled that regular rainfall and the presence of many ponds helped maintain groundwater recharge, preventing springs from drying or declining. The deterioration of these systems now directly affects agriculture and household water availability.

Agricultural problems and livelihood consequences in Chingad

The Chingad participants identify a cluster of agricultural problems: significantly reduced crop production, more frequent prolonged droughts, difficulty obtaining seeds at the appropriate time, increased pests and diseases, inadequate or unavailable irrigation, and declining soil health. They report that the soil lacks organic matter and beneficial microorganisms and that its chemical and physical properties are being negatively affected. Climate change is described as having a strong impact on both agriculture and livelihoods.

These problems interact rather than occur independently. Drought reduces production; inadequate irrigation makes it difficult to compensate for drought; soil degradation reduces crops' ability to withstand stress; and pests and diseases further reduce yields. At the same time, the loss of biodiversity weakens the diversity of the agricultural system.

The livelihood consequences include increasing food insecurity, declining agricultural production, deteriorating soil health, increased incidence of pests and diseases and declining agro-biodiversity.

The overall picture is therefore one of a system becoming increasingly vulnerable to climatic shocks while simultaneously losing some of the ecological and social resources that previously helped absorb those shocks.

Food systems in Chingad

The Chingad participants cultivate a diverse range of crops, including rice, maize, wheat, millet, foxtail millet, potato, vegetables and fruits. The FGD records household food availability as three months in the past and six months at present. The figures should be understood as the participants' reported comparisons rather than as independently measured food-security indicators.

More broadly, however, the discussion shows that the community's food system extends beyond cultivated crops. Forest foods, wild fruits, mushrooms and aquatic resources have historically contributed to diets. Participants mention fish, crab, eel-like fish, ghongi, and other aquatic organisms, as well as wild edible greens such as aule saag and pani saag.

The decline in forest and aquatic resources consequently reduces food-system diversity. When cultivated production is affected by drought or pests, households have fewer alternative sources to draw upon.

Livestock and agriculture previously operated on a larger scale and generated better income. Today, livestock rearing has declined, resulting in lower income generation. Participants also identify food shortages, fewer people engaged in agriculture, the replacement of local food with imported food, and major changes in food habits as impacts associated with climate change and broader changes in the food system.

Chaukune FGD

The Chaukune farming system

The findings from Chaukune closely reinforce the Chingad experience while providing further detail on crop diversity and seed systems.

Ten years ago, farmers allowed crops to fully mature and ripen before harvesting. They selected healthy, well-developed and fully mature seeds, cleaned and

sorted them and stored them for future use. Today, seeds and inputs are obtained from neighbours, cooperatives, agro-vets and local government sources. Participants specifically noted that hybrid seeds cannot be saved and reused for the following season and that seed storage and conservation practices are no longer properly maintained.

Farmers nevertheless continue to cultivate a broad range of crops. Rainy-season crops include rice, maize, beans, sesame, lentils, groundnuts, cucumber, bitter gourd, bottle gourd, pumpkin, sponge gourd, finger millet, eggplant, and chilli. Winter crops include potato, radish, cauliflower, mustard, wheat, leafy mustard, chickpea, pea, lentil, barley, linseed, onion, garlic, coriander, fenugreek and fennel. Spring crops include maize, okra, chilli, eggplant and tomato.

The continued diversity of crops represents an important strength. However, participants report that although many of the same crop types are still cultivated, production has decreased and some crops are gradually disappearing from the farming system. Changes in climate, rainfall and farming practices have affected both productivity and crop diversity.

The agricultural calendar remains closely tied to rainfall. Maize is planted in Baisakh and harvested in Bhadau; rice seed is selected and stored in Jestha, transplanted in Asar/Shravan and harvested in Asoj/Kartik; wheat is sown in Mangsir and harvested in Chaitra; and groundnut and sesame are sown in Asar and harvested in Kartik.

Participants report that rainfall is now irregular and insufficient. The monsoon often starts approximately a month later than before, while winter rainfall has become almost absent. Deforestation, industrial emissions and excessive or improper use of chemical fertilisers and pesticides are also identified as environmental problems.

Traditional organic practices and modern farming in Chaukune

The Chaukune farming system historically relied heavily on locally available organic resources. Farmyard manure, organic pesticides and compost made from weeds, grass and dry leaves were commonly used to maintain soil fertility and support crop production.

These practices demonstrate that ecological management of soil and pests was already part of local farming knowledge. They also provide a

potential foundation for strengthening agroecological approaches under present conditions.

At the same time, agriculture in Chaukune has become increasingly mechanised. Wooden ploughs are being replaced by tractors, and hand tools are becoming less common. Participants acknowledge that modern technologies make farming more time-saving and comfortable. Demonstration and imitation of new agricultural practices are also increasing.

Harvesting, storage and processing have similarly changed. Traditional systems relied on sickles, oxen, manual weeding, doko, sun-drying, bhakari, jato and dhikki. Today, tractors, threshers and flour mills have replaced many of these practices, although water mills remain in use in some areas.

The evidence, therefore, suggests that the communities are not rejecting modern technology. Rather, they are adapting to it because of labour shortages and the practical benefits it offers. The challenge for climate-resilient agriculture is to combine appropriate mechanisation with practices that conserve soil, water, biodiversity and local seed resources.

Land abandonment and the decline of farming as a livelihood

The Chaukune FGD provides a particularly clear account of the changing relationship between land ownership and agricultural production. In the past, many people who farmed did not have sufficient land, while some who did not farm owned more agricultural land. Land distribution was therefore not closely aligned with actual farming activity.

Today, many people have land but are no longer engaged in farming. Participants report a growing perception that agricultural production is either impossible or unprofitable. Farming is no longer viewed as a reliable main source of livelihood for many households, and agricultural land is consequently left uncultivated or underutilised.

This finding is important because it shows that the decline of agriculture is not simply a consequence of a lack of land. Land remains available, but the economic, social and environmental conditions required to make use of it are weakening.

Migration plays an important role in this process. The shortage of agricultural labour is linked to migration and settlement in cities in search of employment. As households lose labour, maintaining diversified farming becomes more difficult.

The resulting cycle is clear: declining agricultural viability encourages migration; migration reduces labour availability; labour shortages contribute to land abandonment and mechanisation; and reduced cultivation further weakens local food production and agricultural livelihoods.

Water, rainfall and disaster vulnerability in Chaukune

Chaukune participants similarly recall that the past was characterised by more stable weather and favourable farming conditions. Natural disasters were less frequent, forests were more extensive, and the environmental balance was considered better. Today, floods, landslides and droughts occur more frequently and cause greater damage. Climate change and environmental imbalance are identified as major contributing factors.

Water sources have declined significantly. In the past, rivers, streams, springs, wells and ponds retained sufficient water throughout the year. Even during the dry season, most sources remained available. Today, rivers and streams are drying up, springs are weakening or disappearing, and river water levels have fallen significantly.

Rainfall has likewise become less predictable. Previously, monsoon rainfall was regular and well distributed, resulting in relatively stable farming conditions and comparatively low crop losses. At present, rainfall has become irregular and extreme. Excessive rainfall during the rainy season can cause flooding, while winter and spring bring little or no rainfall.

This combination of drought and excessive rainfall creates a particularly difficult agricultural environment. Farmers must cope with both water scarcity and excessive water. The loss of predictable rainfall also makes traditional agricultural calendars less reliable.

Food security in Chaukune

The Chaukune FGD provides one of the clearest expressions of the decline in household food self-sufficiency. Participants reported that ten years ago they cultivated rice, millet, maize, barley, wheat, groundnut, potato, fruits and vegetables, and that harvested food was sufficient for up to one year of household consumption. Today, farm production is reported to provide only about three months' worth of household food.

This represents a major change in the role of farming. Agriculture previously served not only as a

source of income but also as the principal basis of household food security. Today, households must rely much more heavily on external sources of food.

The loss of agricultural self-sufficiency is compounded by the decline in forest and aquatic foods. Chaukune participants identify a wide range of wild foods, including jaluke, kholi saag, niguro, syaula, mushrooms, bako, nigalo shoots, bamboo products, kapro, koirala, harra, bayar, amala, khachuri, pateula, githa and yam. Fish and other aquatic foods are also part of the traditional food system. Participants report that these resources are now available in smaller quantities.

The food system is therefore losing diversity on several fronts simultaneously. Cultivated food production is declining, livestock numbers are decreasing and wild and forest foods are becoming less available.

Livestock rearing, once an important part of household production, has also declined. Participants report that households previously kept goats, buffaloes, cows, oxen, chickens and pigs. Livestock were grazed in forests or fed with grass brought home. Today, fewer livestock are kept, and animals are more commonly raised in stalls around the household. Forest grazing has become restricted or uncommon.

The consequences include greater dependence on external sources for meat and dairy, declining self-production of livestock products and reduced income-generating opportunities from agriculture and livestock.

Common findings in the FGDs

The erosion of community-based agricultural practices

One of the most significant findings common to the FGDs is the weakening of collective agricultural practices.

In Chingad, seeds were historically produced in farmers' own fields and exchanged or shared among neighbours and community members. In Chaukune, participants similarly recalled that locally produced seeds and agricultural products were exchanged within communities, while informal sharing and barter were common.

Mutual labour exchange, known in Chaukune as Arma-Parma, was once central to agricultural

production. It covered planting, weeding, carrying manure, harvesting, processing and storage. Participants now report that it is increasingly difficult to find people for such mutual labour exchange.

This change has profound implications. Traditional agricultural systems were not simply collections of individual household activities. They were supported by reciprocal relationships. Farmers could rely on neighbours for labour and seed, while community members collectively maintained agricultural knowledge and practices.

Today, paid labour and mechanisation are becoming more common. In Chaukune, participants report that hiring labour for wages has become increasingly common, while machines and modern tools are replacing traditional manual labour.

This transition reflects changes in the availability of labour and also alters the social organisation of agriculture. The movement from reciprocal labour exchange towards hired labour represents a shift from a system based partly on social relations to one increasingly mediated by money and markets.

Climate change, pests and diseases

The two annexes demonstrate a clear increase in concern over pests and diseases.

In Chingad, participants identify an increase in crop pests and diseases as one of the major agricultural challenges. In Chaukune, reported livestock diseases in the past included anthrax, Foot and Mouth Disease, mastitis, mukhyano, khoret, and byagute, while participants now identify conditions such as lumpi skin disease and cholera. Crop pests and diseases include fall armyworm, tuta, black rust, beetles, borers, and fungal diseases, while storage pests include whitefly, silesa, beetles, and weevils.

Chaukune participants explicitly state that climate change has increased the incidence and severity of crop pests and livestock diseases. Adverse weather conditions damage crops, reduce agricultural production and contribute to food insecurity and hunger.

The problem is aggravated by inadequate access to diagnosis and treatment. Participants identify the lack of proper disease identification, delays in obtaining medicines and treatment, and the increased severity of diseases when treatment is delayed. The resulting impacts include income loss, food insecurity and increased expenditure.

For farmers, this can create another cycle of vulnerability. Climate stress weakens crops and animals; pests and diseases increase; farmers spend more on control measures; production declines; and household income and food security are further undermined.

Unequal impacts on women, youth, children, farmers and livestock herders

The annexes make clear that climate change does not affect everyone in the same way.

Women are among the most affected groups. In Chaukune, participants explain that men increasingly migrate for employment, leaving women to work directly in agriculture while simultaneously managing household responsibilities. Women are also responsible for collecting grass, firewood and water.

This means that environmental degradation can increase women's workloads even where they are not directly affected by a particular disaster. Drying water sources require greater effort to collect water. Declining agricultural labour means more responsibility for women in crop production. The combination of agricultural and domestic work can therefore intensify their vulnerability.

Youth are affected differently. Both communities associate youth migration with a lack of local employment opportunities and declining interest in agriculture. In Chaukune, participants report that young people increasingly believe that better income and employment opportunities are available outside the village or country.

This has implications for the future of agriculture. When young people leave, the rural labour force becomes older and smaller. Traditional agricultural knowledge may also be lost if it is no longer transmitted between generations.

Livestock herders are vulnerable to deforestation, environmental degradation and drying water sources. Reduced forest cover also affects groundwater recharge. Farmers are broadly affected because they depend directly on agriculture, livestock and forest resources for their livelihoods.

Children are also affected. They are involved in farming and household activities and are exposed to the consequences of declining food availability, disease and nutritional problems. Chaukune participants specifically associate climate change with inadequate food availability, poor dietary conditions, malnutrition and nutritional deficiencies among children.

The social distribution of climate vulnerability is therefore closely connected to the organisation of household labour and livelihoods.

Climate change and the wider livelihood crisis

The Chaukune findings summarise the livelihood consequences of climate change in particularly direct terms. Declining agricultural production and increased dependence on imported food have contributed to economic difficulties. Adverse weather and increased pest and disease pressure have reduced production and caused food insecurity. Human and animal diseases have further affected livelihoods. Soil degradation and biodiversity loss have reduced agricultural productivity and increased food shortages. Floods and landslides have damaged farming systems, while drought, excessive rainfall and inadequate irrigation have weakened agriculture. Drying rivers and streams have also contributed to drinking-water shortages.

Chingad participants describe a similar pattern: food insecurity has increased, agricultural production has declined, soil health has deteriorated, pests and diseases have increased, and agro-biodiversity has declined.

These observations demonstrate that climate change is not simply an agricultural issue. It has become a livelihood issue, a food security issue, a water issue, and a social issue.

The impacts also reinforce one another. Reduced production means greater dependence on purchased food. Increased dependence on markets raises household expenditure. Declining agricultural income encourages migration. Migration creates labour shortages. Labour shortages make traditional farming practices more difficult. At the same time, the decline in forests and water resources removes important supplementary sources of food and income.

Existing community responses

Despite the severity of the identified problems, both communities have already adopted several responses consistent with agroecological adaptation.

In Chingad, participants report rainwater harvesting in ponds, conservation and production of local pest-, flood- and drought-resistant seeds, conservation farming, crop rotation, intercropping and mixed cropping. They also use local materials for storage and practise food preservation. Seasonal foods such as dried meat, yams, radish and leafy greens are preserved for consumption during the off-season.

These practices represent a broad approach to resilience. Water is conserved; soil is protected; crop diversity is maintained; locally adapted seed is preserved; and food is stored for periods when fresh production is unavailable.

Chaukune participants identify similar measures, including Chhapo kheti, or mulching-based farming, in which crop residues and organic materials are used to conserve soil moisture and improve soil health. Rainwater harvesting is used for irrigation and household purposes. Farmers also produce and conserve local disease-resistant seeds and use organic manure, compost and biological pest-control methods to reduce chemical use.

These measures are particularly significant because they directly address the problems identified elsewhere in the research. Mulching responds to soil moisture loss; rainwater harvesting responds to declining water availability; local seed conservation responds to the erosion of seed autonomy; organic manure responds to declining soil health; and biological pest management responds to increasing pest pressure and chemical dependence.

Agroecology as a pathway for strengthening resilience

The FGD findings provide a strong basis for understanding agroecology as a practical response to the challenges experienced by the communities.

Many of the practices described by participants already embody agroecological principles. Farmers have traditionally maintained crop diversity, conserved seed, integrated livestock with crops, used organic manure, recycled crop residues, managed soil through locally available materials, practised mixed cropping and intercropping, exchanged seed and labour, and preserved food.

These practices are particularly relevant under changing climate conditions. Crop diversity can spread risk across different crops and seasons. Local seed conservation can maintain varieties adapted to local conditions. Mulching and organic matter can help retain soil moisture. Compost and manure can contribute to soil fertility. Rainwater harvesting can provide water during dry periods. Food preservation can reduce dependence on markets during periods of low production.

Agroecology can therefore be understood not simply as a return to the past, but as a way of combining the strengths of traditional knowledge with appropriate contemporary technologies.

The research does not support an argument that all traditional practices should simply be restored unchanged. The participants themselves recognise the usefulness of modern technologies, particularly those that reduce labour requirements and save time. Tractors, threshers, mills and other machinery have become important precisely because the rural labour force has declined.

Interviews in Chaukune
Rural Municipality,
Ward No. 9, Ghatgaun



The more appropriate direction is therefore one of integration: modern technologies should support, rather than undermine, ecological farming practices. Mechanisation can reduce physical burdens while farmers continue to maintain crop diversity, organic soil management and local seed systems. Digital technologies can expand access to knowledge while local farmers' experience remains central to decision-making.

Rebuilding seed systems and agricultural biodiversity

Seed emerges as a particularly important entry point for strengthening resilience. The traditional seed systems of both communities were based on farmer selection, household conservation and community exchange. These systems maintained locally adapted varieties and reduced dependence on external markets.

The present trend towards purchased and hybrid seeds has weakened this system. Chaukune participants specifically report that hybrid seeds cannot be saved and reused, while seed storage and conservation practices are no longer properly maintained. Chingad participants similarly report that indigenous seed varieties are gradually disappearing.

Strengthening community-based seed conservation could therefore have multiple benefits. It could preserve agricultural biodiversity, maintain farmer knowledge, reduce dependence on external suppliers and improve access to planting material following climatic shocks.

The emphasis should not necessarily be on rejecting improved varieties. Rather, the findings suggest the importance of ensuring that farmers retain the capacity to conserve and reproduce locally suitable varieties alongside access to other seed sources.

Rebuilding soil and water resilience

The FGDs also highlight soil and water as fundamental areas for action.

Farmers in Chingad report that the soil lacks organic matter and beneficial microorganisms and that its chemical and physical properties are deteriorating. Chaukune participants similarly describe the harmful effects of excessive and improper use of chemical fertilisers and pesticides on soil health.

The traditional use of farmyard manure, compost, crop residues and green materials provides a basis for addressing these concerns. Chhapo kheti, in particular, directly connects soil protection with moisture conservation.

Water management is equally important. Both communities describe the drying of rivers, streams and springs and the increasing unpredictability of rainfall. Rainwater harvesting is therefore a practical response that can reduce vulnerability to dry periods.

The evidence suggests that soil and water management should not be treated as separate interventions. Healthy soils can retain moisture more effectively, while water conservation can reduce pressure on agricultural land. Together, they can increase the capacity of farming systems to withstand climatic variability.

Rebuilding community cooperation

The weakening of Arma-Parma, seed exchange, barter and collective knowledge-sharing is one of the less visible but potentially serious consequences of rural transformation.

The traditional agricultural system was supported by social relationships. Farmers could exchange seed, share labour and rely on collective knowledge. These arrangements reduced the costs and risks of farming.

The present system is increasingly based on purchased inputs, paid labour, commercial seed and machinery. These changes address genuine labour shortages and provide practical benefits, but they also reduce certain forms of community interdependence.

Strengthening agroecology should therefore include strengthening community institutions. Farmer groups, community seed systems, collective water management, knowledge-sharing activities and local food preservation initiatives could help rebuild some of the social foundations of resilience.

Such measures could also create opportunities for young people to engage in agriculture in ways that are compatible with contemporary interests and technologies.

Gender and generational considerations

The findings demonstrate that an effective climate response must take gender and generational differences into account.

Women already carry substantial responsibilities for agricultural production and household management. As men migrate, these responsibilities increase. Climate-related water scarcity and declining availability of fodder and other natural resources can further increase the time and labour required for household tasks.

Young people, meanwhile, require viable reasons to remain connected to agriculture. The current perception that agriculture is unprofitable and that better employment opportunities are available elsewhere is contributing to migration. If agriculture is to remain viable, it must provide meaningful livelihoods as well as opportunities for innovation and learning.

The intergenerational transfer of agricultural knowledge is particularly important. Traditional knowledge cannot survive if the people who possess it are unable or unwilling to transmit it. At the same time, younger generations have access to digital technologies and new forms of information. A productive approach would combine these two sources of knowledge.

POLICY AND ADVOCACY IMPLICATIONS

Collaboration between government and non-government organisations can strengthen awareness and advocacy on agroecology and climate change. Participatory approaches such as forum dialogues, awareness programmes, street dramas, training and workshops help communities understand climate-resilient agricultural practices. Seed exhibitions, local food festivals and honey festivals also promote indigenous seeds, local food systems and biodiversity while supporting farmer livelihoods. Together, these initiatives strengthen knowledge sharing and community engagement around agroecology and climate adaptation.

Community campaigns and solidarity

Traditional systems such as Aichopaicho and Arma Parma continue to support agriculture and livelihoods. Aichopaicho is a reciprocal labour-exchange system in which farmers help one another with ploughing, transplanting, harvesting and threshing without cash payment, reducing labour costs and helping ensure timely farm work. Arma Parma refers to the exchange or sharing of agricultural resources such as seeds, tools, and, in some cases, livestock. Seed exchange helps conserve local and climate-resilient varieties, while animal exchange can help poorer households build livestock assets and share benefits such as milk, manure and income. Together, these practices strengthen cooperation, reduce farming costs, conserve biodiversity and improve food security and resilience.

Community advocacy and organisational practices

Rural communities use a range of advocacy and organisational practices to strengthen resilience.

Palika delegations allow farmers and community groups to raise climate and agricultural concerns directly with local government. Memoranda are submitted to request responses to crop losses, water scarcity and gaps in services. Groups and cooperatives can improve access to credit, seeds and training while strengthening farmers' market position. Local food fairs and seed-exchange programmes promote indigenous seed conservation, dietary diversity and local food systems.

CONCLUSION

This Participatory Action Research (PAR) study shows that climate change is significantly affecting agriculture, food security and rural livelihoods in Nepal, particularly among smallholder, marginalised and rainfed farming communities. Rising temperatures, irregular rainfall, droughts, floods, landslides and pest outbreaks are reducing crop productivity, damaging natural resources and weakening traditional farming systems. These pressures also contribute to declining household incomes, rising debt, health and education challenges and migration. At the same time, communities are adopting agroecological practices including crop diversification, mixed farming, composting, mulching, water harvesting, agroforestry, local seed use and livestock integration. Traditional systems such as Aichopaicho and Arma Parma, together with seed and animal exchange and community advocacy, further strengthen local resilience and solidarity. The study concludes that agroecology, combined with indigenous knowledge and community organisation, offers a sustainable pathway to strengthen climate resilience, conserve biodiversity, improve food security and support sustainable rural development in Nepal.

The PAR findings from Chingad and Chaukune Rural Municipalities provide a compelling account of the transformation of rural agriculture under the combined pressures of climate change and socioeconomic change.

The communities describe a past agricultural system characterised by relatively predictable rainfall, abundant water sources, diverse crops, household seed conservation, livestock integration, organic fertilisers, traditional storage and processing, collective labour and strong systems of community exchange. Agricultural knowledge was transmitted through families and communities, while forests and water bodies contributed significantly to food and livelihood security.

The present system is increasingly vulnerable. Rainfall has become irregular and untimely,

droughts are more frequent, and excessive rainfall can produce floods. Rivers, streams, springs and ponds are drying or weakening. Agricultural production has declined, soil health has deteriorated, and biodiversity is being lost. Pests and diseases have become more serious. Livestock rearing has decreased, while agricultural land is increasingly abandoned or underutilised.

At the same time, rural society itself is changing. Young people are migrating in search of employment, creating shortages of agricultural labour. Women are carrying greater responsibilities in farming and household management. Traditional systems of seed exchange, mutual labour and intergenerational knowledge transfer are weakening. Farmers are becoming more dependent on purchased seeds, chemical fertilisers, pesticides, machinery and externally produced food.

The Chaukune findings provide a particularly stark indication of the food-security consequences, with participants reporting that farm production that previously provided household food for up to a year now provides approximately three months of food. The decline in cultivated production is accompanied by a reduction in forest and aquatic food resources, livestock production and local food exchange.

However, the findings also demonstrate that communities retain important adaptive capacities. Farmers continue to use crop rotation, intercropping, mixed cropping, local seed conservation, conservation farming, mulching, rainwater harvesting, organic manure, compost, biological pest management, local storage and food preservation.

These practices are important because they are locally grounded. They draw on knowledge developed through long experience of farming under local ecological conditions. They also provide multiple benefits: improving soil health, conserving moisture, maintaining biodiversity, reducing dependence on external inputs, diversifying production and strengthening food security.

The evidence from Chingad and Chaukune consequently points towards agroecology as a pathway for strengthening both climate resilience and rural livelihoods. Agroecology should not be understood simply as a package of technical practices. The findings show that it also depends upon seed sovereignty, biodiversity, healthy soils, water conservation, livestock integration,

community cooperation, local knowledge and viable rural livelihoods.

The transition to agroecology should therefore build upon what communities already know and practise while responding to the realities of contemporary rural life. Modern machinery can be used where it reduces labour burdens. Digital technologies can complement traditional knowledge. Improved agricultural practices can be introduced without displacing locally adapted seed and ecological knowledge. Market access can be strengthened while maintaining local food production and community exchange.

Most importantly, the research demonstrates that the climate crisis facing these communities is not simply a question of changing weather. It is a challenge to the entire system that connects land, water, seed, crops, livestock, forests, food, labour and community. The loss of one element places pressure on the others. Conversely, strengthening one part of the system can help reinforce the whole.

The communities of Chingad and Chaukune already possess many of the foundations needed for such resilience. Their knowledge of local seeds, organic materials, crop diversity, water conservation, food preservation and collective agricultural practices provides a valuable starting point. What is required is sustained support to protect this knowledge, strengthen viable agroecological practices, address water and soil challenges, improve access to locally appropriate resources and technologies, and create conditions in which farming can once again provide a secure and dignified livelihood.

The PAR findings therefore point towards a vision of climate resilience rooted not in replacing community knowledge with externally imposed solutions, but in strengthening farmers' own knowledge, practices and collective capacities. Agroecology offers a means of doing precisely this: connecting ecological sustainability with food security, livelihood resilience and community self-reliance, while enabling rural communities to adapt their agricultural systems to an increasingly uncertain climate.

Annex 1

Focus Group Discussion at Chingad RM, Surkhet

Farming system

Farming Practices	10 years ago	Today	Reasons/Factors
Seeds selection	- Food crop seeds were selected by selecting healthy panicles and carefully checking grain quality - Selected seeds were mixed with ash and stored properly for future use - Vegetable seeds were collected from large and healthy fruits after full maturity - Vegetable seeds were dried properly in the sun before storage - Fruit crops were propagated through grafting, and seedlings were prepared and transplanted. - Seeds of spices and cash crops were carefully selected before storage - Spice and cash crop seeds were stored underground in pits covered with straw and rice husk for protection - Seeds were mainly preserved within the household	- Seeds are mainly purchased from agro-vets. - Irregular and untimely rainfall has affected farming practices. - Chemical fertilisers are predominantly used in agricultural production. - The use of hand tractors has increased significantly in farming activities. - Broiler feed sacks are commonly used for storage and other household agricultural purposes.	- Indigenous seed varieties are gradually disappearing. - Deforestation has increased in rural areas. - Development and construction activities are often carried out in an unscientific manner. - Agricultural subsidies have become more accessible to farmers. - Modern practices require less time and labour compared to traditional methods.
Seeds/plants brought from	If seeds were unavailable at home, they were exchanged or borrowed from neighbours and relatives		
Crop cycle & monsoon status	- Rice (Dhaan): Seed is prepared in Baisakh, transplanted from <i>Jestha</i> 12 to <i>Asar</i> 15, and harvested in Kartik - Wheat (Gahu): Sown in <i>Ashoj/Kartik</i> and harvested from <i>Baisakh</i> to <i>Jestha</i> - Maize (<i>Makai</i>): Manure is applied and transported in <i>Baisakh</i>, planted in <i>Baisakh</i>, weeded in <i>Baisakh-Asar</i>, and harvested in <i>Bhadra</i> - Finger millet (<i>Kodo</i>): Manure is applied, and seeds are sown in <i>Jestha</i>, followed by weeding and earthing-up with manure application; harvesting is done later - Mixed cropping: In the month of <i>Shrawan</i>, <i>Kodo</i> is often intercropped with black gram (<i>Mas</i>)	- Rice (Dhaan): Seed is prepared in <i>Jestha</i>, transplanted from <i>Asar</i> to mid-<i>Shrawan</i> (around <i>Shrawan</i> 15), and harvested by the end of Kartik - Wheat (<i>Gahu</i>): Sown from <i>Kartik</i> to <i>Mangsir</i> and harvested in <i>Baisakh</i> to <i>Jestha</i> - Maize (<i>Makai</i>): Sown in <i>Baisakh</i>, weeded in <i>Asar</i>, and harvested in <i>Asoj</i> - Finger millet (<i>Kodo</i>): Sown in <i>Jestha</i>, weeded in <i>Asar</i>, and harvested in <i>Kartik</i>	- Irregular rainfall and lack of timely precipitation - Climate change has become more severe - Deforestation has increased significantly - Rising temperature levels. - Frequent occurrence of droughts
Biofertilisers (cow, buffalo, goat, sheep and chicken)	- Mulching materials such as straw (<i>chhapo</i>), crop residues (<i>sotar</i>), and green leaves (<i>syuala</i>) were commonly used - Organic fertilisers, such as cow, buffalo, and goat urine and dung-based compost manure, were applied in farming. - In the month of <i>Shrawan</i>, cow urine (gouth) was traditionally applied in the fields	- The number of cattle, such as cows, buffaloes, and goats, being reared has decreased - Chemical fertilisers are widely used in agriculture - Organic fertilisers are also purchased and used from the market	- Livestock rearing is declining. - There is a shortage of people collecting traditional resources like leaf litter (<i>syuala</i>), crop residues (<i>sotar</i>), and mulch (<i>chhapo</i>) - Chemical fertilisers are easily available in the market and are also supported through subsidies
What tools and technologies are there? (Cropping system, sowing method, inflow, storage)	- Traditional tools such as the plough, yoke, wooden leveller, hoe, and spade were commonly used for planting and sowing activities - Agricultural products and seeds were stored in traditional storage structures such as <i>Bhakari</i>, <i>Thahara</i>, <i>Thun</i>, <i>Doko</i>, and <i>Doilo</i>	- Mini tillers and power tillers are commonly used in modern farming practices - Iron ploughs are used instead of traditional wooden ploughs - Plastic sacks (<i>kata</i>) are used for storing and transporting agricultural products - Plastic drums are used for storing grains and other materials - Plastic containers made from sheets (<i>palen pata ko drum</i>) are also used for storage purposes	- Farming practices have become less labour-intensive and more convenient - There is a shortage of available human labour for agricultural activities

Farming Practices	10 years ago	Today	Reasons/Factors
What tools and technologies are there? (Cropping system, sowing method, inflow, storage)	- Traditional tools such as the plough, yoke, wooden leveller, hoe, and spade were commonly used for planting and sowing activities - Agricultural products and seeds were stored in traditional storage structures such as <i>Bhakari</i>, <i>Thahara</i>, <i>Thun</i>, <i>Doko</i>, and <i>Doilo</i>	- Mini tillers and power tillers are commonly used in modern farming practices - Iron ploughs are used instead of traditional wooden ploughs - Plastic sacks (<i>kata</i>) are used for storing and transporting agricultural products - Plastic drums are used for storing grains and other materials - Plastic containers made from sheets (<i>palen pata ko drum</i>) are also used for storage purposes	- Farming practices have become less labour-intensive and more convenient - There is a shortage of available human labour for agricultural activities
Honey bee for pollination	- Beehives were commonly found in every household - Wild bees used to naturally come and settle in the hives - Bees were abundantly found in forests and natural environments	Bees have become increasingly rare in recent times	
Method of harvest, storage & processing	- Traditional processing tools such as <i>Dhikki</i>, <i>Jato</i>, and water mills (<i>Pani Ghat</i>) were used for processing agricultural products - These tools were commonly used for grinding, husking, and processing grains before consumption	Combined mills, diesel mills, and electric mills are now commonly used for processing agricultural products	
What animals are reared? And how are they raised?	- Cattle such as cows, buffaloes, goats, and local chickens were commonly reared in rural households - Cows and buffaloes were traditionally kept and raised in sheds (cow sheds or barns)	- Traditional livestock rearing of cows and buffaloes has declined, and people are now more engaged in broiler and layer poultry farming - Improved breeds of goats, pigs, and poultry are increasingly being raised instead of local indigenous animals	- Farming practices have become less labour-intensive and more convenient - There is a shortage of available human labour for agricultural activities
Disaster vulnerability (flood, landslides, erosion & earthquake)	In the past, natural disasters such as floods, landslides, earthquakes, storms, and soil erosion occurred less frequently compared to the present	More	Deforestation and forest fires have increased significantly in recent times
Changes in Water Sources (River, ponds, wells, pits/ small ditches)	There used to be abundant water sources, such as rivers, streams, traditional wells, and ponds	Less	Rainfall is no longer occurring in its proper season, and snowfall in the mountains has also decreased or become irregular
Pattern of rainfall & drought	- In the past, rainfall was regular, so droughts were rare - Due to the presence of many ponds and water bodies, groundwater recharge was good, and water sources (springs) did not dry up or decrease	Due to irregular rainfall, water sources such as ponds and springs are gradually drying up	Deforestation and fire
What are the problems and challenges of farming?	- Crop production has decreased significantly - Prolonged droughts have become more frequent - Seeds are not available at the right time for farming - The incidence of pests and diseases has increased - Irrigation facilities are inadequate or unavailable - Soil lacks organic matter and beneficial microorganisms - The chemical and physical properties of soil are being negatively affected - Increasing climate change has had a strong impact on agriculture and livelihoods		

Farming Practices	10 years ago	Today	Reasons/Factors
How have problems and challenges affected livelihoods?	- Food insecurity has increased in rural communities - Agricultural production has declined - Soil health has deteriorated over time - The incidence of pests and diseases has increased significantly - Biodiversity has been declining, leading to the loss of agro-biodiversity	- Traditional livestock rearing of cows and buffaloes has declined, and people are now more engaged in broiler and layer poultry farming - Improved breeds of goats, pigs, and poultry are increasingly being raised instead of local indigenous animals	- Farming practices have become less labour-intensive and more convenient - There is a shortage of available human labour for agricultural activities

Food

Subject	10 yrs ago	Now
What are the crops produced on your land, and for how many months does the food last?	- Rice, maize, wheat, millet, foxtail millet, potato, vegetables, fruits 3 months	- Rice, maize, wheat, vegetables, fruits, etc 6 months
Non-farm foods & fodder/timber (Uncultivated) (Khetbari, Kholanala, Pokhari, Banjangal)	- Forest foods include wild edible plants and products such as <i>Kaapro</i>, bamboo shoots, <i>Jibre saag</i>, <i>Dungre saag</i>, <i>Koiralo</i>, <i>Nigalo</i>, wild garlic (<i>Ban lasun</i>), <i>Asuro</i>, and <i>Rakta chandan</i>. - Wild fruits and other forest products include <i>Phale kafal</i>, <i>Khair</i>, <i>Daalchini</i>, <i>Chuttraa Tiju kafal bako</i>, <i>Aiselu</i>, and <i>bhakamilo</i>	- Forest-based foods include edible wild plants such as <i>Jibre</i>, <i>Koiralo</i>, <i>Maalu</i>, <i>Nigalo</i>, and <i>Asuro</i>. - Wild fruits and mushrooms include <i>Kafal</i>, <i>Vakamilo</i>, <i>Chyau</i> (mushroom), <i>Chutra</i>, <i>Aiselu</i>, <i>Patyaula</i>, <i>Phale kafal</i>, <i>Tiju amala</i>, and <i>Hada</i>. - Other important forest resources include <i>Raktachandan</i>, <i>Khair</i>, <i>Dungre</i>, and <i>Bako</i>.
What is the status of food obtained from rivers and water resources?	- Forest and aquatic foods include fish (<i>maachbha</i>), crab (<i>gagata</i>), eel-like fish (<i>pataina</i>), ghongi and earthworm - Wild edible greens include aule saag and pani saag. - Rivers used to have abundant wild edible greens (<i>saag</i>) and aquatic organisms.	- Forest and aquatic foods include fish (<i>maachbha</i>), crab (<i>gagata</i>), eel-like fish (<i>pataina</i>), ghongi, and earthworm - Wild edible greens include <i>aule saag</i> and <i>pani saag</i>. - Rivers used to have less abundant wild edible greens (<i>saag</i>) and aquatic organisms.
What are the problems and challenges of farming?	- Crop production has decreased significantly - Prolonged droughts have become more frequent - Seeds are not available at the right time for farming - The incidence of pests and diseases has increased - Irrigation facilities are inadequate or unavailable - Soil lacks organic matter and beneficial microorganisms - The chemical and physical properties of soil are being negatively affected - Increasing climate change has had a strong impact on agriculture and livelihoods	
What is the status of livestock rearing? How much profit was made from sales previously, and how much is made now?	In the past, livestock and other agricultural activities were practised on a larger scale, and income generation was good.	Nowadays, livestock rearing has declined, resulting in lower income.
What are the problems and challenges of food?	- Less production - Unhealthy food - Food insecurity	- Less production - Unhealthy food - Food insecurity
What is the impact of climate change on food security and livelihoods?		- Food shortage - Fewer people are engaged in agriculture - Exported food replaces the local food - Food habits have drastically changed

Social practices of farming

Theme	10 years ago	Now
Exchange of seeds and crop products	Seeds were produced in farmers' own fields and exchanged and shared among neighbours and community members.	Due to dependence on the market for seeds, seed exchange and sharing among community members have decreased.
Mutual participation of agricultural manpower	In agricultural activities, the traditional practice of mutual labour exchange (Arma-Parma) was followed from planting, weeding, and carrying manure to harvesting, processing, and storage	Nowadays, it is difficult to find people for mutual labour exchange (Arma-Parma).
Sharing agricultural skills, knowledge, and experience	Knowledge and skills related to agricultural and household tools and practices—such as ploughing with a plough (halo), yoke (juwali), traditional alarm systems (jagaran), carrying baskets (doko), storage tools, milling devices (mehi), house construction, bamboo containers (perungo), winnowing trays (suli/dalo), and grain storage bins (bakhari)—were commonly shared and exchanged within the community	It is comparatively less visible now.
What are the social problems and challenges?	There is low interest among youth in exchanging agricultural knowledge and skills, and many people are migrating abroad for employment.	
How have problems and challenges affected livelihoods?	Increased use of imported goods, a growing preference for more comfort and facilities, rising dependence on external sources, and a decline in income-generating opportunities.	

Crops and livestock pests and diseases

Theme	10 years ago	Now
Livestock pest/ diseases	Anthrax, Foot and Mouth Disease, Mastitis, <i>mukhyano</i> , <i>khoret</i> , and <i>byagute</i>	Lumpi skin diseases & Cholera
Crop pest/diseases	Fall armyworm, <i>tuta</i> , black rust, beetle and borer, and fungal diseases	-
Storage pest	White fly, silesia, beetle, and weevil	-
What are the social problems and challenges?	Climate change has increased the incidence and severity of crop pests and livestock diseases.	
How have problems and challenges affected livelihoods?	Adverse weather conditions have damaged crops, reduced agricultural production, and led to food insecurity and hunger, thereby negatively affecting livelihoods.	

Who has been most affected by climate change? Why and how?

Target group	Why are they affected?	How are they affected?
Women	Women are the most affected because men migrate for employment, leaving women to manage agricultural work while also handling household responsibilities.	Women and farmers are the most affected, as they are directly engaged in agriculture and other livelihood activities. The use of chemical inputs in farming, crop cultivation and harvesting, and natural hazards have a greater impact on those actively involved in agricultural work.
Youth	Less attraction towards agriculture	
Livestock herders	Due to the outbreak of livestock diseases and pests, livestock farmers have suffered significant losses.	
Children	Climate change has directly affected children as well, as the prevalence of various diseases has increased. Inadequate food availability and poor dietary conditions have led to malnutrition and nutritional deficiencies among children.	
Farmers	Due to insufficient rainfall at the right time, agricultural production has decreased. The increase in pest and disease outbreaks has led to greater use of chemical inputs for control. Natural hazards have also caused the loss of seeds and farmland.	

How is climate change affecting livelihoods?

- Declining agricultural production and increased dependence on imported food items have led to economic crises.
- Adverse weather conditions and increased outbreaks of pests and diseases have reduced production and caused food insecurity.
- The spread of various diseases among humans and animals has further affected livelihoods.
- Soil degradation and biodiversity loss have reduced agricultural productivity and exacerbated food shortages.
- Floods and landslides have damaged farming systems and increased disease outbreaks.
- Drought, excessive rainfall, and lack of irrigation have weakened the agricultural system.
- Rivers and streams are drying up, leading to a shortage of drinking water

What kinds of efforts have been adopted to mitigate the impacts of climate change?

- Rainwater harvesting in ponds (ghaito) to store rainfall
- Conservation and production of local, pest-, flood-, and drought-resistant seeds
- Adoption of conservation farming practices
- Crop rotation and intercropping systems
- Mixed cropping systems
- Use of local materials for different types of storage structures
- Food preservation practices
- Drying seasonal food items and consuming them in off-season forms, such as dried meat (sinki), yams (pidalu), radish (mula), and leafy greens (saag) for storage and later use

Annex 2

Focus Group Discussion at Chaukune RM, Surkhet

Farming system

Farming Practices	10 years ago	Today	Reasons/Factors
Seeds selection	- Allow crops to fully mature and ripen properly in the field before harvesting, even if harvesting is slightly delayed - Harvest at the right stage to ensure good quality and mature seed production - Select and clean seeds properly after harvest (seed sorting and screening) - Choose only healthy, well-developed, and fully mature seeds for storage - Remove broken, immature, and poor-quality seeds - Store only pest-free, insect-free, and undamaged seeds - Keep selected seeds separately for safe storage and future use	Seeds and inputs are purchased from neighbours, cooperatives, agro-vets, and local government sources.	- Hybrid seeds cannot be saved and reused for the next season as seed - Seed storage and conservation practices are not properly maintained - Quality seed production is not ensured or is very limited - Different sources of seeds are available for farmers (neighbours, cooperatives, agro-vets, and other suppliers)
Seeds/plants brought from	Seeds were traditionally produced at home and stored for future use.	- From cooperatives (sahakari) - From neighbours (chhimeki) - From agro-vets - From local government sources	- Problem of insect and pest infestation in crops - The belief that agro-vet seeds give higher production - Perception that traditional/local seeds give lower yield
Crop cycle & monsoon status	- Rainy season crops: Rice (dhan), maize (makai), beans (bodi), sesame (teel), lentil (maas), groundnut, cucumber (kaankara), bitter gourd (karela), bottle gourd (lauka), pumpkin (pharsi), sponge gourd (chichinda), finger millet (kodo), eggplant (bhanta), chilli (khursani) - Winter season crops: Potato (aalu), radish (mula), cauliflower (kauli), mustard (tori), wheat (gahu), leafy mustard (rayo), chickpea (chana), pea (kerau), lentil (masuro), barley (jau), linseed (alsi), onion (pyaj), garlic (lasun), coriander (dhaniya), fenugreek (methi), fennel (saup) - Spring season crops: Maize (makai), okra (bhindi), chilli (khursani), eggplant (bhanta), tomato (golbheda), etc. - In the past, there was sufficient and regular rainfall - Crops used to grow and thrive well due to favourable weather conditions	- The types of crops grown in the past and present are mostly the same - However, crop production has decreased over time - Some crops are gradually disappearing from the farming system - Changes in climate, rainfall, and farming practices have affected productivity and crop diversity - Nowadays, the monsoon has shifted and become irregular, often starting about a month later than before - In the winter season, there is almost no rainfall - This change has affected farming patterns and crop production due to a lack of timely and sufficient water availability	- Irregular and insufficient rainfall has led to drought and environmental imbalance - Deforestation has contributed to environmental degradation and climate change - Emissions of gases from industries and factories have increased air pollution - Excessive and improper use of chemical fertilisers and pesticides has harmed soil health and the environment
Crop calendar	- Maize (<i>Makai</i>): Planting in Baisakh (with manure application); Weeding in <i>Jestha</i> and <i>Ashar</i>, and again in <i>Saun</i>; Harvesting in <i>Bhadau</i> - Rice (<i>dhan</i>): Seed selection/storage in <i>Jestha</i>; Transplanting in <i>Asar/Shravan</i>; Weeding in <i>Bhadau</i>; Harvesting in <i>Asoj/Kartik</i> - Wheat (<i>gahu</i>): Sowing in <i>Mangsir</i>; Harvesting in <i>Chaitra</i>; Groundnut - Sesame (<i>teel</i>): Sowing in <i>Asar</i>; Harvesting in <i>Kartik</i>		
Biofertilisers (cow, buffalo, goat, sheep and chicken)	- Farmyard manure (gothmal) was commonly used - Organic pesticides were used for pest control - Weeds, grass, and dry leaves were collected, decomposed, and used as compost manure - These organic practices were applied to improve soil fertility and crop production		

Farming Practices	10 years ago	Today	Reasons/Factors
What tools and technologies are there? (Cropping system, sowing method, inflow, storage)	- A wooden plough (kath ko halo) was used for tilling the land - Hand tools such as spade (kodalo), hoe (kuto), and sickle (asi) were commonly used - Storage containers like doko and bhakari, made from bamboo, were used for storing grains	- The use of the traditional wooden plough (kath ko halo) is being replaced by tractors - The use of hand tools like kuto and kodalo has decreased - Modern technologies and machines are increasingly being used in farming - Agriculture is becoming more mechanised compared to traditional practices	- Youth are showing less interest in agriculture - Elderly farmers have limited physical ability to work in farming activities - Farming has become more time-saving and comfortable due to modern practices - Demonstration and imitation of new agricultural practices are increasing among farmers
Honey bee for pollination	- In the past, bees used to naturally come and settle in homes - Beekeeping was practised in traditional mud houses - Bees were also kept in wall holes, especially in wooden or mud structures, particularly in the spring season - Traditional and natural methods of beekeeping were commonly used	- Nowadays, due to drought and dry conditions, forests are being degraded - Bee populations are decreasing, and they do not naturally settle in homes as before - Loss of habitat and environmental changes are affecting traditional beekeeping practices	
Method of harvest, storage & processing	- Crops were harvested using a sickle (aasi) - Fields were ploughed using a wooden plough drawn by oxen - Weeding and digging were done manually using tools like kuto and kodalo - Weeds were also removed by hand - Harvested crops were collected and transported using a doko - Grain processing was done after ploughing and threshing with oxen - Produce was dried in the sun for preservation - Stored grains were kept in bhakari - Grain was traditionally processed using jato and dhikki	- Nowadays, tractors are widely used for ploughing and land preparation - Threshers are used for faster crop threshing after harvest - Processing is increasingly done using mills (flour mills) - Water mills (pani ghatta) are also used in some areas for grinding grains - Modern machinery has replaced many traditional manual practices	
What animals are reared? And how are they raised?	More goats, buffalo, oxen, chickens, and cows	Only buffalo and goat are reared in smaller quantities	- Lack of human resources - Migration - Settlement in the city for job opportunities
What is the availability of land?	- In the past, those who practised farming often did not have sufficient land - Those who did not engage in farming sometimes owned more agricultural land - Land distribution was not closely linked with actual farming activity	- Nowadays, many people have land but are not engaged in farming - There is a perception that agricultural production is not possible or is not profitable - Farming is no longer seen as a reliable main source of livelihood for many households - As a result, agricultural land is often left uncultivated or underutilised	
Disaster vulnerability (flood, landslides, erosion & earthquake)	- In the past, the weather was stable and favourable for farming - Natural disasters were less frequent - There were more forests and a better environmental balance	- Nowadays, natural disasters such as floods, landslides, and droughts have increased - These events are occurring more frequently and causing greater damage - Climate change and environmental imbalance are major contributing factors	
Changes in Water Sources (River, ponds, wells, pits/ small ditches)	- In the past, rainfall used to occur on time and in a regular pattern - Rivers, streams, and springs had sufficient water throughout the year - Even during the dry season, water was available in most water sources	- Nowadays, rivers and streams are drying up - Water sources and springs have started to disappear or weaken - River water levels have dropped significantly - Rainfall is no longer regular or sufficient as before	

Farming Practices	10 years ago	Today	Reasons/Factors
Pattern of rainfall & drought	- In the past, monsoon rainfall was regular and well-distributed - Crop damage and agricultural losses were relatively low - Farming conditions were more stable and predictable	- Nowadays, rainfall patterns have become irregular and extreme - During the rainy season, there is often excessive rainfall, leading to problems like flooding - In the winter and spring seasons, there is little to no rainfall	
What are the problems and challenges of farming?	- Decreased agricultural production has reduced youth interest in farming - The incidence of pests and diseases in crops has increased - Lower production has led to increased food insecurity		
How have problems and challenges affected livelihoods?	- Increased risk of food insecurity and hunger (bhokamari) - Higher cases of malnutrition, especially among children and vulnerable groups - Increased severity of diseases due to poor nutrition and weakened immunity		

Food

Theme	10 yrs ago	Now
What are the crops produced on your land, and for how many months does the food last?	- Rice, millet, maize, barley, wheat, groundnut, potato, fruits, and vegetables - Previously, harvested food was sufficient for up to one year	Nowadays, farm production is only enough for about 3 months of household food consumption
Non-farm foods & fodder/timber (Uncultivated) (Khetbari, Kholanala, Pokhari, Banjangal)	Wild and forest foods commonly used include: <i>jalukey, kholi saag, niguro</i> (fiddlehead fern), <i>syaula, ghaas</i> (young edible grasses in some areas), mushroom, <i>bako, nigalo</i> shoots, bamboo (bas) products, <i>kapro, koiralo</i> (<i>Bauhinia</i> flowers/pods), <i>barra, bayar, amala, khachuri, pateula, gitba, yam, machha</i> (fish), <i>gaganta, jalakumbi</i>	Nowadays less quantity
What is the status of livestock rearing? How much profit was made from sales previously, and how much is made now?	- Goat, buffalo, cows, oxen, chicken, pig, - Livestock were traditionally taken to forests for grazing - Grass was cut and brought home for feeding animals	- Nowadays, fewer livestock are kept by households - Animals are mostly raised in stalls or sheds at home (stall feeding system) - Grazing in forests is restricted or not commonly practised - Livestock are mainly allowed to graze around home areas and nearby fields only
What are the problems and challenges of food?	- There is a shortage of household labour for farming activities - Human resources for agricultural work at home are limited - The incidence of livestock diseases has increased	
What is the impact of climate change on food security and livelihoods?	- Dependence on external sources for meat and dairy products has increased - Self-production of livestock products has decreased - Income-generating opportunities from agriculture and livestock have declined	

Social practices of farming

Theme	10 years ago	Now
Exchange of seeds and crop products	• Production was carried out at the local level • Seeds and agricultural products were exchanged within the community • Locally produced goods were shared and traded informally • Community-based exchange systems, such as bartering, were common • Social cooperation and mutual support in agriculture were strong	• There is a growing trend of purchasing hybrid and improved seeds from the market • The practice of using and sharing locally produced food and seeds has declined • Consumption and use of self-produced agricultural products have decreased
Mutual participation of agricultural manpower	• During rice transplanting, people work together in groups • Maize is sown and managed through collective labour practices • Pest control activities are carried out using traditional methods (such as hand-picking and simple traps) • Supporting structures or supports are used where needed in crop fields • Harvesting is done collectively during the cutting of crops • Land preparation and ploughing are done using shared labour and traditional tools	Nowadays, it is difficult to find people for mutual labour exchange (Arma-Parma).
Sharing agricultural skills, knowledge, and experience	• Traditional knowledge and skills were transferred from elders to the younger generation • Parents and grandparents taught children farming practices and local wisdom	• With modern technological development, knowledge and skills are shared through digital platforms • People learn by searching for information on the internet • Training and capacity-building programs are used for skill development
What are the social problems and challenges?	• Problems related to the availability and access to fertilisers and seeds • Lack of proper irrigation facilities for agriculture • Market-related problems for selling agricultural products • The impacts of climate change are increasing in agriculture and livelihoods • Rainfall is not occurring on time and has become irregular • Temperature is increasing over time • The incidence of pests and insects in crops has increased	
How have problems and challenges affected livelihoods?	• Decrease in agricultural production and productivity • Increased food insecurity among households • Rising cases of malnutrition due to a lack of sufficient and nutritious food • Increase in household and farming-related expenses • Decline in income generation and livelihood opportunities • Greater vulnerability to diseases and health problems due to the effects of climate change	

Crops and livestock pests and diseases

Theme	10 years ago	Now
Livestock pest/ diseases	• <i>Khoret</i> • <i>Bhyagute</i> • Cough-related diseases (khoki) • Diarrheal diseases (pakhala) • Foot and mouth disease (mouth and hoof infections) • <i>Upaya</i> • <i>Kirna-barta</i> (parasitic or insect-related diseases)	• Flu • paralysis • mastitis
Crop pest/diseases	Cutworm, borer, blight, red pumpkin beetle, and aphid	Snail slug, tuta, FYM & red pumpkin beetle
Storage pest	Fly, weevil, silesa	-
What are the social problems and challenges?	• Lack of proper identification and diagnosis of diseases • Medicines and treatment are not available on time • Delayed treatment increases the severity of diseases	
How have problems and challenges affected livelihoods?	• Loss of income • Food insecurity • Effect on livelihood • Increases expenditure	

Who has been most affected by climate change? Why and how?

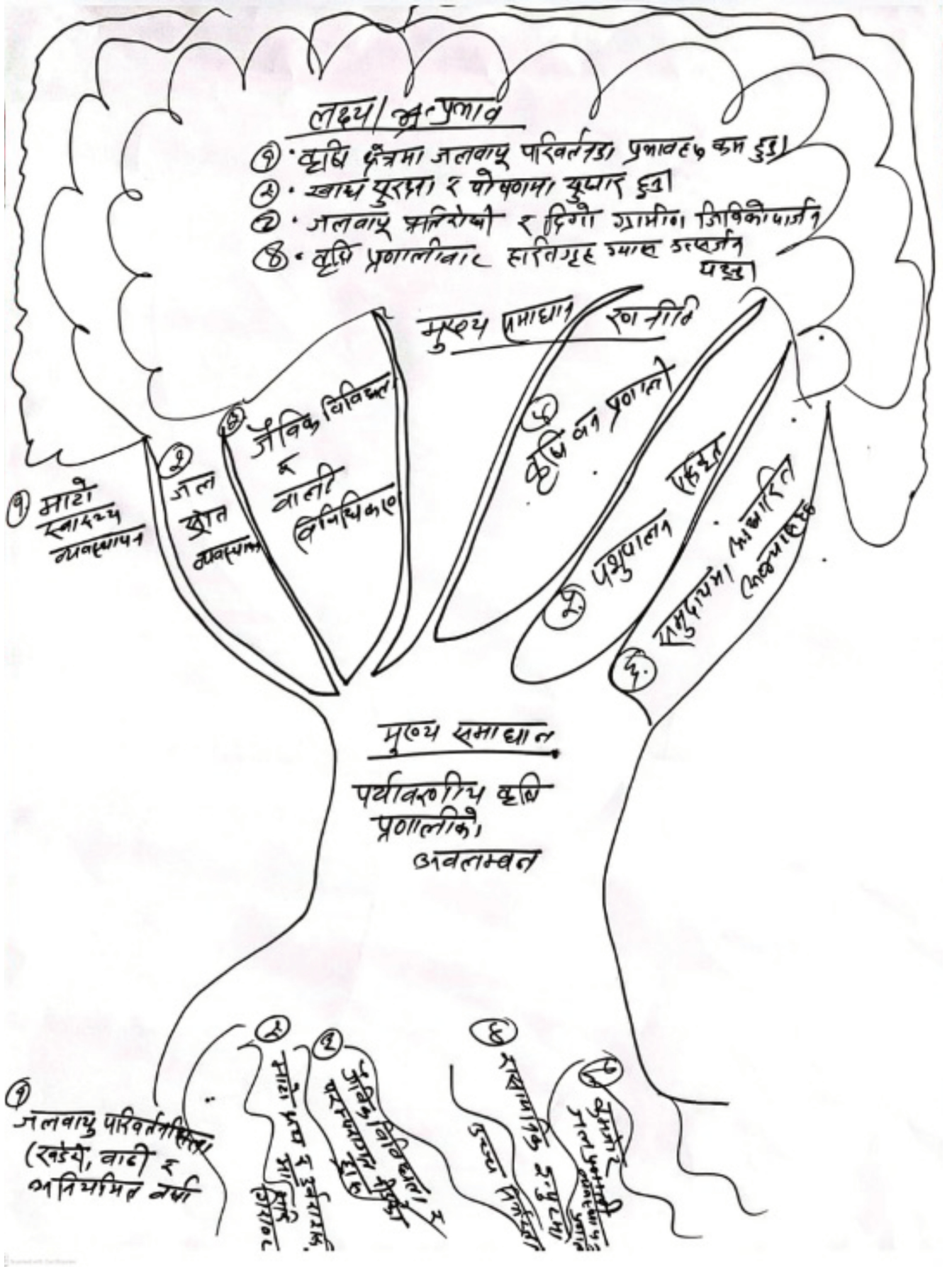
Target group	Why are they affected?
Women	• Women are more affected because men are often away for work outside the home • Women carry a greater workload in both farming and household responsibilities • Women are mainly responsible for collecting grass, firewood, and water from canals and sources
Youth	• Migration abroad is common due to a lack of local employment opportunities • There is a perception that there are insufficient opportunities in rural villages • People believe that income and job prospects are better outside the village or the country
Livestock herders	• Deforestation has led to environmental degradation • Water sources (springs and wells) are drying up • Reduced forest cover has affected groundwater recharge
Children	• Children are closely involved in farming and household activities
Farmers	• Farmers are more affected because they depend on agriculture, livestock, and forest resources for their livelihoods • Any changes in farming conditions, forests, and natural resources directly impact their income and food

How is climate change affecting livelihoods?

- Irregular rainfall has reduced agricultural production
- This has led to increased food insecurity among households
- Water sources (springs and sources of irrigation) are drying up
- Lack of drinking water and irrigation directly affects livelihoods
- Climate change has increased the incidence of crop pests and diseases
- There is a decrease in forest-based food resources and wild foods

What kinds of efforts have been adopted to mitigate the impacts of climate change?

- Chhapo kheti (mulching-based farming): Use of crop residues or organic materials to conserve soil moisture and improve soil health
- Rainwater harvesting (barshako pani sankalan): Collection and storage of rainwater for irrigation and household use
- Production and conservation of local, disease-resistant seeds: Development and protection of traditional seed varieties with higher resistance to local pests and diseases
- Use of organic manure and bio-pesticides: Application of farmyard manure, compost, and biological pest control methods to reduce chemical use





PAN Aisa Pacific (PANAP) is one of the five regional centres of Pesticide Action Network (PAN). PANAP works for the elimination of harm caused by pesticides on human health and the environment. PANAP also promotes agroecology, helps strengthen people's movements in the assertion of rights to land and livelihood, and advocates food sovereignty and gender justice.

As a network, PANAP is currently comprised of more than 100 partner organizations from the Asia-Pacific region and has links with about 400 other regional and global civil society and grassroots organizations.

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