GREENING AGRICULTURE
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Identification and Assessment of Climate-Resilient Agricultural Practices for Cashew and Pepper Value Chains

15 Climate-Resilience Practices

សហការដោយ៖
In cooperation with:

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Executive Summary

Climate change poses significant threats to global agriculture, driving erratic weather patterns and prolonged droughts that undermine food systems and rural livelihoods. In Cambodia, where agriculture contributes 22% of GDP and employs over 60% of the workforce, high-value crops like cashew nuts and pepper face growing climate-related challenges. Despite being the world's largest producer of raw cashew, Cambodia lacks local processing capacity, leading to considerable value loss. At the same time, pepper farming remains vulnerable due to low adoption of green and climate-resilient technologies.

To address these challenges, People in Need (PIN), through the CAPSAFE initiative, launched the "Greening Agriculture" project (2025–2028) to promote scalable, climate-resilient innovations across Cambodia's cashew and pepper value chains. This assessment supports the identification, evaluation, and prioritization of sustainable agricultural practices that enhance climate resilience, smallholder productivity, and economic viability.

The assessment utilized a three-stage methodology:

- Desk-based research of peer-reviewed and grey literature (2000–2025);
- Development of a selection framework with inclusion/exclusion filters based on cost (<$5,000/unit), agroecological relevance, and local feasibility;
- Demonstration site assessment in collaboration with field experts and local stakeholders.

Practices were assessed across six evaluation criteria:

Each climate-resilient practice was assessed against five evaluation criteria and their associated indicators. These include:

- Environmental sustainability, measured using indicators such as water storage capacity and soil organic matter content;
- Economic viability and cost efficiency, assessed through cost per unit of production, yield, and value addition;
- Technical feasibility and ease of adoption, evaluated based on technical feasibility, labor demand (or efficiency), and farmer adoption rates;
- Gender, Youth, and Social Inclusion (GYSI), tracked through gender-based labor and time burden, youth engagement rate, and gender-disaggregated adoption rates; and
- Scalability and Agroecological Relevance, examined using perceived Complexity (or simplicity) by farmers, ecological relevance, and policy support for climate-resilient practices.

Selected Climate-Resilient Practices (CRPs)

For Cashew:

- **Cover Cropping** – Supports healthier cashew trees and improves long-term productivity.
- **Local biofertilizer production** – On-farm composting to boost soil fertility and reduce input costs.
- **Solar-Powered Irrigation System** – Reduces energy costs and boosts cashew growth and yields in an eco-friendly way.
- **Bee Keeping** – Enhances cashew yields through better pollination while providing extra income from honey and bee products.
- **Cashew–legume intercropping** – Legume integration to enhance nitrogen fixation and income diversity.
- **Biochar application** – Soil amendment to increase water retention and long-term fertility.
- **Integrated Pest and Disease Management (IPM)** – Reduces production costs, minimizes environmental impact, and helps maintain healthy cashew trees with stable yields.

For Pepper:

- **Cover cropping with legumes** – Soil fertility enhancement and erosion control through legume cover crops.
- **Solar Drying Dome for Pepper** – Protects peppers from weather and contaminants while speeding drying and preserving quality without electricity or fuel.
- **Raised bed planting** – Reduces root rot in flood-prone areas and improves drainage.
- **Site-specific nutrient management** – Targeted fertilization strategies based on local soil needs.
- **Solar Drip irrigation with fertigation** – Precise water and nutrient delivery to improve efficiency.
- **Compost-based organic fertilizers** – Enhances soil biology and reduces reliance on chemical inputs.
- **Biochar Application in Pepper Fields** – Soil amendment to increase water retention and long-term fertility.
- **Solar-Powered Sprinkler Systems for Pepper** –A water-efficient, labor-saving solution that automates irrigation and reduces heat stress.

Demonstration Sites

Demonstration sites will be established across 13 districts in Kratie, Kampong Thom, Tboung Khmum, and Kampot provinces to showcase 15 climate-resilient practices (CRPs) for cashew and pepper. Site selection was based on farmer's willingness, land suitability, and alignment with prioritized CRPs.

Introduction

1.1 Background

Agricultural systems globally are under increasing pressure from climate change, which manifests in erratic rainfall patterns, prolonged droughts, and frequent extreme weather events. These disruptions pose significant risks to crop productivity, rural livelihoods, and food system sustainability. In response, climate-resilient agricultural technologies and green innovations have emerged as key strategies for enhancing the adaptability and sustainability of smallholder-based value chains.

Cambodia, as a predominantly agrarian economy, is highly vulnerable to climate variability. Agriculture contributes approximately 22% of the country's GDP and employs over 60% of the national workforce. Cambodia's high-potential value chains, cashew nut and pepper crops have experienced both notable growth and significant climate-related constraints in recent years.

Cashew nut cultivation now spans over 580,117 hectares, with Kampong Thom hosting Cambodia's largest cashew area (approx. 90,959 ha), followed by Kratie (approx. 47,858 ha). The country produced almost 1 million tons of raw cashew nuts in 2024, making it the world's largest producer by volume. Cashew has surpassed rice in terms of export value, estimated at nearly $2 billion annually, underscoring its growing strategic importance. The crop supports more than 22,000 smallholder farmers and provides employment to approximately 38,000 people across the value chain, including seasonal laborers.

Despite this potential, Cambodia has limited processing capacity, with most raw cashew nuts exported unprocessed to Vietnam and other countries. The absence of domestic processing capacity leads to substantial value loss. Additionally, cashew production faces increasing challenges from climate change, particularly irregular rainfall, droughts, and heavy rains during flowering and fruiting stages (January–April), which reduce yields and quality. Most cashew plantations are located in low-fertility sandy soils, which have poor water retention, compounding drought vulnerability, and nutrient management issues.

Meanwhile, Kampot pepper—an internationally protected Geographical Indication (GI) product—offers high market value but is also increasingly sensitive to climate-related stressors and faces adoption barriers to green technology due to limited smallholder resources.

To address these challenges, People in Need (PIN), in collaboration with GIZ through the EU-German CAPSAFE initiative, has launched the "Greening Agriculture" project (2025–2028). This project seeks to improve the sustainability, competitiveness, and inclusiveness of Cambodia's cashew and pepper value chains by promoting climate-smart practices, empowering smallholders and Agri-cooperatives (ACs), and enhancing the role of MSMEs and private sector partners. A key strategic focus is to strengthen the enabling environment for green innovations and identify practical agricultural solutions that are adaptable, cost-effective, and scalable within the Cambodian context.

1.2 Objectives

The overarching objective of this assessment is to support PIN in the identification, evaluation, and prioritization of climate-resilient green agricultural solutions with high potential for adoption and scalability within Cambodia's cashew nut and pepper value chains. The assignment will also assist in establishing a robust evidence base to inform the selection of demonstration sites and guide strategic engagement with farmers, cooperatives, and other stakeholders.

Methodologies

2.1 Research Approaches

The proposed methodology consists of three interlinked components—(i) desk-based research, (ii) development of a selection framework, and (iii) demonstration site assessment—designed to sequentially generate evidence, capture local perspectives, prioritize climate-resilient solutions, and operationalize field demonstrations.

The literature search covered peer-reviewed and gray literature published between 2000 and 2025. Searches were conducted across academic databases, online research repositories, and institutional sources, including FAO, IFAD, CGIAR, GIZ, the World Bank, ADB, ASEAN, and the IPCC, as well as national policy reports relevant to Cambodia's agricultural resilience and climate adaptation. All searches were conducted primarily in English, with additional Khmer-language reports and studies reviewed where available, particularly those related to cashew and pepper production and practice-based climate-resilient technologies or solutions at the national, community, and field levels.

The following search string was adapted across databases and institutional search engines:

> ("climate-smart" OR "climate resilient" OR "climate-resilience*" OR "climate adaptation" OR "resilience*") AND (cashew OR "Anacardium occidentale" OR pepper OR "Piper nigrum")
>
> AND (technology* OR practice* OR "soil management" OR irrigation OR mulching OR intercrop* OR agroforestry OR "pest management" OR "post-harvest" OR processing) AND (smallholder* OR "value chain" OR adoption OR scalability OR "economic" OR "gender" OR "inclusion") AND ("tropical" OR "subtropical" OR "developing countries" OR "Southeast Asia" OR "South Asia" OR "Africa" OR "Latin America")

The desk-based research consisted of two stages. The first involved a review aimed at identifying guidelines, strategies, and assessment tools from global, regional, and commodity-specific resources to establish a robust foundation for identifying climate-resilient solutions for Cambodia's cashew and pepper value chains. The objective was to identify criteria and specific indicators to support the development of a selection or decision-making framework for evaluating more than 30 climate-resilient agricultural practices.

To ensure evidence quality and applicability to the Cambodian context, the review incorporated both peer-reviewed scientific literature and gray literature. This mixed-source approach provided a balanced view of theoretical knowledge and practical implementation experiences, helping to identify relevant practices and to develop impact evaluation indicators for use during the implementation phase, once the technologies or solutions were adopted by farmers.

The review of indicators focused on five core evaluation criteria derived from and aligned with global Climate-Smart Agriculture (CSA) frameworks and standards established by FAO, CGIAR, IFAD, and GIZ. These criteria included environmental sustainability; economic viability and cost efficiency; technical feasibility and ease of adoption; gender, youth, and social inclusion; scalability and agroecological relevance; and adaptability (climate resilience).

The second phase of the desk review systematically identified and catalogued potential climate-resilient agricultural practices and technologies relevant to the cashew and pepper value chains. This process reviewed both evidence-based approaches and their practical applicability. Best practices from major cashew- and pepper-producing countries with agroecological and socio-economic conditions similar to Cambodia were reviewed and benchmarked to identify adaptable climate-resilient practices for the final shortlist.

Inclusion and exclusion criteria were applied to filter practices most relevant to Cambodia's agroecological context, smallholder farmers, and replicability. Studies were included if they described agronomic, ecological, or value chain practices such as soil and water management, climate-resilient crop management, or post-harvest processing. Studies were also included if they explicitly mentioned adaptation, resilience, sustainability, or climate-smart agriculture (CSA).

Studies were excluded if they were limited to purely genetic, botanical, pharmacological, or nutraceutical research without agricultural relevance. Research from regions with no agroecological similarity to Cambodia (e.g., temperate zones such as Europe and North America) or studies addressing only yield or pest management without linking to resilience, adaptation, or sustainability were also omitted.

In addition, to ensure contextual feasibility in Cambodia, practices were excluded if they required capital investments above USD 5,000 per unit or hectare, relied on infrastructure not widely available (e.g., cold chain, industrial-scale processing, or advanced IoT irrigation), or were suited only for large plantations. Practices requiring specialized skills or excessive labor inputs beyond the capacity of smallholder farmers were likewise excluded.

The identified climate-resilient agricultural practices were evaluated using indicators developed during the earlier phase of the desk review, based on five core evaluation criteria: environmental sustainability; economic viability and cost efficiency; technical feasibility and ease of adoption; gender, youth, and social inclusion; scalability and agroecological relevance; and adaptability. Each specific indicator was scored on a scale from 1 to 5. The scoring guide is provided in Appendix A.

To support the selection framework, lead cashew and pepper farmers from project beneficiary groups across different provinces were consulted, particularly regarding the perceived complexity of the practices and their adoption potential. Key experts—those with in-depth technical knowledge of the identified practices, commodity-specific systems, agroecological conditions, and community-level barriers—were also consulted to help refine and shortlist the most suitable climate-resilient practices for cashew and pepper. In some cases, these experts also advised how to adapt the practices to make them more locally relevant and feasible.

Finally, among the 29 climate-resilient practices identified for cashew and pepper, 15 were selected, and 15 demonstration sites were recommended to pilot these practices. The recommended sites serve as learning platforms for piloting and scaling climate-resilient agricultural practices in Cambodia's cashew and pepper value chains, with preference given to sites that represent diverse production conditions, geographic spread, and strong potential for peer-to-peer learning, visibility, and scalability. The goal is to ensure agroecological relevance, community ownership, and representativeness across diverse farming conditions.

Participatory workshops were also conducted across the four provincial project target areas—Kampot, Tboung Khmum, Kampong Thom, and Kratie—to gather further farmer and stakeholder perspectives, adapt the practices, support implementation and adoption, and address identified barriers.

2.2 Evaluation Indicators of Climate Resilient Agriculture Practices

The criteria for evaluating climate-resilient practices for cashew and pepper are structured around five domains—environmental sustainability; economic viability and cost efficiency; technical feasibility and ease of adoption; scalability and ecological relevance; and gender, youth and social inclusion. These domains collectively guide the assessment of practices based on their profitability, technical practicality, ecological performance, inclusiveness, and climate resilience.

Adaptability is an overarching dimension embedded across these five domains. Climate change requires agricultural systems to develop adaptive capacity—the ability to adjust and modify practices in response to changing environmental conditions. Understanding how to measure adaptability is essential for building climate-resilient cashew and pepper production systems that can sustain and refine climate-smart practices over time.

The reviewed literature provides empirical and case-based evidence that several types of indicators predict greater implementation and diversification of adaptation measures. Field studies show that on-farm crop diversity, access to multiple water sources, use of drought- and heat-tolerant varieties, and water conservation practices enhance growers' ability to maintain production under climate stress (Douglass Gallagher & Stuart, 2019; van Zonneveld, Turmel, & Hellin, 2020). Institutional support, seed systems, and enabling policies influence how tree crop diversity and adaptive practices are adopted and scaled among smallholders (Su et al., 2013).

Tree crop systems such as cashew and pepper, which have long production cycles, require sustained adaptive capacity over decades to remain productive and resilient. Accordingly, adaptability indicators are embedded within the above five domains, particularly under economic viability and cost efficiency, technical feasibility and ease of adoption, and scalability and ecological relevance. Within these domains, drought-tolerant and disease-resistant varieties emerged as priority practices for review and evaluation.

2.2.1 Environmental Sustainability

Climate change poses significant challenges to agricultural systems worldwide, necessitating the development and adoption of climate-resilient production practices. Environmental sustainability indicators serve as critical tools for monitoring, evaluating, and guiding the implementation of such practices.

A review of the literature highlights several key indicator domains, including carbon, energy, and soil, water-use and hydrological, and biodiversity and ecosystem service indicators. Biodiversity and ecosystem service indicators encompass on-farm species diversity, functional traits, pollinator and natural enemy presence, and soil microbial function. Organic and low-input systems have demonstrated biodiversity and quality benefits for pepper, while soil microbial profiles are recognized as strong soil health indicators for tropical smallholder systems (Wang et al., 2024; Mpai et al., 2025; Ribes Moya et al., 2018).

Under the environmental sustainability dimension, three indicators were prioritized for evaluating climate-resilient agricultural practices for cashew and pepper in this study: Water Storage Capacity and Soil Organic Matter Content. These indicators were selected for their relevance to climate adaptation, field-level measurability, and linkage to productivity and resource-use efficiency in smallholder systems.

2.2.2 Economic Viability and Cost Efficiency

Understanding the economic performance of climate-resilient practices in cashew and pepper systems is crucial for informed decision-making and supporting smallholder farmers. A review of the literature reveals significant economic potential for climate-resilient practices in both systems. Cashew production demonstrates strong profitability in some contexts, while pepper systems show more variable outcomes depending on irrigation management, variety selection, and production scale. Cost-effective irrigation strategies have been shown to deliver optimal returns.

Commonly used economic metrics include profitability (e.g., NPV, IRR, BCR, and payback period), cost efficiency (e.g., cost per unit of output and comparison across management options) (Rodríguez Padrón et al., 2016), and financial sustainability (e.g., cash flow and breakeven analysis).

However, many of these indicators are resource-intensive and difficult to measure at the smallholder field level. To improve practicality, simplified indicators or selected elements from the above metrics were adopted to evaluate the economic and cost-efficiency dimensions of climate-resilient practices. The selected indicators—cost per unit of production, yield, and value addition—are easier to measure through farmer records, observations, or field data collection.

2.2.3 Technical Feasibility and Ease of Adoption

Cashew and pepper both support low-tech climate-resilient practices, but the degree of technical complexity and adoption depends on pest risks, labor and capital requirements, access to extension services, and market or processing incentives.

Technical feasibility relates to the practical requirements for implementing a practice—primarily the balance between complexity (high-tech options) and simplicity (low-tech options), as well as the associated needs for labor, inputs, capital, and equipment. Empirical evidence on the technical feasibility and adoption of climate-resilient practices for cashew and pepper shows that common low-tech measures are widely used and technically feasible for smallholders.

Shared success factors for both commodities are associated with demonstrable short-term benefits (income or yield stability), minimal behavioral change requirements, strong farmer networks, and the presence of demonstration plots and supportive policies that accelerate adoption (Antwi-Agyei et al., 2022; Gemtou et al., 2024). In contrast, shared barriers include inadequate extension services, limited access to finance or credit, the high cost of improved varieties, and pest or disease incidence—challenges observed in both cashew and pepper production systems (Peiris & Wimalaratana, 2024; Karmawati et al., 2025; Antwi-Agyei et al., 2022).

Two key recommendations highlighted for enhancing technical feasibility and adoption from empirical evidence are:

- Target low-cost, high-benefit practices first — Scale up mulching, pruning, manure use, and legume intercropping through farmer field schools and demonstration plots, as these practices show strong uptake and measurable agronomic benefits (Bello et al., 2017).
- Invest in extension and IPM training — Strengthen technical capacity for pest monitoring and best-practice pruning and fertilization in cashew production to enhance technical efficiency without increasing input costs (Karmawati et al., 2025).

In this regard, three indicators are selected to evaluate the technical feasibility of climate-resilient practices for cashew and pepper: technical feasibility, labor demand, and farmer adoption. Farmers were consulted to provide their perspectives on the identified practices.

2.2.4 Gender, Youth and Social Inclusion (GYSI)

Gender, youth, and social inclusion (GYSI) indicators for climate resilience in cashew and pepper value chains cluster around asset and resource access, decision-making and leadership, labor and time burdens, access to climate information and finance, and the adoption of climate-smart practices.

A Latin America and the Caribbean (LAC) dataset adapting the Women's Empowerment in Agriculture Index (WEAI) captured sex-disaggregated empowerment indicators in cashew production and processing nodes and was used to inform gender and social inclusion strategies for project interventions (Domínguez Moreno et al., 2021).

In the cashew value chain gender assessment in Tanzania, a study documented key GYSI constraints—including lack of land and asset ownership, limited access to credit, low cooperative membership, and insufficient technical skills—and recommended indicators to track asset ownership, credit access, and training participation to make interventions gender-inclusive (Mihyo et al., 2019).

Analysis of indigenous adaptation and gendered uptake in Nigeria illustrated gender differences in the adoption of indigenous adaptation strategies and the resulting shifts in social relations, supporting disaggregated adoption and time-use indicators by gender (Deji et al., 2021).

One of the key practical best practices is to disaggregate all indicators by sex, age (youth cohorts), and relevant social stratifies (ethnicity, disability, tenure status) to reveal intersectional gaps (Huyer et al., 2024; Huyer et al., 2021).

For GYSI indicators, gender-based labor and time burden (e.g., hours per day on farm and processing by sex), youth engagement rate, and gender-disaggregated adoption rates were selected to evaluate participation and adaptation in climate-resilient practices for cashew and pepper. Mihyo et al. (2019) noted time use and labor burden as key constraints in Agro-processing in Tanzania.

2.2.5 Scalability and Agroecological Relevance

Scaling climate-resilient agricultural interventions requires balancing rapid adoption with ecological sustainability. Understanding how to measure both scalability and agroecological relevance is crucial for ensuring that climate adaptation strategies in cashew and pepper value chains are both effective and environmentally sound.

The concept of scalability in agricultural interventions traditionally focuses on adoption rates, geographic spread, and institutional uptake. However, this approach often overlooks agroecological dimensions that are crucial for long-term sustainability and climate resilience. Agroecological relevance encompasses biodiversity conservation, soil health, ecosystem services provision, and system resilience — all critical for sustaining climate adaptation capacity.

Perceived complexity emerges as a key barrier for adoption (Lee et al., 2024). Institutional uptake tracks formalization and the development of enabling environments. Success requires multi-stakeholder engagement across public, private, and civil society sectors.

Under scalability and agroecological relevance, perceived complexity by farmers is selected as an indicator to measure adoption intent. Ecological relevance in broad terms (e.g., climate and soil conditions) and policy support for climate-resilient practices form the remaining indicators.

2.3 Review of Climate Resilient Agriculture Practices for Cashew and Peppers

The review assessed 365 studies across multiple databases, and after deduplication and full screening, 119 studies were retained for further analysis. The major geographic coverage included West Africa, South and Southeast Asia, and Latin America.

The review identified climate-resilient practices for cashew and pepper that can be categorized into three main stages: production, post-harvest, and information management. Most studies focused on the production stage, which formed the largest share of the reviewed literature. These included water management practices (e.g., drip irrigation, rainwater harvesting), crop varieties (e.g., drought-tolerant cashew, disease-resistant pepper), soil management (e.g., organic matter enhancement, conservation tillage), and agroforestry systems (e.g., cashew-based agroforestry and pepper shade management).

The post-harvest stage accounted for almost half of the studies, covering technologies such as drying systems (e.g., solar and mechanical drying), storage systems (e.g., improved storage structures and moisture control), and climate-adapted processing equipment for cashew and pepper.

A significant number of studies were also associated with information and advisory systems, including climate services (e.g., weather forecasting and early warning systems) and decision support systems (e.g., mobile-based advisory services).

For Cambodia-specific recommendations, high-priority technologies—with a modest investment capital—include locally adapted cashew and pepper cultivars, solar drying post-harvest technologies, organic management practices such as mulching and composting, drip irrigation, integrated pest management, and agroforestry integrated with native tree species.

As previously highlighted, implementation considerations should focus on economic feasibility—promoting low-cost and high-impact practices; technical simplicity—ensuring systems are easy for communities to maintain; and alignment with local resources, policy frameworks, and traditional practices to enhance sustainability and adoption.

2.3.1 Prioritized Climate-Resilient Practices for Cashew and Peppers

After an extensive literature review, 29 climate-resilient practices were prioritized—17 for cashew and 12 for pepper—spanning across three key stages: production, post-harvest, and information systems. As highlighted earlier, most climate-resilient practices for smallholder farmers are concentrated in the production stage, reflecting the critical role of on-farm interventions in enhancing climate adaptation.

For cashew (Table 1), the selected practices include:

- 1 practice in Crop Varieties and Genetic Improvement,
- 6 practices in Soil and Nutrient Management,
- 1 practice in Information, Training, and Advisory Systems,
- 3 practices in Pest and Disease Management, and
- 1 practice in Agroforestry and Intercropping.
- 1 practice in Water Management/Renewable Energy
- 1 practice in Ecosystem Service Enhancement

For pepper (Table 2), the distribution includes:

- 1 practice in Crop Varieties and Genetic Improvement,
- 6 practices in Soil and Nutrient Management,
- 2 practice in Water Management/Renewable Energy,
- 3 practices in Agroforestry and Intercropping,

- 1 practice in Post-Harvest, Processing and Value Addition,
- 1 practice in Information, Training, and Advisory Systems,
- 3 practices in Crop and Farm Management, and
- 1 practice in Pest and Disease Management.

Each climate-resilient practice was assessed against five evaluation criteria and their associated indicators. These include:

- Environmental sustainability, measured using indicators such as water storage capacity and soil organic matter content;
- Economic viability and cost efficiency, assessed through cost per unit of production, yield, and value addition;
- Technical feasibility and ease of adoption, evaluated based on technical feasibility, labor demand (or efficiency), and farmer adoption rates;
- Gender, Youth, and Social Inclusion (GYSI), tracked through gender-based labor and time burden, youth engagement rate, and gender-disaggregated adoption rates; and
- Scalability and Agroecological Relevance, examined using perceived Complexity (or simplicity) by farmers, ecological relevance, and policy support for climate-resilient practices.

Each indicator was scored on a scale of 1 to 5 (see Appendix 1 for the scoring guide), and Table 1 and 2 below presents the overall weighted scores and final rankings of the selected practices.

The top seven highest-ranking climate-resilient practices for cashew were ultimately selected for field demonstration. These include drought-tolerant cashew varieties (Crop Varieties and Genetic Improvement), local biofertilizer production for cashew (Soil and Nutrient Management), cooperative-led nursery systems (Information, Training and Advisory Systems), pesticide-free pest traps for cashew (Pest and Disease Management), cashew–legume intercropping (Agroforestry and Intercropping), biochar application with cashew (Soil and Nutrient Management), and mulching with organic residues for cashew (Soil and Nutrient Management).

Table 1. Final List of Prioritized Climate-Resilient Practices (CRPs) for Cashew with Weighted Score Ranking

Rank	Practices	Thematic Areas	Production Stage	Overall Weighted Scoring
1	Local Biofertilizer Production for Cashew	Soil and Nutrient Management	Production	4.8
2	Cashew–Legume Intercropping	Agroforestry and Intercropping	Production	4.7
3	Biochar Application with Cashew	Soil and Nutrient Management	Production	4.5
4	Cover Cropping in Cashew	Soil and Nutrient Management	Production	4.6
5	Solar-Powered Irrigation System for Cashew	Water management	Production	4.6
6	Bee Keeping for cashew	Ecosystem Service	Production	4.6
7	Integrated Pest and Disease Management (IPM)	Pest and Disease Management	Production	4.5
8	Drought-Tolerant Cashew Varieties	Crop Varieties and Genetic Improvement	Production	4.4
9	Cooperative-Led Nursery Systems for Cashew	Information, Training and Advisory Systems	Information Systems	4.4
10	Pesticide-Free Pest Traps for Cashew	Pest and Disease Management	Production	4.4
11	Mulching with Organic Residues for Cashew	Soil and Nutrient Management	Production	4.4
12	Organic Cashew Production	Soil and Nutrient Management	Production	4.3
13	Cashew Climate-Smart Pruning Practices	Pest and Disease Management	Production	4.1
14	Cashew Agroforestry with Multipurpose Trees	Agroforestry and Intercropping	Production	3.1

For pepper, the eight highest-ranking practices selected are cover cropping in pepper orchards (Soil and Nutrient Management), disease-resistant pepper varieties (Crop Varieties and Genetic Improvement), raised bed pepper planting in flood-prone areas (Crop and Farm Management), site-specific nutrient management for pepper (Soil and Nutrient Management), drip irrigation with fertigation (Water Management), compost-based organic fertilizers for pepper (Soil and Nutrient Management), vertical trellis systems for pepper (Crop and Farm Management), and shade pepper intercropping (Agroforestry and Intercropping).

Table 2. Final List of Prioritized Climate-Resilient Practices (CRPs) for Pepper with Weighted Score Ranking

Rank	Solutions/Technologies	Thematic Areas	Production Stage	Overall Weighted Scoring
1	Cover Cropping in Pepper Orchards	Soil and Nutrient Management	Production	4.8
2	Raised Bed Pepper Planting in Flood-Prone Areas	Crop and Farm Management	Production	4.6

3	Farmers' Participatory Site-Specific Nutrient Management for Pepper	Soil and Nutrient Management	Production	4.6
4	Solar Drip Irrigation with Fertigation for Pepper	Water Management and Soil and Nutrient Management	Production	4.6
5	Compost-Based Organic Fertilizers for Pepper	Soil and Nutrient Management	Production	4.6
6	Biochar Application in Pepper Fields	Soil and Nutrient Management	Production	4.5
7	Solar Drying Dome for Pepper	Post-Harvest, Processing and Value Addition	Post Harvest	4.5
8	Solar-Powered Sprinkler Systems for Pepper	Water management	Production	4.5
9	Disease-Resistant Pepper Varieties	Crop Varieties and Genetic Improvement	Production	4.5
10	Vertical Trellis Systems for Pepper	Crop and Farm Management	Production	4.5
11	Shade Pepper Intercropping (Agroforestry)	Agroforestry and Intercropping	Production	4.5
12	Pepper in Multi-Strata Agroforestry Systems	Agroforestry and Intercropping	Production	4.4
13	Mycorrhizal Inoculation in Pepper	Soil and Nutrient Management	Production	4.3
14	Mulching with Organic Residues for Pepper	Soil and Nutrient Management	Production	4.1
15	Climate-Smart Pruning for Pepper	Crop and Farm Management	Production	4.1
16	Farmer Field Schools for Pepper	Information, Training and Advisory Systems	Information Systems	4.1
17	Integrated Pest and Disease Management (IPM) in Pepper	Pest and Disease Management	Production	4.1
18	Pepper–Fruit Tree Intercropping	Agroforestry and Intercropping	Production	3.5

Consultation and Prioritization Workshops were conducted from 19 to 25 November 2025 in Kratie, Kampong Thom, Tboung Khmum, and Kampot. The objectives were to disseminate preliminary findings, gather farmer impressions and feedback on the 32 CRPs, and facilitate prioritization based on perceived relevance, feasibility, and interest. The workshops also identified farmers or communities interested in partnering to host demonstration plots for the 15 prioritized CRPs.

The detailed functional descriptions of all 32 identified practices, along with the 15 final selected practices, a brief protocol for conducting field demonstrations, and the selected demonstration sites for each final practice are presented in the following chapters.

Climate-Resilient Practices For Cashew

This section outlines climate-resilient practices for cashew cultivation, covering improved varieties, soil and water management, organic fertilization, climate-smart pruning, and integrated pest management, all aimed at enhancing resilience and productivity under changing climatic conditions.

3.1 Soil and Nutrient Management

3.1.1. Local Biofertilizer Production for Cashew

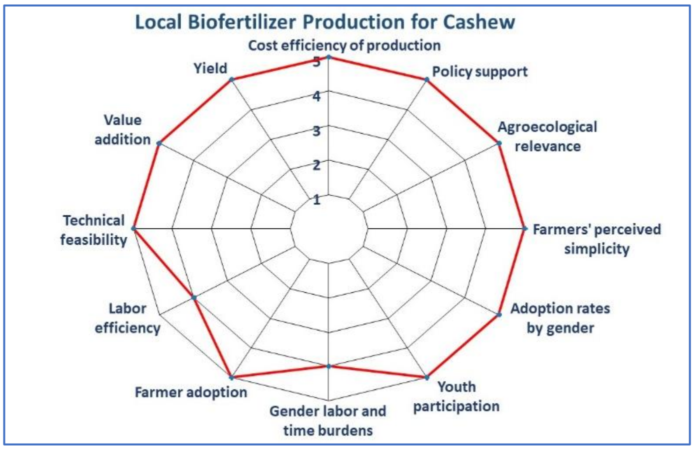
Description

Local biofertilizer production involves creating microbial-rich fertilizers using locally available materials such as animal manure, plant residues, and specific microbial cultures. These biofertilizers promote plant growth by enhancing soil microbial activity and nutrient availability. For cashew, such fertilizers can support better seedling establishment and long-term productivity by improving soil health and nutrient cycling.

Specifically for cashew, local biofertilizer production uses biofertilizers made from readily available community resources such as fallen cashew leaves, green plant residues, kitchen waste, animal manure, and poultry droppings. The process includes collecting organic waste and composting it into nutrient-rich material that is applied around cashew trees. This method improves soil health, enhances moisture and water retention, supports nutrient uptake, and increases cashew yields. It also reduces reliance on expensive chemical fertilizers. Biofertilizers further improve soil quality by increasing organic matter and water retention, with no harmful environmental impacts.

Economic Viability and Cost Efficiency

The use of locally sourced materials makes biofertilizer production highly cost-effective. It reduces farmers' dependence on external inputs and lowers overall production costs. Biofertilizers help stabilize yields by enhancing soil fertility and supporting healthy plant development even under suboptimal conditions.



The interviewed farmers reported that necessary materials for biofertilizer production, such as organic residues or composting ingredients, are locally available, and the process does not depend on external or imported inputs. Many noted that biochar could be added to enhance effectiveness, and that tools and ingredients are easily sourced from nearby areas.

Producing five tons of biofertilizer using local materials costs approximately $500. This investment can significantly increase yields and farmer income. On cost, farmers consistently said that biofertilizer is not expensive, with some even highlighting that it is more affordable than chemical fertilizers. No respondent reported significant financial barriers to production or use.

Studies in cashew farming show better yields when using organic methods, such as manure and bio-fertilizers. Enriched plots produced around 1.1 to 1.2 tons per hectare per year, compared to about 0.88 tons in untreated plots (Yadukumar et al., 2012). Nut weight also increased, reaching about 10.1 grams in the best treatment (Gajbhiye et al., 2020). Although detailed income data are limited, lower spending on fertilizers and chemicals, combined with higher yields, suggests better profits for farmers.

Technical Feasibility and Ease of Adoption
Biofertilizer production is technically simple and can be implemented using basic tools and knowledge. While training is recommended to optimize microbial management and application, the process is manageable. Labor is needed for material collection, compost preparation, fermentation, and application, but the workload is moderate.

Adoption is increasing, particularly among smallholders looking for alternatives to costly chemical fertilizers. Extension supports further builds farmer confidence. Interviews with farmers revealed that they have basic knowledge of biofertilizer production, which is already widely implemented at varying scales with generally effective results. They cited several perceived benefits, including increased yields, improved soil health, reduced input costs, environmental friendliness, and in some cases, greater drought resilience.

Gender, Youth, and Social Inclusion

Biofertilizer production is accessible to both men and women. All respondents indicated that youth and family members could participate, making the practice feasible without requiring outside labor. Youth can actively involve, particularly when it is connected to income-generating opportunities such as on-farm input sales or cooperative-led enterprises.

Scalability and Agroecological Relevance
Farmers described the process as easy to apply and not technically challenging, especially after basic instruction or observation. It is highly adaptable across provinces. Biofertilizer production and use are supported by various agricultural interventions and align with national policies promoting sustainable agriculture.

3.1.2. Biochar Application with Cashew

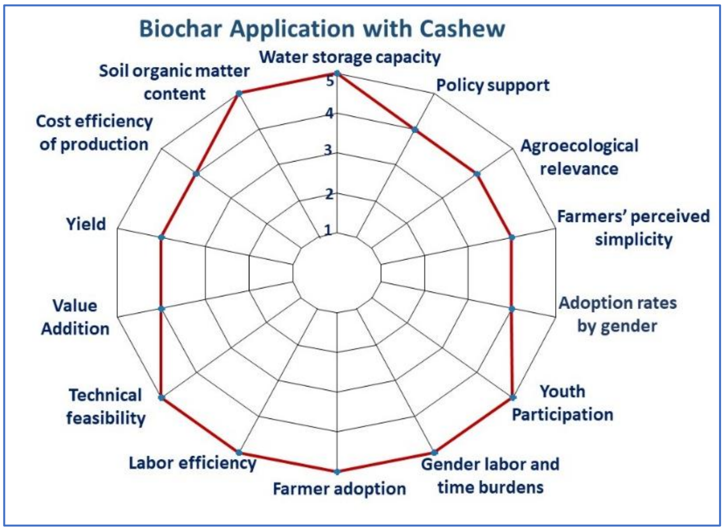
Description
Biochar is a carbon-rich material produced through the thermal decomposition of organic matter in the absence of oxygen (pyrolysis). It is widely recognized for its benefits in improving soil fertility, water retention, and crop productivity, while also reducing greenhouse gas emissions. Countries such as India, China, Nepal, Kenya, and Brazil have incorporated biochar into climate-resilient agricultural frameworks (Rawat et al., 2019; Yadav et al., 2023).

In cashew farming, biochar improves soil structure by loosening compacted layers and enhancing moisture retention, particularly beneficial in sandy or dry soils during the dry season. Its effectiveness is enhanced when combined with compost, green manure, or animal manure. This integration promotes beneficial microbial activity, reduces soil toxicity, and supports nutrient absorption by adjusting soil pH from acidic to slightly alkaline. These effects contribute to deeper root development, healthier plant growth, and increased yields.

Field observations in Cambodia shows that biochar has already been adopted through agricultural interventions. The Cashew Association of Cambodia (CAC) is promoting regenerative agriculture using biochar derived from cashew nutshell extract (CNSE), a byproduct of processing, to create low-cost organic fertilizer. A project in Kampong Thom, led by Midori Climate Partner and CSNC Agriculture Co., Ltd., turns cashew waste into biochar for soil improvement and carbon credit generation. On August 7, 2025, the first BIOCHAR HUB Roundtable at the Institute of Technology of Cambodia gathered over 40 participants from government, academia, NGOs, and the private sector to discuss biochar's potential. In parallel, the V-BIOCHAR project in Pursat Province (March 2025–March 2026), implemented by UNDP and supported by the Czech Republic, trains farmers to apply biochar and vermicompost to enhance soil fertility, reduce chemical inputs, and increase farm incomes. It is considered technically simple and accessible, both for smallholders and larger-scale farms.

Environmental Sustainability

Biochar significantly enhances soil water-holding capacity, reducing the need for frequent irrigation and improving drought resilience (Murtaza et al., 2023). It also contributes to the buildup of soil organic carbon, which plays a key role in supporting microbial activity and nutrient retention (Yadav et al., 2023).



Its nutrient composition per kilogram includes 398 grams of carbon, 19.7 grams of nitrogen, 7.8 grams of phosphorus (P_2O_5), 13.4 grams of potassium (K_2O), 1.4 grams of calcium, 3.7 grams of magnesium, and 178 grams of silicon. Trace elements include 1.2 grams of iron, 63 ppm of zinc, and 8.15 ppm of sodium. These elements support long-term soil fertility, improve ecological resilience, and contribute to sustainable land restoration, particularly in degraded or nutrient-poor soils.

Economic Viability and Cost Efficiency

Biochar use reduces dependency on chemical fertilizers and irrigation, thereby lowering overall cultivation costs. Its application has demonstrated significant agronomic benefits under drought and low-nutrient conditions. In Nigeria, combining biochar with compost improved nutrient uptake and resulted in healthy and strong plant growth in cashew seedlings, supporting better soil health and early-stage crop performance (Nduka et al., 2019). Similarly, a field trial in Brazil tested two cashew clones (BRS 226 and CCP 76) with biochar treatments of 0, 1.0, 2.0, and 4.0 kg per plant, and observed positive effects on irrigation-water productivity and improvements in individual cashew apple weight for one of the clones (Gondim et al., 2024). These findings highlight the role of biochar in enhancing productivity and climate resilience in cashew systems, especially under water-limited and degraded soil conditions. For cashew trees aged five years, the recommended application rate is six kilograms per tree. With a planting density of 156 trees per hectare (using 8-meter spacing), this equates to 936 kilograms of biochar per hectare. When purchased, the cost is estimated at approximately USD 270 per hectare per year.

In areas where farmers have access to dry leaves, wood branches, or rice husks, biochar can be locally produced, significantly reducing input costs. Using low-tech pyrolysis methods, smallholders can convert agricultural waste into biochar, turning waste into a valuable soil amendment. In Cambodia, both low-tech and industrial-scale applications are emerging. Projects like V-BIOCHAR in Pursat Province have introduced simple, locally built kilns suitable for farmer use, while enterprises such as HUSK and CSNC in Kampong Thom operate pyrolysis units that convert cashew and rice byproducts into biochar at scale.

Most farmers reported that the method is not expensive, particularly when they can source and produce biochar themselves. However, in areas where feedstock is scarce, the cost of purchasing biochar becomes a significant barrier, and farmers questioned the cost-benefit of buying processed biochar.

Technical Feasibility and Ease of Adoption

Biochar production is technically feasible and can be implemented using readily available local biomass such as dry leaves, rice husks, and wood. Small-scale production is manageable by individual farmers or cooperatives, and the required tools are simple and affordable. While labor is needed for biomass collection, pyrolysis, and field application, these tasks are not considered labor-intensive. Adoption is influenced by farmer awareness, technical training, and demonstration of yield benefits.

Interviews with lead farmers in Cambodia confirm a strong willingness to adopt biochar practices. Many agricultural development programs in the country have already introduced biochar as part of soil improvement initiatives. Once the technique is understood, implementation is straightforward and does not disrupt existing farming systems. In terms of access to tools and inputs, many farmers said they can collect fresh rice husks or other biomass locally and produce biochar themselves, often using traditional methods or farmer-constructed kilns. Still, several mentioned that purchasing ready-made biochar is expensive, especially if raw materials are unavailable due to the area's limited paddy field activity.

Gender, Youth, and Social Inclusion

Biochar production and application are inclusive practices that allow equal participation by women and youth. The tasks involved—such as gathering materials, preparing the biochar, and applying it to fields—are not labor-intensive, making them accessible to all household members. Decentralized biochar production also offers income-generating opportunities for youth and women's groups, particularly in rural areas where access to off-farm employment is limited. The practice does not impose any additional burden on marginalized or vulnerable populations. All interviewed farmers noted that youth and family members are available to assist, and the technique is generally not labor-intensive or technically difficult. Training was considered helpful but not essential for implementation.

Scalability and Ecological Relevance
Biochar is especially effective in sandy, nutrient-deficient, and acidic soils, which are prevalent across many tropical and subtropical agricultural zones. Its relevance to climate adaptation makes it a strategic tool for sustainable cashew production. Successful scaling depends on farmer education and clear guidance on how biochar interacts with soil and other inputs.

Among the four provinces assessed, the availability of raw materials such as rice husks is a limiting factor only in Kratie. In other regions, organic residues are abundant. Although there is currently no formal national policy endorsing biochar, its promotion through NGO and development agency programs has increased adoption. Given its simplicity, cost-effectiveness, and ecological benefits, biochar is highly scalable across Cambodia's provinces and can be replicated in similar agroecological contexts.

Biochar Application

Biochar | Biochar mixed with cow manure

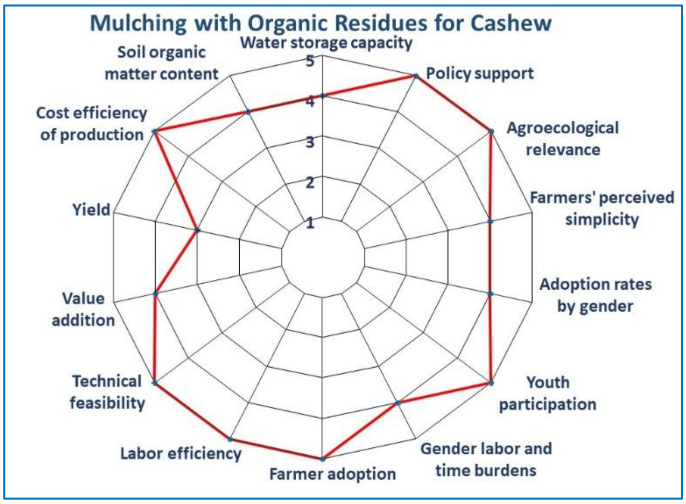
3.1.3. Mulching with Organic Residues for Cashew

Description
Mulching involves applying organic residues—such as leaves, grass, and crop waste—around cashew trees to reduce evaporation, suppress weeds, and enhance soil fertility. Mulching with organic residues in cashew plantations is a climate-resilient practice that significantly supports soil health and environmental protection. It shields the soil from intense sunlight and direct rainfall, helping to prevent compaction and erosion. By suppressing weed growth, it reduces nutrient competition and decreases labor required for weeding. The practice helps maintain clean fields, free from insect habitats, and lowers the risk of disease transmission from wild plants to cashew crops. Farmers who adopt mulching avoid the need to burn or clear forests, instead of reusing plant residues as eco-friendly ground cover.

Environmental Sustainability

Organic mulching helps conserve water in cashew soils by preventing surface evaporation. As residues decompose, they enrich the soil with organic matter, enhance moisture retention, and improve overall soil structure and fertility. Additionally, mulching reduces the need for chemical fertilizers and pesticides and helps mitigate heat stress around plant roots.

Economic Viability and Cost Efficiency



Mulching relies on available on-farm residues, reducing the need for external inputs and lowering overall production costs. Fields managed with mulching show higher and more stable cashew yields across multiple seasons. For instance, in a study on cashew trees in India, applying mulching (paddy straw, green leaf, or plastic film) in combination with irrigation significantly enhanced vegetative growth and yields compared to no-mulch controls (Panda et al., 2018). While the study did not isolate the yield increase solely due to mulching, it demonstrated clear agronomic benefits. In broader dryland agriculture contexts, mulching has shown substantial benefits—improving crop yields by 10% to 145% depending on crop types and enhancing water-use efficiency (Demo & Asefa Bogale, 2024).

The practice adds value by converting farm waste into a soil fertility asset. Although the cost per hectare is difficult to quantify due to variability in labor and residue availability, yield improvements are consistently observed. To maximize its effectiveness, a thicker mulch layer is recommended, while care should be taken not to cover young seedlings or place fresh organic matter directly against stems to avoid heat damage.

All farmers stated that the practice is not expensive, with several even describing it as low-cost or without additional expense when materials are locally sourced.

Technical Feasibility and Ease of Adoption

Mulching is technically simple and requires minimal equipment, making it especially suitable for smallholder farmers. Although moderate labor is needed for residue collection and application, this is offset by the long-term reduction in weeding labor. Farmers are more likely to adopt the practice when they observe clear benefits, such as reduced weeding and increased yields. Every farmer expressed willingness to adopt the practice, emphasizing its ease of use and affordability. The perceived benefits were unanimous: improved soil health and increased yield, which made mulching a highly favored practice among the farmers.

Gender, Youth, and Social Inclusion

While mulching tasks may add to women's workload, they also contribute to household food security. Both women and youth can participate equally in the practice, making it inclusive and accessible across diverse farming households. Lead farmers interviewed shared that youth and family members can support the activity, and the practice itself is technically simple and easy to apply, although one farmer noted it may take a bit more time during implementation.

Scalability and Agroecological Relevance

Most farmers find mulching straightforward, especially when using locally sourced materials. They consistently noted that their cooperative or community is interested in the practice, especially when clear benefits are observed. The practice is highly scalable and can be replicated across provinces without significant cost constraints. It is particularly relevant in areas facing soil degradation, moisture loss, and weed pressure—conditions commonly found in cashew-growing zones. Mulching is especially effective in sandy soils and semi-arid regions. Strong policy support exists under national soil conservation and climate-resilient agriculture schemes, further promoting its adoption.

Mulching with Organic Residues

Mulching from banana leaves

Mulching from grass and green plants

Mulching from coconut shells

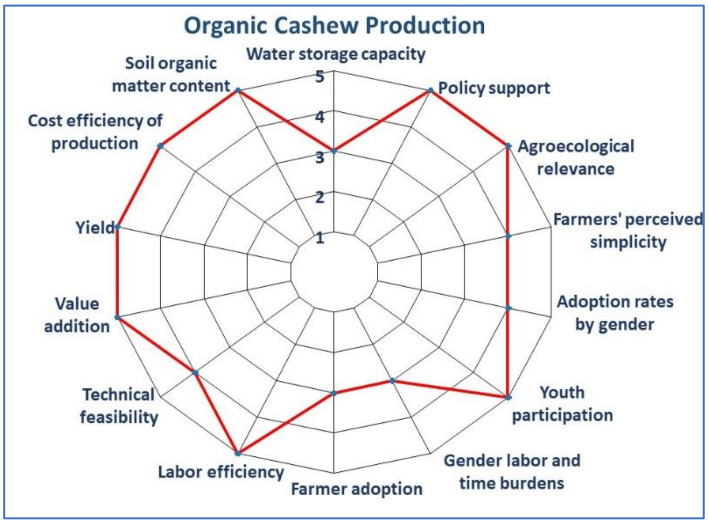
3.1.4. Organic Cashew Production

Description
Organic cashew farming is a low-input, environmentally sustainable approach that can rehabilitate degraded land. It is generally cheaper to manage than conventional systems. Many countries have introduced and supported organic farming as a sustainable agricultural strategy to reduce chemical use, restore soil health, and promote biodiversity.

Environmental Sustainability
Cashew's deep root system and wide canopy help reduce evaporation and enhance water infiltration. The practice contributes to soil health by maintaining surface biomass and increasing organic carbon storage. In organic cashew systems, farmers substitute synthetic fertilizers with compost or green manure, replace chemical pesticides with botanicals/biocontrol, adopt cover crops or intercropping, and avoid herbicides. These practices collectively reduce chemical input use and support on farm biodiversity (e.g., soil biota, beneficial insects, ground flora).-farm biodiversity (e.g., soil biota, beneficial insects, ground flora).

Economic Viability and Cost Efficiency

Organic systems minimize costs by avoiding synthetic fertilizers and reducing tillage. Despite erratic rainfall, yields have remained stable. In Ghana, for instance, stable yields were observed, with only 2.3% of farmers reporting yield loss under variable rainfall conditions (Victor Adjei & Alormu, 2020). Organic cashew production has also generated employment, carbon credit opportunities, and wood from pruning activities.



The cost per hectare for organic production is slightly lower than for conventional farming. For instance, in Karnataka, India, a comparison between conventional and low-input (natural) cashew systems found the cost of maintenance to be approximately 97,785 rupees per hectare for conventional farming, compared to around 90,400 rupees per hectare for the natural system—a reduction of about 7.5%. Yields were comparable, at 17.15 quintals per hectare for conventional versus 16.76 quintals per hectare for natural farming (Mastiholi et al., 2023). Organic and low-input systems reinforce the use of locally sourced inputs—such as farmyard manure, on-farm residues, and biocontrol measures—which help reduce reliance on external inputs and supports cost efficiency. Although yields under organic systems are generally lower than those of conventional methods, they remain stable under proper management. There is also potential to increase the use of locally sourced inputs, which could further reduce costs and enhance sustainability.

Technical Feasibility and Ease of Adoption

This method is accessible to smallholder farmers due to its low input and simplified management requirements. Labor demands are moderate, primarily related to regular pruning and weeding. In Cambodia, some farmers consider adoption moderately challenging due to the need for technical knowledge and initial training.

Gender, Youth, and Social Inclusion

Pruning may introduce a slight additional labor burden for women. However, the overall labor requirements are not intensive, making the practice manageable across diverse farming contexts. Both women and youth can participate equally in organic cashew farming.

Scalability and Agroecological Relevance

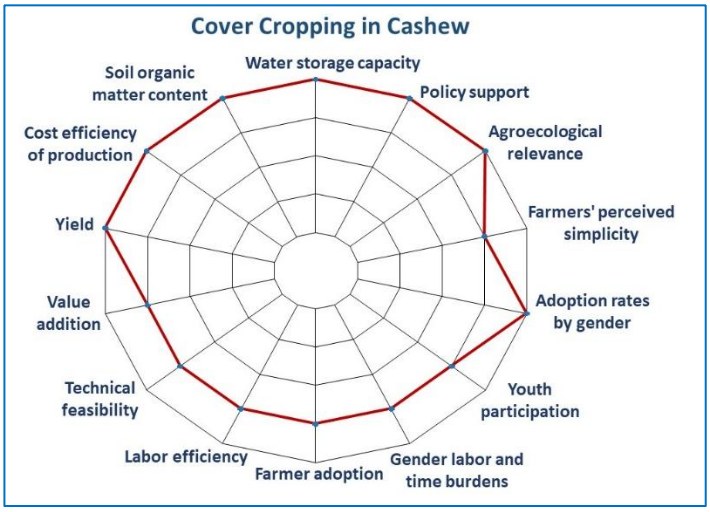
Organic cashew production is relevant across various agroecological zones. However, its expansion has been slow at the provincial level in Cambodia. Greater training and institutional support could improve adoption and enable broader replication and scaling.

3.1.5. Cover Cropping in Cashew

Description

Cover crops have emerged as an effective strategy for diversifying agricultural practices. They contribute to climate change mitigation through carbon sequestration, while also increasing crop yields and enhancing resilience to adverse weather conditions.

Stylo (Stylosanthes guianensis (Aublet) Sw.) is a tropical legume shrub that is widely cultivated as forage throughout tropical and subtropical regions. It is a short-lived, erect or semi-erect perennial legume that typically reaches heights of 1 to 1.5 meters and develops a strong nodulated taproot. Stylo is used in various systems including hay production, cut-and-carry systems, and pastures. It remains fairly palatable to livestock even when mature and is capable of growing in relatively infertile soils.



When used as a cover crop, Stylo helps to improve soil health, regulate moisture levels, and enhance biodiversity. It plays a significant role in reducing soil erosion, suppressing weeds and pests, and minimizing the need for chemical fertilizers and pesticides. Its root system captures nitrogen from the atmosphere and transfers it to the stems and leaves, thereby enriching soil fertility and supporting nutrient cycling.

Environmental Sustainability

Stylo improves soil structure and microbial activity, which in turn enhances the soil's capacity to retain water. It contributes to carbon sequestration in the soil and helps to reduce greenhouse gas emissions. The accumulation of soil organic carbon (SOC) is one of the key benefits of cover cropping, which significantly improves soil quality over time. By maintaining soil moisture and supporting soil life, Stylo contributes to long-term agroecosystem sustainability.

Economic Viability and Cost Efficiency

Cover cropping with Stylo promotes yield stability, especially under climate stress, by maintaining healthy soil conditions. The practice is cost-efficient, requiring about six kilograms of seeds per hectare at an estimated cost of 60 US dollars. Stylo is highly adaptable to a wide range of soil types and demonstrates resilience to weather variability. In addition to its agronomic benefits, Stylo can be harvested and sold as a high-protein livestock feed, particularly dairy cows, thereby adding value and providing supplementary income to farming households. All respondents highlighted that cover cropping is affordable, with no major financial constraints reported.

Technical Feasibility and Ease of Adoption
From a technical perspective, the practice is simple to implement. While some labor is needed during the initial establishment and harvesting phases, the effort is justified by clear agronomic and economic returns. Farmers consulted during the assessment expressed strong interest in adopting Stylo as a cover crop due to its practical benefits and ease of management. They particularly valued its non-toxic nature, affirming that it is harmless to health and beneficial for the environment.

Gender, Youth, and Social Inclusion
The practice is socially inclusive and provides equal opportunities for participation among women and youth. Given its low labor requirements and the economic value of both inputs and outputs, Stylo-based cover cropping can be adopted equitably without adding to existing labor burdens or creating barriers to adoption. Farmers confirmed that youth and family members can help with labor, and the technique is generally seen as easy to implement and understand.

Scalability and Agroecological Relevance
Stylo cover cropping is highly scalable due to its low cost, practical advantages, and demonstrated economic value. It is compatible with all soil types, making it suitable for widespread adoption across different agroecological zones. Furthermore, the existence of national policy support for cover cropping systems strengthens the potential for broader implementation and integration into sustainable agricultural practices.

Cover Cropping in Cashew

Planting Stylo as a cover crop in cashew plantation

Harvesting Stylo grass as fodder for cows

3.2 Crop Varieties and Genetic Improvement

3.2.1 Drought-Tolerant Cashew Varieties

Description

Breeding programs have developed drought-tolerant cashew varieties through traditional selection methods. In Cambodia, eight officially recognized cashew varieties are promoted by the Ministry of Agriculture, Forestry, and Fisheries (MAFF). These include M-1, M-7, M-10, M-23, P-2, H09, IM-4 and SAN-1.

Among them, M-23 is the most widely planted variety. This dominance is due to its high productivity, large nut size, and premium market price, making it especially attractive to farmers. M-23 is officially registered as a national variety. Other important varieties such as IM-4, H09, SAN-1, M-10, M-7, P-2, and M-1 are also cultivated and contribute to local adaptability, nut quality, and drought tolerance.

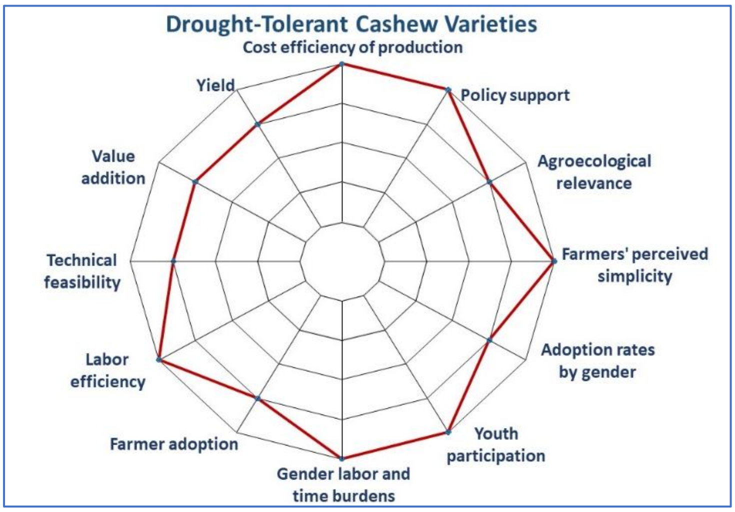
Each variety has specific characteristics suited for different agroecological zones. For example:

- M-10 and M-23 are well-adapted to drought-prone areas.
- P-2 and H09 are valued for their nut size and early fruiting.
- SAN-1 shows resilience in marginal soils and contributes to varietal diversification.

According to MAFF's classification, the selection of these eight varieties was based on nut size, kernel yield, and adaptability to climate conditions.

Economic Viability and Cost Efficiency

Drought-tolerant cashew varieties reduce costs by minimizing irrigation needs. They maintain consistent yields even under irregular rainfall and meet quality standards required for profitable marketing. The cost per hectare is comparable to that of traditional (non-drought-tolerant) varieties, with no added financial burden. These varieties typically deliver higher yields than non-resistant types, enhancing economic returns. In the project sites, farmers noted that the variety M23 is available for order from various sources, and reasonably priced, comparable to other cashew types.



Technical Feasibility and Ease of Adoption

These varieties are technically simple to adopt and compatible with existing farming practices. The only change involves selecting appropriate varieties. Adoption is growing, particularly in semi-arid zones, due to strong field performance during dry years.

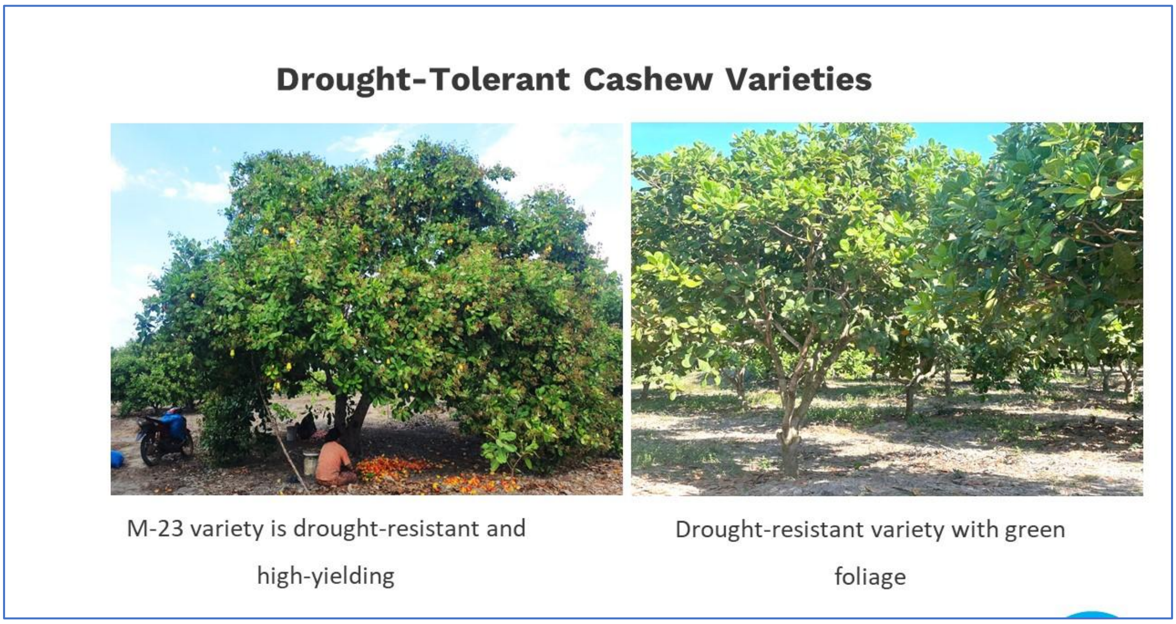
Among the interviewees, the variety M23 was only recently introduced; previously, they relied on mixed or non-specific cashew types. Some of the interviewed farmers have already harvested from M23, while others are still in the early stages of testing or planting. Farmers reported a range of perceived benefits—including higher yields, time savings, and improved income returns—which further reinforced their support for expanding M23 cultivation across their farms. They demonstrated a high intention to adopt, and all consulted farmers expressed support for these improved varieties.

Gender, Youth, and Social Inclusion

There are no gender disparities in the adoption of drought-tolerant cashew varieties, with both women and youth can participate equally in decision-making and implementation. Family members, including youth, are commonly involved in these activities.

Scalability and Agroecological Relevance

Farmers find these varieties easy to adopt and manage. They are well suited to a range of dry soil types and low-rainfall environments. National and provincial government programs actively promote their adoption as part of climate-resilient agriculture strategies. The practice is highly scalable across provinces and applicable across all agroecological zones. It is also fully supported by national agricultural policies.



M-23 variety is drought-resistant and high-yielding

Drought-resistant variety with green foliage

3.3 Pest and Disease Management

3.3.1 Pesticide-Free Pest Traps for Cashew

Description

The use of pesticide-free pest traps and integrated pest management (IPM) techniques in cashew cultivation involves biological agents and natural predators to manage pest populations. Pesticide-free traps specifically target harmful insects and moths without relying on agricultural chemicals. This approach helps farmers reduce chemical usage, thereby preventing environmental pollution.

Several types of traps are commonly used:

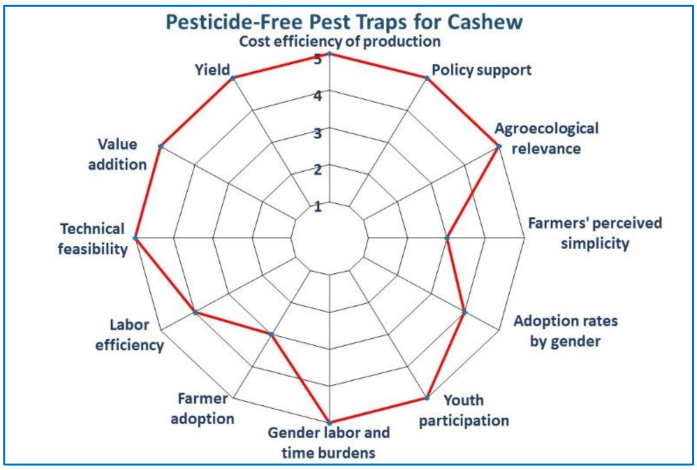
- **Sticky Boards:** Yellow or green adhesive panels attract flying pests and moths, which mistake them for food sources and become stuck.
- **Color Bowl Traps:** Yellow or blue-painted bowls or plates are partially filled with water and placed in the field. Insects and moths are attracted by the color, fall into the water, and drown.
- **Light Traps:** Solar-powered or kerosene lamps are used at night, placed above a container of water or a pit lined with rubber. The light attracts moths and insects, which then fall into the water and die.
- **Pheromone or Food Bait Traps:** Plastic bottles are filled with insect pheromones or food-based attractants, punctured with small holes. Insects enter and become trapped inside.

This pest management practice is applied in agricultural systems across various countries.

Pesticide-Free Pest Traps

Yellow sticky traps for capturing adult pests	Night-time electric light traps to attract insects into fish ponds for feeding	Pheromone traps for capturing adult moths	Solar-powered light traps for capturing adult pests using water-filled metal trays	Solar-powered light used to trap adult insects

Economic Viability and Cost Efficiency This practice reduces input costs by lowering reliance on chemical pesticides. The use of pest-resistant varieties and biological control contributes to yield stability. The estimated cost is approximately USD 100 per hectare for sticky boards and solar traps. Field evidence suggests improved crop yields where this method is implemented.



The farmers noted that necessary materials, such as traps and solar-powered lamps, are generally available in local markets, although some components may need to be pre-ordered. While the materials are accessible, several farmers highlighted that the solar-powered lamps seem somewhat expensive for them, making upfront costs a consideration for adoption. However, all respondents noted that pesticide-free pest traps remain more affordable than continuous purchases of chemical pesticides, with long-term savings seen as a clear advantage

Technical Feasibility and Ease of Adoption

The approach is technically feasible with proper training and includes the promotion of natural predators and the use of bio-agents. It requires moderate labor for trap setup, regular monitoring, and handling of biological agents. While farmer adoption is dependent on training and awareness, uptake can be significantly enhanced through extension services. During consultations, farmers expressed moderate interest in adopting the practice. They cited financial savings, health safety, and environmental friendliness as key motivations. Several also emphasized that the practice helps save time and reduce dependency on chemical inputs.

Gender, Youth, and Social Inclusion

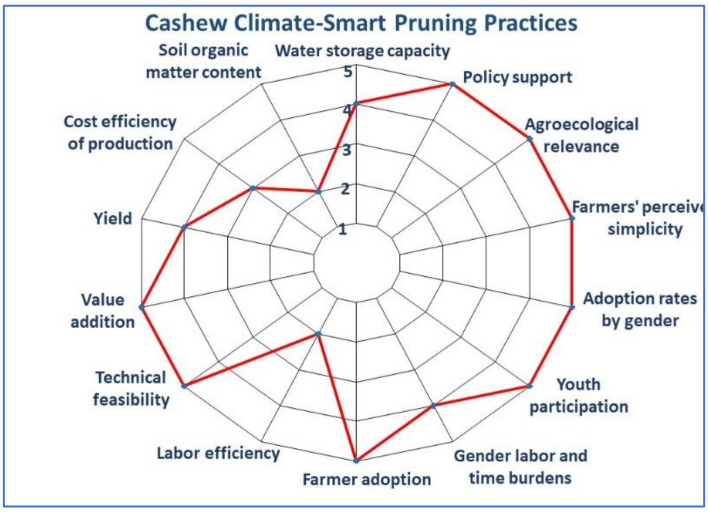
The practice is relatively simple once training is provided. Although it may require moderate labor and time investment, it is compatible with daily farm routines. Women can engage easily, and the approach allows for full participation by both women and youth. Farmers also shared that youth and family members can assist, and the practice is described as easy to understand and simple to apply, requiring minimal technical knowledge.

Scalability and Agroecological Relevance

Farmers may initially perceive the practice as complex without adequate training, but adoption improves substantially with the support of extension programs. It is highly relevant in tropical climates where pest pressures are intensifying due to warming trends. The method is readily scalable across provinces when accompanied by technical support and is fully endorsed by national agricultural policies.

3.3.2 Cashew Climate-Smart Pruning Practices

Description



Climate-smart pruning (CSA pruning) is a targeted strategy that adjusts the timing and intensity of pruning based on local conditions. It helps crops and trees both mitigate and adapt to climate stresses such as drought and heat while maintaining productivity. In cashew cultivation, pruning significantly influences growth, flowering, and fruiting. It involves removing crowded, weak, or unhealthy branches and is typically conducted when trees are young or after harvest. Pruning strengthens the tree structure and promotes a well-balanced canopy, facilitating tasks such as spraying and general maintenance. Additionally, it encourages uniform fruit development across branches, leading to increased yields, larger nuts, and improved taste. The primary goal of pruning is to eliminate dead, diseased, damaged, or non-productive branches—such as overlapping, inward-growing, or stunted ones. This practice is applied in all cashew-growing countries.

Environmental Sustainability

Pruning modifies canopy structure to reduce transpiration and improve water retention in drought-prone conditions. Retaining leaf cover shades the soil and reduces evaporation. Pruned residues can be chipped and used as mulch, enriching the soil with organic matter and contributing to carbon sequestration.

Economic Viability and Cost Efficiency

Strategic pruning helps maintain productivity by reducing climate-induced stress, supporting stable yields during drought, heat, and other extreme weather events. Utilizing pruning waste as mulch or for other farm purposes adds on-farm value and reduces reliance on external inputs. While there are slight additional costs, pruning generally results in better yields and returns per hectare. It is most effective when applied after harvest to enhance fruit size. In several field trials on strategic pruning in productive cashew orchards, yield improvements of 17–24% have been observed. For example, a study in Andhra Pradesh, India, found that mid-July leader shoot pruning increased nut yield from approximately 2.38 kg/tree (unpruned trees) to 2.95 kg/tree (pruned trees) — a 23.6% uplift (Kumar et al., 2019). Separately, a review of canopy management practices in older cashew trees across India found that pruning dead wood and crisscross branches can boost yield by 30–40% (Adiga et al., 2020). Additionally, a study in Togo found that the modified leader pruning system significantly improved growth and yield traits compared to no-pruning controls, even in the absence of chemical fertilizer (Amen & Alèdi, 2022).

Despite these perceived benefits, the cost of implementation was a consistent concern across all respondents. Each farmer mentioned that pruning requires some financial investment, especially tools and possibly hired labor, making it relatively expensive in their view.

Technical Feasibility and Ease of Adoption

CSA pruning is technically feasible for most smallholder farmers and can be adapted to suit local climatic conditions and crop types. Although it may require periodic labor, strategic planning can help balance the intensity and frequency of pruning. It may also reduce labor associated with applying chemical inputs. Adoption is likely if farmers understand the benefits and receive proper guidance. Relevance depends on perceived climate risks, and the level of extension support available. The practice requires moderately skilled labor. The practice is widely adopted, and farmers reported positive experiences or interest, noting that the approach contributes to cost-efficiency and yield improvement over time.

Gender, Youth, and Social Inclusion
Pruning tasks may be assigned to specific household members depending on local gender norms. However, the practice is fully accessible to youth and can be incorporated into inclusive farming activities. Farmers stated that youth and other family members can support the pruning activities, and all of them agreed that the technique is easy to apply and not technically complicated. Training or guidance was not identified as a barrier.

Scalability and Agroecological Relevance
CSA pruning is widely applicable and replicable across provinces. It is particularly relevant in areas prone to drought and heat. The practice aligns well with national strategies promoting climate-smart agriculture and agroforestry.

Climate-Smart Pruning Practices in Cashew

Pruning of cashew tree canopies

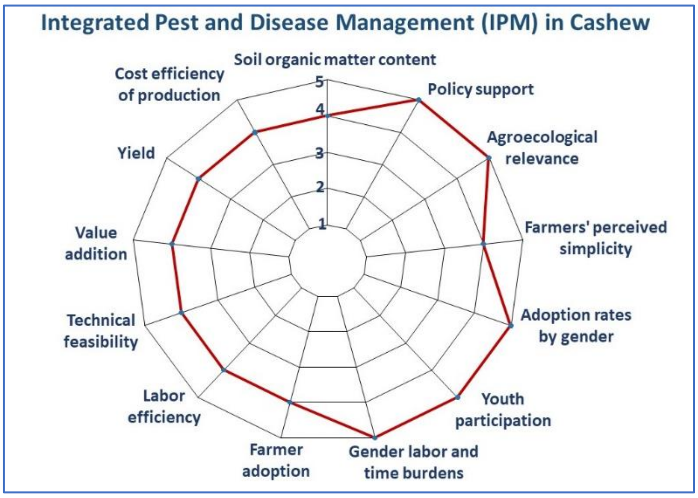
3.3.3 Integrated Pest and Disease Management (IPM) in Cashew

Description
Integrated Pest and Disease Management (IPM) is a sustainable agricultural approach that combines biological, cultural, mechanical, and need-based chemical methods to manage pests and diseases while minimizing risks to human health and the environment. In cashew cultivation, IPM typically involves monitoring pest populations, applying cultural and biological controls, and promoting natural predators or parasitoids to manage key pests. The method emphasizes long-term protection of crops, using knowledge of pest life cycles, and ecological interactions to guide interventions. It aims to reduce economic damage by

preventing pest outbreaks and promoting healthy crop ecosystems through integrated and environmentally friendly practices.

Environmental Sustainability

IPM significantly reduces the overuse of chemical pesticides, thereby protecting biodiversity and preserving soil, water, and air quality. By encouraging natural pest control and ecosystem balance, it contributes to the overall environmental resilience of cashew farming systems.



Economic Viability and Cost Efficiency

The reduction in pesticide use under IPM lowers input costs for farmers, enhancing the economic sustainability of cashew production. Although initial investments in training and implementation may be required, the long-term savings from reduced chemical use and improved pest control make the approach cost-effective. The one consistent concern expressed by farmers interviewed was cost. IPM was perceived as relatively expensive, potentially due to the need for regular monitoring, tools, or input costs.

Technical Feasibility and Ease of Adoption

Cashew IPM is technically feasible and accessible to farmers with basic agricultural training. It involves moderate labor for tasks such as pest monitoring and trap maintenance. However, as cashew is a long-duration crop, successful implementation demands consistent investment in training, field demonstrations, and monitoring. Interviews with lead farmers show a mixed response, with roughly half expressing intent to adopt, particularly when extension support is provided.

Gender, Youth, and Social Inclusion

The approach is inclusive of both women and youth. Many IPM tasks, such as pest surveillance, trap setting, and record-keeping, are well-suited to the roles often managed by these groups in farming communities. This inclusiveness promotes equitable participation and capacity building among marginalized groups.

Scalability and Agroecological Relevance

IPM is scalable across provinces and agroecological zones where cashew is cultivated, particularly in areas prone to high pest pressure. Although it may initially be perceived as complex, this barrier is effectively addressed through structured training and practical demonstration. The method aligns with national agricultural policy and is well-supported by research and institutional frameworks, making it both ecologically relevant and institutionally viable.

3.4 Water Management

3.4.1 Solar-Powered Irrigation System

Description

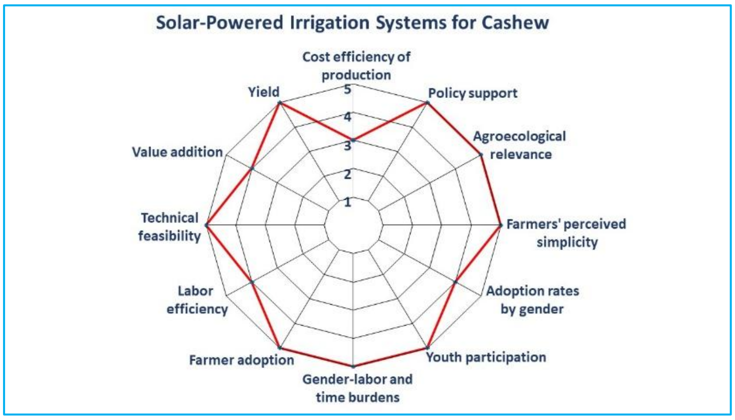
Solar Powered Irrigation Systems (SPIS) use photovoltaic (PV) panels to run water pumps, allowing irrigation without dependence on grid electricity or fossil fuels. They are particularly valuable for smallholder farmers in off grid or irregular rainfall areas, helping ensure water supply during dry periods and key growth stages in cashew.-Powered Irrigation Systems (SPIS) use photovoltaic (PV) panels to run water pumps, allowing irrigation without dependence on grid electricity or fossil fuels. They are particularly valuable for smallholder farmers in off-grid or irregular rainfall areas, helping ensure water supply during dry periods and key growth stages in cashew.

SPIS offers a sustainable way to improve cashew yields while reducing fuel and electricity costs. Systems typically combine solar panels with efficient delivery methods such as drip or micro sprinklers, adapted to orchard age, soil type, and water availability. Solar panels power either surface or submersible pumps, and water is often stored in elevated tanks so it can be gravity fed when needed.-sprinklers, adapted to orchard age, soil type, and water availability. Solar panels power either surface or submersible pumps, and water is often stored in elevated tanks so it can be gravity-fed when needed.

For distribution, drip irrigation is well suited to cashew trees because it delivers water directly to active root zones. Micro sprinklers are useful in young orchards or sandy soils where broader coverage supports early growth and reduces moisture stress.-sprinklers are useful in young orchards or sandy soils where broader coverage supports early growth and reduces moisture stress.

Environmental Sustainability

Solar irrigation aligns with multiple environmental goals by reducing greenhouse gas emissions and air pollution associated with diesel or petrol-powered pumps, contributing to cleaner energy and climate action objectives. Research indicates that solar irrigation can significantly lower carbon dioxide and other emissions compared to conventional energy sources, thereby lessening the environmental footprint of irrigated agriculture and promoting sustainable water use in rural landscapes. In the Philippines, a study found that solar irrigation reduced GHG emissions by up to 26.5 tons CO_2eq/ha/year and avoided emissions of air pollutants such as carbon monoxide, nitrogen oxides, sulfur oxides, and particulate matter (Gono & Agaton, 2022).-powered pumps, contributing to cleaner energy and climate action objectives. Research indicates that solar irrigation can significantly lower carbon dioxide and other emissions compared to conventional energy sources, thereby lessening the environmental footprint of irrigated agriculture and promoting sustainable water use in rural landscapes. In the Philippines, a study found that solar irrigation reduced GHG emissions by up to 26.5 tons



Economic Viability and Cost Efficiency Although initial investment costs for solar irrigation systems can be higher than for conventional pumps, long-term economic benefits are well documented across different crops. Solar pumps eliminate recurring diesel and electricity costs and can reduce overall irrigation expenses, enabling farmers to improve yields and net income over time.-term economic benefits are well documented across different crops. Solar pumps eliminate recurring diesel and electricity costs and can reduce overall irrigation expenses, enabling farmers to improve yields and net income over time.

In the Philippines, energy savings ranging from 11.36 to 378.54 L/ha of diesel per year translated into net present values from −USD 1,255/ha to USD 68,582/ha, returns on investment between 30% and 2,958%, and payback periods ranging from 0.3 to 30 years, with an average of 2.88 years (Gono & Agaton, 2022).

Comparative lifecycle cost analyses also show that solar irrigation pumps generally have lower annualized costs than diesel and electric pumps, due to minimal operational and maintenance expenses despite higher upfront costs (Kumar et al., 2024).-cycle cost analyses also show that solar irrigation pumps generally have lower annualized costs than diesel and electric pumps, due to minimal operational and maintenance expenses despite higher upfront costs (Kumar et al., 2024).

Research in smallholder systems, including solar-powered drip irrigation in the Sudano Sahel of Niger, further demonstrates increased household income and improved economic outcomes following solar irrigation adoption, suggesting that similar benefits could reasonably extend to cashew farmers (Burney et al., 2009).-powered drip irrigation in the Sudano-Sahel of Niger, further demonstrates increased household income and improved economic outcomes following solar irrigation adoption, suggesting that similar benefits could reasonably extend to cashew farmers (Burney et al., 2009).

Technical Feasibility and Ease of Adoption

Off-grid solar photovoltaic irrigation is expanding globally as a reliable and scalable solution to improve water access, reduce fuel use, and strengthen climate resilience. In regions like Southeast Asia, Sub-Saharan Africa, and the Middle East, adoption is driven by falling equipment costs, supportive policies, and development initiatives. Solar irrigation systems are modular and adaptable to different farm sizes, crops, and water sources. While some technical training is required, farmers can often integrate these systems with minimal infrastructure changes.

In Cambodia, solar irrigation is gaining traction. A recent installation at a nursery in Tboung Khmum showcases its potential to improve productivity while creating local jobs and enhancing water reliability (PV Know How, 2024). National efforts led by UNDP and the

Ministry of Agriculture also promote solar technologies for agricultural resilience and rural development (UNDP & MAFRA, 2020). These examples highlight the system's suitability for smallholders, including cashew farmers, particularly when coupled with training and support.

Farmers expressed strong interest in solar-powered irrigation systems, recognizing their long-term economic benefits and low operational costs. Most did not view technical complexity as a major barrier, especially with the availability of local installation and maintenance services. The primary constraint remains the high initial investment; however, many farmers indicated they would adopt the system independently if financially able, and even modest support could significantly accelerate uptake.

Gender, Youth, and Social Inclusion
Solar irrigation systems support inclusion by easing labor demands and encouraging broader involvement in decision-making. Off-grid solar solutions improve access for women and youth, who often manage water collection, freeing time for productive tasks. Gender-responsive training and financing models help ensure marginalized groups benefit fairly from technology adoption.

Improved irrigation access also enhances productivity and household nutrition, allowing women to diversify crops and increase income. Additionally, the expansion of solar technologies creates new roles in installation, maintenance, and technical services, offering job opportunities for youth through targeted vocational training.

Scalability and Agroecological Relevance
Solar irrigation technology is highly adaptable across agroecological zones with reliable sunlight, making it particularly relevant for dryland and semi-arid cashew-growing regions where water access is a constraint. By reducing reliance on diesel and grid electricity, solar-powered systems can be scaled through cooperative models or community-based investment schemes, with potential to transform water management practices at landscape and watershed levels. Their scalability is further supported by integration into broader climate-smart agriculture initiatives that emphasize sustainable intensification and resilience.

SPIS are suitable for small, medium, and semi-large cashew farms, especially when paired with intensive practices like ultra-high-density planting and drip irrigation. When coupled with efficient delivery systems like drip or micro-sprinklers, which are proven to increase cashew yields while improving water-use efficiency.

3.5 Agroforestry and Intercropping

3.5.1 Cashew–Legume Intercropping

Description
Cashew–legume intercropping involves cultivating legumes such as groundnuts or beans between rows of cashew trees to enhance land productivity and improve soil fertility. It is a climate-resilient practice that contributes significantly to environmental sustainability and soil health. Intercropping with legumes increases soil carbon content, reduces greenhouse gas emissions, and improves soil structure and moisture retention. Legumes also fix atmospheric nitrogen through symbiotic relationships with soil microbes, enriching the soil

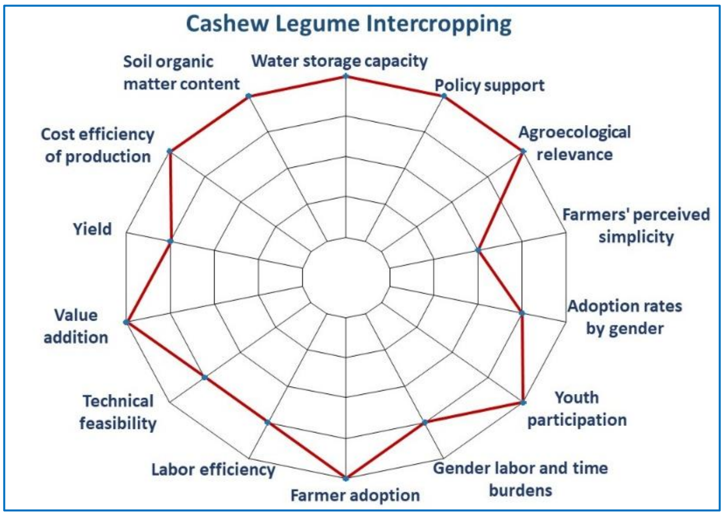
naturally. This practice has been adopted in countries like Nigeria, Ghana, and Mozambique, where cashew farming is prevalent (Ajayi et al., 2021).

Environmental Sustainability

Legume intercropping provides ground cover that reduces evaporation and improves soil water retention. It also boosts soil organic matter through leaf litter, root biomass, and nitrogen fixation. Legume residues serve as organic fertilizer, and the system supports ecological balance by promoting integrated interactions between plants, soil, water, and animals. On average, legumes contribute around 4,000 kg/ha of dry biomass, delivering approximately 80 kg of nitrogen, 31 kg of phosphorus (P_2O_5), and 110 kg of potassium (K_2O) to the soil.

Economic Viability and Cost Efficiency

This practice reduces fertilizer costs and diversifies income through dual cropping. It improves cashew yield stability by enhancing soil conditions and suppressing weeds. Legume seed costs are low—typically $1.50 to $2.00 per kilogram—and a hectare requires about 25 to 30 kg of seed. Total costs, including labor, seeds, and plowing, range from $100 to $120 per hectare. Yield improvements have been widely observed. The system supports various legumes, such as mung beans, cowpeas, jack beans, and lablab, providing an additional source of food and marketable produce that supports food security.



Technical Feasibility and Ease of Adoption

The practice is technically simple, low-cost, and suitable for smallholder farmers using traditional methods. It requires moderate labor for planting and crop management, but the returns justify the investment. Adoption depends on farmer awareness, training, and demonstration of benefits. Interviews with lead farmers confirm a strong interest in adopting the practice, highlighting soil health improvement and additional income from legume sales as the main perceived benefits. Access to inputs and legume seeds was considered relatively easy across most villages, with farmers reporting they could purchase them from local markets or seed shops. Only one farmer indicated difficulty sourcing legume seeds locally due to limited availability.

Gender, Youth, and Social Inclusion

Cashew–legume intercropping is inclusive and accessible, allowing both women and youth to participate equally. Women are often involved in legume cultivation, especially during planting and harvesting, while the short cropping cycles and quick returns appeal to youth.

Scalability and Agroecological Relevance

Farmers report the practice as simple and beneficial, especially after receiving training. It is well-suited to tropical and subtropical regions with well-drained soils. The practice has strong scalability potential. In Cambodia, there is growing promotion of agroecological practices, including intercropping and cover crops, within the cashew sector. For example, the Cashew Nut Association of Cambodia (CAC) has highlighted intercropping as part of regenerative agriculture practices being introduced. In some cashew-producing provinces, farmers have already started adopting legume intercropping, particularly beans. However, specific data on adoption, such as hectares intercropped or percentage of farmers implementing the practice, remains limited. This indicates that despite a supportive policy environment, the scaling of legume intercropping in cashew systems is still in its early stages (HEKS/EPER, 2019).

Legume Intercropping across Fruit Trees and Food Crops

Planting Alfalfa legumes between fruit trees | Planting groundnuts between cassava rows | Bacteria absorb nitrogen from the atmosphere

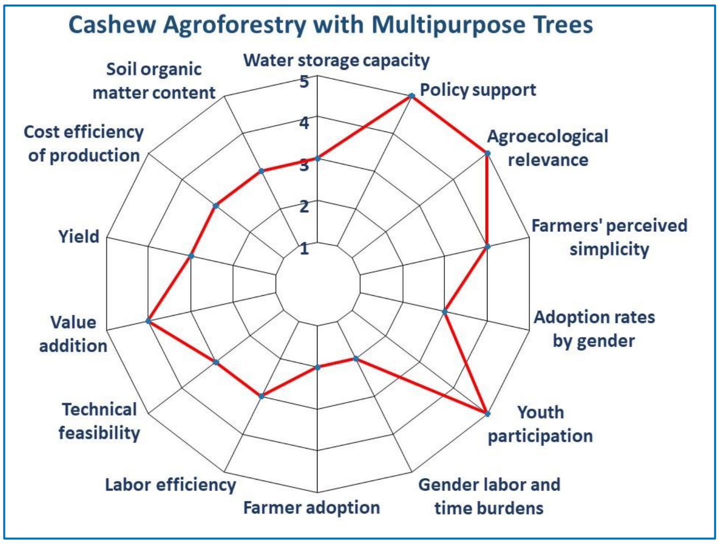
3.5.2 Cashew Agroforestry with Multipurpose Trees

Description

Agroforestry involves the integration of multipurpose trees into cashew plantations to improve soil health, biodiversity, and microclimatic conditions. Cashew agroforestry with multipurpose trees is a climate-resilient practice that contributes significantly to environmental sustainability. It provides shade, which enhances soil moisture retention and promotes better aeration. Agroforestry systems are already practiced in several countries, such as India, under climate-smart agriculture initiatives (Mandal & Mandal, 2024).

Environmental Sustainability

Trees in agroforestry systems improve water retention and microclimates, aiding soil moisture conservation. Leaf litter and biomass decomposition increase soil organic matter, which enriches fertility and biological activity. Additionally, trees contribute to carbon sequestration, reducing greenhouse gas emissions. However, improper planning or species selection may lead to negative effects—such as competition for nutrients and water—due to deep and extensive root systems.



Economic Viability and Cost Efficiency

While initial investments are higher due to tree establishment, long-term benefits include improved yield stability and diversified income. Tree shade and enhanced microclimate support consistent cashew yields even under climatic stress. Multipurpose trees provide additional resources such as fuelwood, fruits, and fodder, adding to economic value. The viability of this practice also depends on the types of trees chosen for intercropping. When properly managed, yields tend to increase, and farmers can generate higher income—especially when selecting trees and crops suited to Cambodian markets.

For example, in central Tamil Nadu, India, a study found that cashew intercropped with groundnut and bajra under rainfed conditions yielded more favorable benefit–cost ratios than mono-cashew systems. The analysis used financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and annuity values to demonstrate the long-term viability of these intercropping systems (Sekar & Karunakaran, 1994). In Ghana's Northern Savannah Zone, a World Bank study showed that one hectare of cashew intercropped with food crops produced equivalent returns to 1.53 hectares under sole food crop cultivation (World Bank, 2023). Similarly, in Cameroon, research near the Benoué National Park found that cashew intercropped with cassava or maize achieved total system yields of 42.8 tonnes/ha (cashew + maize) and 46.1 tonnes/ha (cashew + cassava), respectively (Haiwa et al., 2024).

Although these examples primarily involve cashew combined with food crops—rather than timber or non-timber multipurpose species—they represent a practical and scalable subset of multipurpose tree systems. In Cambodia, estimation of initial establishment costs (e.g., labor, seedlings, and inputs) and projected benefits could draw on these international benchmarks, adapted for local species selection, market conditions, and farming systems.

Technical Feasibility and Ease of Adoption

With proper technical guidance on species selection and spacing, the practice is feasible for farmers. Although labor-intensive during the establishment phase, maintenance requirements reduce over time. Adoption tends to increase where extension services and successful demonstration plots are available. While the approach is generally accessible, some farmers report low interest, possibly due to the complexity of managing trees alongside crops. This lack of interest points to a clear gap in awareness, perceived relevance, or practical feasibility of cashew agroforestry systems in their current farming contexts. No benefits were reported or perceived, and there was no mention of willingness to adopt, even in the future.

Gender, Youth, and Social Inclusion

This practice is inclusive, allowing both women and youth to participate across all stages. Women benefit from reduced burdens in fuelwood and fodder collection due to closer access within farm systems. Agroforestry also creates youth employment opportunities in nursery management and tree maintenance, promoting engagement in sustainable agriculture.

Scalability and Agroecological Relevance

Cashew agroforestry is highly scalable, with strong potential for replication across provinces. It is especially well-suited to dry and degraded areas in need of ecological restoration. While farmers acknowledge the practice's benefits, some find tree-crop integration complex without proper training. Nonetheless, national policies promoting climate-resilient farming endorse agroforestry as a key strategy for adaptation in Cambodia’s agricultural sector.

3.6 Ecosystem Services

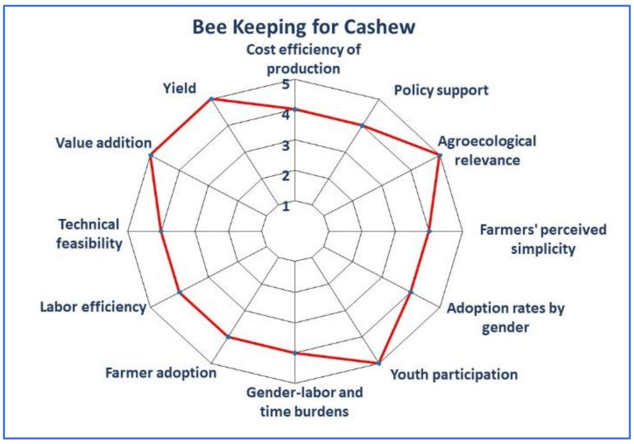
3.6.1 Bee Keeping

Description

Beekeeping integrated with cashew orchards enhances both pollination services and farm income. In Ghana and Benin, research by the African Cashew Initiative found that placing honeybee colonies (Apis mellifera adansonii) close to cashew trees significantly increased cashew nut yields compared with orchards without managed bees, while also producing harvestable honey, beeswax, and propolis for farmers (Aidoo et al., 2013). This dual benefit of improved crop productivity along with supplemental hive products makes beekeeping a compelling complement to conventional cashew farming.

Beekeeping can be integrated into cashew systems in several practical ways. Hives can be placed within or near orchards, for example at approximately two colonies per hectare, to ensure optimal pollinator presence. Pollination can be further supported by maintaining pollinator-friendly habitat, such as preserving natural vegetation including trees and shrubs, planting brightly colored flowering strips around orchards to provide forage during off-seasons, and leaving limited areas of bare ground to support soil-nesting bee species. Bee-friendly pesticide practices are also essential, including selecting less toxic products such as neem or insect-growth regulators, applying chemicals after sunset when bees are inactive, and avoiding spraying altogether during flowering periods. Finally, farmers can make better use of cashew by-products, as bees may utilize cashew apple resources, and biochar produced from cashew shells can be applied to improve soil health and support sustainable production.

Environmental Sustainability



Beekeeping strengthens essential ecosystem services by relying on natural pollination rather than chemical inputs. Cashew trees depend heavily on insect pollination to maximize fruit set, and higher bee visitation has been shown to improve both productivity and nut quality (Eradasappa & Mohana, 2016). Bees also enhance biodiversity across the farm landscape, supporting healthier flowering plants and strengthening overall ecosystem function. The integration of beekeeping into cashew orchards delivers tangible benefits, as managed hives can significantly increase fruit set and raise yields, improving land-use efficiency while encouraging farmers to conserve natural vegetation that sustains pollinators. In many contexts, beekeeping is also associated with reduced reliance on synthetic chemicals, which helps maintain healthier soils and water resources and protects both managed bees and wild pollinators. By maintaining reliable pollination under variable climatic conditions, strong pollinator communities help stabilize cashew production in the face of climate change and environmental stress.

Economic Viability and Cost Efficiency

The economics of beekeeping in cashew systems are attractive because initial investments in hives and basic equipment are relatively modest, and ongoing costs remain low. In the Ghana and Benin study, farms that integrated beekeeping earned significant additional income from hive products alongside increases in nut yield, with honey and beeswax contributing measurable value to farm revenue (Aidoo et al., 2013). The study reported that pollination from managed honeybee colonies increased raw cashew nut yields by 116.7 percent in Ghana and 212.5 percent in Benin. On a per-tree basis, yields rose from 4.2 kilograms to 9.1 kilograms in Ghana and from 2.16 kilograms to 6.75 kilograms in Benin. At the same time, one hectare of cashew farm with two hives produced 41.4 kilograms of honey, 2.8 kilograms of beeswax, and 0.74 kilograms of propolis in Ghana, valued at 208.53 USD. In Benin, the same system generated 27.48 kilograms of honey, 1.84 kilograms of beeswax, and 0.5 kilograms of propolis worth 138.40 USD. Overall annual income per hectare reached 591.74 USD in Ghana and 575.96 USD in Benin. The study further showed that closed-canopy orchards could integrate domestic birds, small ruminants, and even crops such as ginger, cocoyam, and black or white pepper, creating additional income streams within the same land area.

From a cost-efficiency perspective, beekeeping is feasible with minimal resources, since hives can be constructed from locally available materials, and bee colonies are sometimes sourced from the wild. Bees make efficient use of nectar and pollen that are otherwise unused by other farm enterprises, meaning they do not compete with livestock or crops. Economic analyses consistently indicate that modern beekeeping systems have a high benefit-cost ratio. Because most equipment has a long lifespan, depreciation costs remain relatively low while income potential grows over time, reinforcing the financial attractiveness of integrating beekeeping into cashew production systems.

Technical Feasibility and Ease of Adoption

Beekeeping requires only minor adjustments to standard cashew orchard practices. Hives can be made locally at low cost, and short trainings are usually enough for farmers to manage colonies, monitor hive health, and harvest honey safely. Research from Côte d'Ivoire shows that bees consistently visit cashew flowers throughout the season, confirming that managed beekeeping fits well into existing cashew systems without major changes in field layout or crop management (Silué et al., 2021).

In practical terms, integration mainly involves choosing secure apiary sites with shade and clean water, using simple equipment such as top-bar or log hives, and carrying out routine colony care, including inspections, feeding during floral gaps, and basic pest control. Honey can be harvested with simple techniques and upgraded gradually as farmer capacity grows.

Beekeeping adoption is encouraged by clear farm-level benefits. Bees increase cashew nut yields through improved pollination while providing additional income from honey, beeswax, and propolis. Because bees use nectar and pollen that do not compete with other farm activities, they integrate easily into mixed farming systems and often encourage farmers to conserve natural vegetation that supports pollinators.

Experience from Haryana, India, illustrates both interest and feasibility. Many young and small or landless farmers viewed beekeeping as a viable supplementary livelihood, with about 70 percent expressing willingness to adopt it. However, constraints such as limited awareness, bee-flora shortages, pesticide risks, theft, and weak marketing systems underscore the need for training, extension support, and basic risk-management measures to sustain adoption (Singh et al., 2024).

Gender, Youth, and Social Inclusion

Beekeeping broadens participation in agricultural value chains because it requires relatively little physical labor and can be managed close to households. In the Ghana and Benin initiative, women's groups were trained and supported to engage in beekeeping, which helped diversify household income and strengthen women's economic roles within farming communities (Aidoo et al., 2013). Beekeeping can therefore provide women with an independent income from honey and simple value-added products such as beeswax that can often be processed at home.

Youth also benefit from beekeeping through involvement in hive construction, colony management, processing, and marketing. These activities create accessible entry points into green employment and entrepreneurship in rural areas. When linked with cashew production, beekeeping becomes an attractive supplementary or primary livelihood for unemployed or underemployed youth. Training in beekeeping skills, value addition, and small business management can build confidence and improve long-term income prospects.

Scalability and Agroecological Relevance

Beekeeping for cashew is easily scalable, as hives can be introduced gradually and placed across neighboring farms to strengthen pollination at the landscape level. Because it works with natural ecological processes, it improves pollination stability under changing climatic conditions and supports beneficial insects that contribute to sustainable farming systems. From a livelihood standpoint, beekeeping aligns well with smallholder farming because start-up costs are modest, hives can be made locally, and bee colonies require only periodic care. Alongside increased cashew yields, households gain additional income from honey, beeswax, and propolis, reducing dependence on a single crop. Expansion can be accelerated through cooperatives and training networks that share knowledge and improve market access.

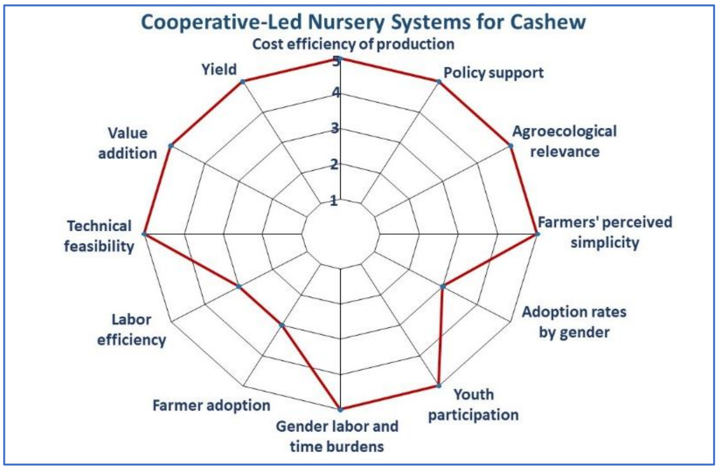
3.7 Information, Training and Advisory Systems

3.7.1 Cooperative-Led Nursery Systems for Cashew

Description

Developing seeds that are resilient to current and future climate shocks is recognized as one of the most important strategies for smallholder adaptation. Farmer-managed nurseries contribute to decentralized tree seedling production, promoting sustainable land use, and the development of natural, human, and social capital. To ensure long-term community resilience in the face of climate change, cooperatives should manage at least one climate-smart livelihood activity. Establishing a cooperative-led cashew nursery not only secures income and creates rural employment but also supports the local production of climate-resilient seedlings. These nurseries play a vital role in scaling the use of drought-tolerant and disease-resistant varieties suited to evolving agroecological conditions.

Economic Viability and Cost Efficiency



Evidence from Malawi and Tanzania shows that the adoption of resilient seeds delivers a high return on investment, with estimated benefits ranging from $984 million to $2.1 billion between 2020 and 2050 (Cacho et al., 2020), highlighting strong economic potential. Resilient seeds reduce yield variability and buffer farms against climate shocks, contributing to greater yield stability. Cashew nurseries add value by enabling local production of seedlings tailored to community needs. The estimated cost of establishing a cooperative-led nursery is around $5,000, covering site preparation and nursery equipment. Income is generated through seedling sales. Members also benefit from additional earnings by participating in nursery activities and marketing cashew seedlings.

Technical Feasibility and Ease of Adoption

Nursery establishment is technically feasible and, once operational, requires minimal external support as it relies on locally available resources. Success depends on farmer participation in breeding, delivery, and adoption processes. While labor is a major constraint for individual nurseries, cooperative-led models facilitate labor sharing and reduce individual risks.

Interviews with lead farmers indicate moderate interest due to access to land and some technical and operational concerns. Many farmers stated that they do not have access to land for setting up a nursery. This land constraint was the primary limitation preventing participation or interest. Additionally, a farmer cited lack of sufficient irrigation water in addition to land, making nursery development even more impractical in their context.

Gender, Youth, and Social Inclusion

The cooperative-led nursery model supports the inclusion of women and youth through a community engagement approach. Women often participate in shared labor and gain access to resources, while youth benefit from employment and skills development opportunities. For example, in the cooperative led nursery model, women may manage seedling propagation, potting, labelling and nursery bed maintenance. This gives them leadership of a core nursery function and access to income and technical training. Meanwhile youth may take on roles such as digital inventory management, seedling order fulfilment, logistical delivery to farmers, or running a youth nursery agent network across villages. These roles combine technical, entrepreneurial, and field skills. These roles help ensure that the nursery is commercially viable and socially inclusive.-led nursery model, women may manage seedling propagation, potting, labelling and nursery bed maintenance. This gives them leadership of a core nursery function and access to incomes and technical training. Meanwhile youth may take on roles such as digital inventory management, seedling order fulfilment, logistical delivery to farmers, or running a youth nursery agent network across villages. These roles combine technical, entrepreneurial and field skills. These roles help ensure that the nursery is commercially viable and socially inclusive.

Scalability and Agroecological Relevance

Cashew nursery systems are generally manageable in complexity, and adoption is feasible when farmers are engaged in participatory models. In agroecological zones increasingly affected by climate variability, cooperative-led nurseries are becoming essential for supporting sustainable cashew production.

Cooperative-Led Nursery Systems

Cashew seedling nursery

Transporting cashew seedlings

Climate-Resilient Practices For Pepper

This section outlines climate-resilient practices for pepper farming, including disease-resistant varieties, compost use, water-efficient irrigation, intercropping, agroforestry systems, improved pruning, and solar drying—each designed to enhance productivity, reduce vulnerability, and promote sustainable cultivation.

4.1 Soil and Nutrient Management

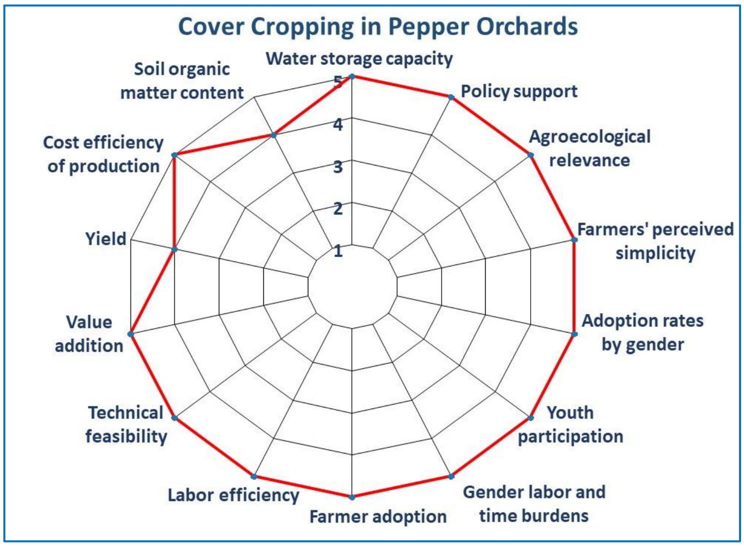
4.1.1. Cover Cropping in Pepper Orchards

Description

Cover crops have emerged as an effective strategy for diversifying agricultural practices. They contribute to climate change mitigation through carbon sequestration, increase crop yields, and enhance crop resilience to adverse weather conditions.

As a cover crop, legumes are planted to cover the soil surface, improve soil health, regulate moisture, and increase biodiversity. They also help reduce erosion, suppress weeds and pests, lower the need for chemical fertilizers, and control diseases. Their root systems capture atmospheric nitrogen and transfer it to the plant's stems and leaves, enriching soil fertility.

Common leguminous cover crops, such as green beans or cowpeas, are typically planted at a rate of 30 kilograms per hectare, with an approximate cost of 75 US dollars per hectare. These species are adaptable to various soil types and show strong tolerance to diverse weather conditions.



Environmental Sustainability

Cover crops enhance soil aggregation and microbial biomass, which helps retain moisture in pepper-growing soils and strengthens resilience to drought. Leguminous cover crops contribute to soil health by storing carbon, reducing greenhouse gas emissions, improving soil quality, and maintaining moisture levels.

Beans fix atmospheric nitrogen, and their residues can be used as organic fertilizer. Increased microbial activity in the soil, including nitrogen-fixing bacteria, promotes ecological interactions among plants, soil, water, and animals, improving overall agroecosystem functioning.

Beans can contribute up to 4,000 kilograms per hectare of dry biomass, with nutrient contributions approximately as follows:

- Nitrogen: 80 kg/ha
- Phosphorus (P_2O_5): 31 kg/ha
- Potassium (K_2O): 110 kg/ha

Their deep root systems improve soil structure and water infiltration, reduce surface runoff, and enhance the soil's water-holding capacity.

Economic Viability and Cost Efficiency

Stable soil function resulting from cover cropping supports consistent pepper yields, particularly under climate variability. Seed costs are low: one kilogram of cowpea, or mung bean costs approximately 1.50 to 2.50 US dollars. Farmers typically require 25 to 30 kilograms of seed per hectare. Including labor for plowing and planting, total costs range from 100 to 120 US dollars per hectare. Most farmers interviewed indicated that cover cropping is not expensive, and materials can be sourced affordably, sometimes even without monetary cost. This made the approach accessible to most farmers without needing large investments.

Yields are generally good when beans are used as cover crops. These crops can also be sold or consumed as nutritious food for both humans and animals, providing multiple income and food security benefits.

Technical Feasibility and Ease of Adoption

Cover cropping is technically simple and easily adoptable in tropical soils. This requires only sowing of legumes/grasses, low input cost, and minimal additional labor. In Cambodia, national policy and seed certification of cover crops provide a foundation for scaling. Adoption among smallholders is already underway in multiple provinces. In the project, several farmers mentioned that they had grown cover crops before or were currently able to do so. Farmers generally agreed that this practice can be carried out within community settings or cooperatives, with many learning from their neighbors and adopting the practice through observation and peer interaction. Many farmers consistently identified strong perceived benefits, including improved soil health, better crop quality, and increased yield. They also noted that cover crops contribute to more resilient soil conditions, particularly by reducing erosion and maintaining fertility.-certification of cover crops provide a foundation for scaling. Adoption among smallholders is already underway in multiple provinces.

Gender, Youth, and Social Inclusion
There is no significant additional labor burden for women or marginalized groups. The practice allows for equal participation and benefits across social groups. Youth can also engage because of its practicality and benefits.

Scalability and Agroecological Relevance
The practice is rapidly replicable across provinces due to its proven benefits, simplicity, and adaptability to all soil types. In Cambodia, the certification of 15 cover-crop species in June 2024 opens up seed access and supports scale-up (CamNess, 2025). On the ground, over 1,550 households in Battambang have adopted cover cropping across some 5,000 acres (Kim 2025), and a UNDP/HEKS-EPER initiative has engaged 1,600 farmers (70% women) across tree-crop farms including young plantations for cover crop use (UNDP, 2025). Uptake of cover cropping in pepper orchards is still emerging, the conditions are in place for rapid replication across provinces and soil types.

4.1.2. Farmers' Participatory Site-Specific Nutrient Management (FP-SSNM)

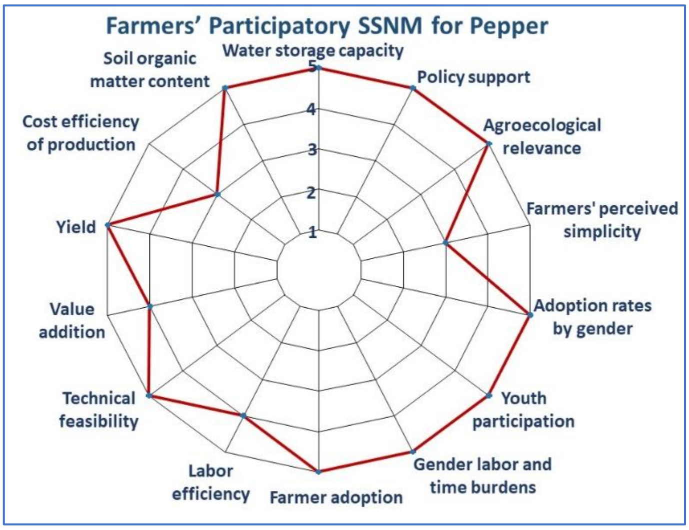
Description
Farmers' Participatory Site-Specific Nutrient Management (FP-SSNM) is a participatory and adaptive approach to supplying nutrients tailored to the specific growth stages of the pepper crop. It involves collecting site-specific data, such as soil conditions, weather, and crop development patterns, to determine the optimal timing, type, and placement of nutrients.

FP-SSNM is a structured method wherein farmers co-develop or validate nutrient management practices in collaboration with researchers or extension workers, typically through trials, demonstrations, and localized learning. The level of technology or digital tool usage varies depending on the farmers' local context. The process emphasizes co-creation, testing, and refinement of nutrient strategies, fostering both capacity building and empowerment through hands-on experimentation.

This approach uses 16 nutrient components adapted to the pepper crop's growth cycle. It is designed to improve yield, enhance nutrient use efficiency, reduce environmental impact, and support plant traits.

Environmental Sustainability

FP-SSNM promotes the use of compost and organic matter, which enhances the soil's water-holding capacity and improves crop resilience—particularly in dryland and rainfed systems. When combined with compost, nutrient inputs contribute to better moisture retention, improved nutrient availability, and enhanced soil structure. The practice also promotes aeration and boosts beneficial microbial activity, resulting in healthier, nutrient-rich soils essential for sustainable crop production.



Economic Viability and Cost Efficiency

This practice reduces dependency on chemical fertilizers while increasing yields, leading to improved cost efficiency. Trials have demonstrated both higher yields and greater yield stability, which in turn enhance income security for farmers. The approach offers higher economic returns per unit of fertilizer compared to conventional methods, further reducing overall input costs. While the practice does involve the cost of annual soil testing and laboratories, this investment is offset by the improved efficiency of nutrient application and the resulting yield and quality gains. Farmers consistently stated that the practice is somewhat costly, primarily due to soil testing requirements, the need to follow a specific nutrient calendar, and labor costs for timely monitoring and application.

Technical Feasibility and Ease of Adoption

As a co-developed approach, FP-SSNM adapts technical complexity to the local context and evolves through a learning process. With basic training and support, the method is relatively feasible to implement and technically feasible. While it demands considerable labor, especially during application and monitoring stages, interviews with lead farmers reflect strong interest in adoption due to the promise of yield gains and cost savings. Most farmers agreed that with proper training and support, it becomes understandable and emphasizes the need for guidance, particularly in the early stages of adoption.

Gender, Youth, and Social Inclusion

The tasks involved in FP-SSNM are generally manageable for all household members, including women and youth. Its simple implementation offers entry points for youth engagement, particularly in training, field monitoring, and demonstration roles. This inclusive nature encourages equitable participation in agricultural decision-making and practices. Farmers noted that youth and family members can help, particularly with record-keeping and nutrient application tasks, making the workload more manageable within the household.

Scalability and Agroecological Relevance

Although some farmers initially perceive FP-SSNM as complex, targeted training and visible yield improvements significantly increase adoption. The participatory approach considers soil heterogeneity and climatic variability, making it highly adaptable across agroecological zones. Once understood, the practice is easily replicable and scalable across regions. Moreover, it aligns with national strategies focused on improving nutrient use efficiency and fostering sustainable agriculture.

4.1.3. Compost-Based Organic Fertilizers for Pepper

Description

Compost-based organic fertilizers are created by decomposing organic materials such as crop residues, animal manure, and green waste. This decomposition process produces a nutrient-rich substance that enhances soil fertility and promotes healthier plant growth. In pepper cultivation, compost application has been shown to significantly improve root development, boost disease resistance, and enhance long-term soil productivity.

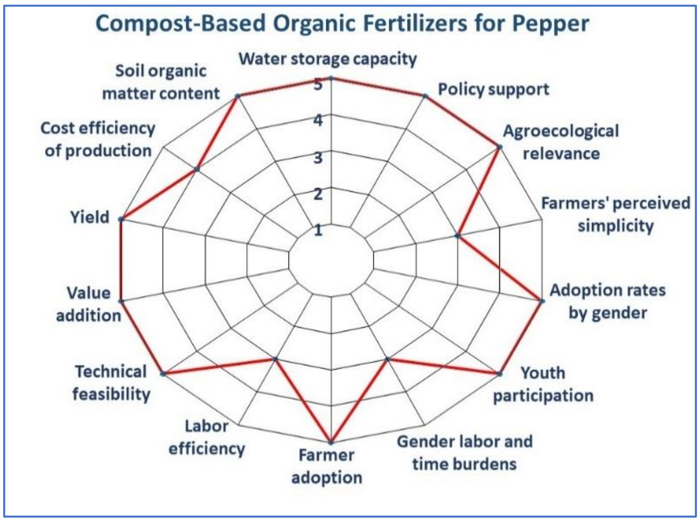
Compost strengthens pepper plants by providing slow-release nutrients that improve soil structure and increase microbial activity. Rich in essential nutrients, it contributes to higher yields and promotes fruit quality, resulting in more abundant and tastier pepper harvests. This practice has demonstrated positive effects on drought and disease resistance, making it particularly valuable in challenging climates. Its widespread adoption in Cambodia and neighboring countries—particularly within smallholder farming systems.

Environmental Sustainability

Compost improves soil structure, which enhances the soil's ability to retain water—an especially important trait in drought-prone areas. It significantly increases the organic matter content of the soil, leading to improved fertility, enhanced microbial activity, and better soil aggregation. Unlike synthetic fertilizers, compost does not contaminate the environment or pose health risks. Moreover, plants grown with compost are less susceptible to pest attacks compared to those treated with chemical inputs.

Economic Viability and Cost Efficiency

The financial cost of compost use is relatively low, especially when farmers produce it on-farm using readily available biomass. Although the initial labor investment, such as material collection and compost preparation, can be high, it is generally manageable and yields long-term economic benefits. By improving soil health and buffering against climate stressors, compost supports more stable yields even under erratic weather conditions. Additionally, compost use can enable farmers to market their produce as



organically or sustainably grown, potentially earning premium prices in niche or export markets.

As earlier indicated in the context of biofertilizer for cashew, five tonnes of compost input materials cost around USD 500, making it significantly more affordable than conventional chemical fertilizers. This cost advantage makes compost a more accessible input for smallholder farmers aiming for cost-effective, sustainable production.

All farmers interviewed reported that compost materials such as animal manure and plant residues are readily available within their area, though some supplements from external sources when needed. A few mentioned occasionally purchasing additional components like agricultural compost products. The use of on-farm materials reduced their reliance on expensive chemical inputs and helped lower overall production costs.

Technical Feasibility and Ease of Adoption
Composting is technically straightforward and can be implemented using common methods such as pit or heap systems. While some training may be necessary to ensure quality control, especially regarding moisture and carbon-nitrogen balance, the technique is accessible to most farmers. Labor requirements are moderate during the preparation stages, such as material collection, layering, and turning, but are typically manageable with family or cooperative support. Adoption tends to be higher in areas with strong extension services or demonstration plots. Every farmer expressed a strong willingness to continue and expand their use of compost in pepper cultivation. They described a readiness to apply it more widely based on their positive experiences.

Gender, Youth, and Social Inclusion
Composting activities often involve women, and while the practice demands labor, it is not gender exclusive. Tasks can be managed collectively within households or communities. Youth can also be engaged in composting as part of broader pepper production efforts, through farmer field schools, or even as entrepreneurial ventures. Both male and female farmers actively adopt the practice, particularly when compost is produced at the household level.

Scalability and Agroecological Relevance
Farmers generally perceive composting as a simple and practical technique, especially when training is provided. However, maintaining the correct moisture content, temperature, and carbon-to-nitrogen ratio can present challenges without adequate support. The practice is highly suitable across diverse agroecological zones and proves particularly effective in degraded, sandy, or nutrient-poor soils. It performs well in both wet and dry climates. Composting aligns closely with national and regional goals for sustainable agriculture.

4.1.4. Biochar Application in Pepper Fields

Description
Biochar is a carbon-rich material produced through the thermal decomposition of organic matter in the absence of oxygen (pyrolysis). It improves soil fertility, enhances water retention, and reduces greenhouse gas emissions. Countries such as India, China, Nepal,

Kenya, and Brazil have adopted biochar for soil amendment under climate-resilient agriculture frameworks (Rawat et al., 2019; Yadav et al., 2023). In pepper fields, biochar enhances soil health and productivity, reduces reliance on fertilizers, and increases yields. It improves soil structure by loosening compacted layers and enhancing moisture retention, particularly benefiting dry or sandy soils during the dry season. Its effectiveness improves when combined with compost, green manure, or animal manure. Additionally, biochar promotes beneficial microbial activity, reduces soil toxicity, and improves nutrient absorption by shifting soil pH toward neutral or slightly alkaline levels. This supports deeper root development and healthier plant growth.

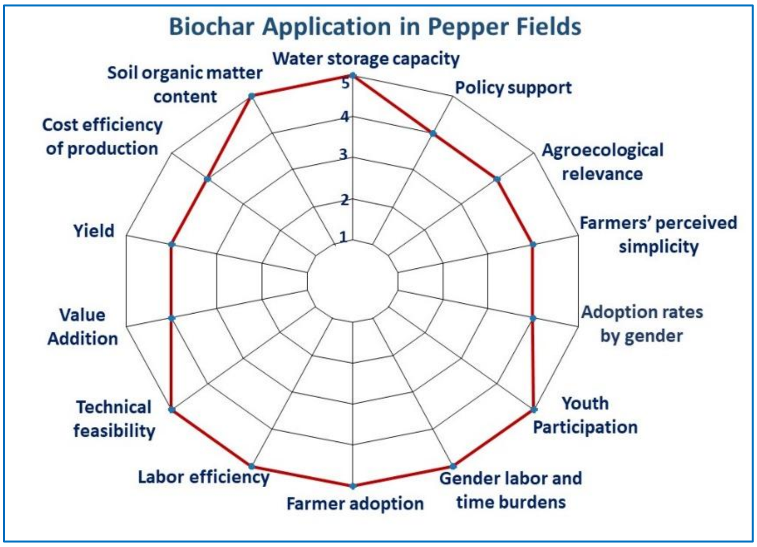
Environmental Sustainability
Biochar increases the soil's water-holding capacity, reducing irrigation needs, and improving drought tolerance (Murtaza et al., 2023). It significantly boosts soil organic carbon, enhancing microbial activity and nutrient retention (Yadav et al., 2023).

Economic Viability and Cost Efficiency
Biochar reduces dependence on chemical fertilizers and irrigation, lowering overall cultivation costs. It has shown positive yield effects, particularly under drought and low-nutrient conditions (Yadav et al., 2023). For mature pepper plantations, about 2 kg of biochar is required per plant. At a spacing of 2m x 2m (2,500 plants per hectare), the estimated requirement is 5,000 kg per hectare annually. If purchased, the cost is approximately USD 1,350 per hectare. Yield improvements have been widely observed.

The majority of farmers stated that biochar production is not difficult, as raw materials like wood, branches, or agricultural waste are available on their farms. They emphasized that there is no need to purchase biochar. Farmers can collect and produce it themselves using local biomass, making the practice cost-effective and self-reliant.

Technical Feasibility and Ease of Adoption

Biochar production is simple and affordable, using locally available biomass such as rice husks, dry leaves and wood branches. Small-scale production is manageable for smallholder farmers. Labor needs vary depending on biomass collection, pyrolysis, and field preparation, but are not a major constraint. Adoption depends on farmer awareness, training, and observable yield improvements. Interviews with lead farmers confirm strong willingness to adopt the practice. They were motivated by its perceived benefits, particularly its ability to improve yields, restore soil health, and reduce farming costs. Several noted its long-term potential to strengthen their



farm's climate resilience and productivity. Biochar has already been widely implemented in Cambodia through various agricultural interventions.

Gender, Youth, and Social Inclusion
Both women and youth actively participate in biochar implementation due to its simplicity and accessibility. Decentralized production provides opportunities for youth engagement in sustainable agriculture at the community level. Tasks such as gathering biomass, burning biochar, and applying it to the soil are manageable without intensive labor. Some farmers noted that biochar could be mixed with cow manure and plant matter, creating a richer, more effective soil amendment.

Scalability and Agroecological Relevance
Biochar is especially effective in sandy, nutrient-poor, and acidic soils, common in tropical and subtropical regions. Successful scaling requires farmer education on how biochar interacts with soil and inputs. Among the four targeted provinces, availability of raw materials (e.g., rice husk) poses a challenge only in Kratie. Although there is no explicit national policy supporting biochar, it has been widely applied through development partnerships. The practice is highly scalable and replicable across Cambodia, offering a viable climate adaptation strategy in pepper-growing areas.

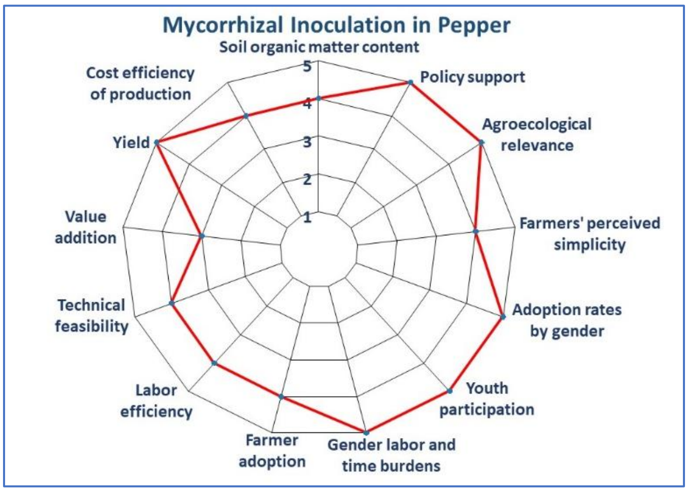
Biochar Application in Pepper Fields

Biochar | Biochar mixed with animal manure | Compost application

4.1.5 Mycorrhizal Inoculation in Pepper

Description
Applying biofungicides to pepper plants involves introducing beneficial fungi to their root systems to enhance growth, health, and yield. These fungi establish a symbiotic relationship with plants, expanding root networks, and improving the absorption of key nutrients such as phosphorus, nitrogen, and potassium. This practice also helps pepper plants become more resistant to saline soil conditions, which is particularly valuable in coastal areas. Bio fungicides are used in all pepper-growing countries, although the specific type of biofungicide may vary by region.

Environmental Sustainability



When mixed with compost, biofungicides contribute to better soil moisture retention and higher organic matter content. For example, mycorrhizal inoculation (arbuscular mycorrhizal fungi) help pepper plants withstand environmental stresses such as high salt concentrations by improving membrane stability and supporting continued plant growth. Beyond these direct plant health benefits, mycorrhizal symbiosis also supports environmental sustainability. The fungal networks improve soil structure and aggregation, enhance water and nutrient uptake efficiency, and reduce reliance on synthetic fertilizers and chemical fungicides. In saline and dry conditions, inoculated pepper plants retain more water and maintain better nutrient balance by increasing potassium levels while reducing sodium accumulation. This makes the system more resilient, protects long-term soil health, and supports sustainable, smallholder-friendly pepper farming.

Economic Viability and Cost Efficiency

Inoculation with biofungi has shown positive effects on plant height, leaf diameter, root length, and overall yield. While the cost is moderate—considering the combination of biofungicide and organic fertilizer—it leads to a reduced need for synthetic fertilizers. This not only lowers input costs but also promotes plant resilience to drought and salinity, thereby protecting farmers' investments and preventing potential yield losses. Farmers indicated that the product is available in local markets, and most said that the price is reasonable.

Technical Feasibility and Ease of Adoption

Mycorrhizal inoculation is technically feasible for pepper cultivation and requires minimal labor when proper inoculation techniques and timing are followed. It is relatively easy to adopt. However, in some areas such as Kampot, farmers traditionally prefer using limestone over biofungi-based treatments. Another farmer expressed fear that chemical substances could enter the farm through the inoculum. He also noted that his cooperative showed no interest in the approach. This reflects some degree of hesitation and the need for further clarity and awareness building, especially among organic farmers or those with concerns about product origin.

Gender, Youth, and Social Inclusion

Although specific data on gender roles in the application of mycorrhizal inoculation is limited, the practice is generally inclusive of women and youth. It does not place additional labor or time burdens on women beyond existing farming responsibilities, and it offers opportunities for youth engagement through extension training or field trials.

Scalability and Agroecological Relevance

Mycorrhizal inoculation is highly scalable for pepper cultivation. Studies consistently demonstrate its effectiveness in enhancing pepper growth, biomass, and yield under diverse agroecological conditions. It is also considered an environmentally friendly alternative to chemical fertilizers, aligning well with sustainable agriculture practices.

Mycorrhizal Inoculation in Pepper

Trichoderma solution against fungal pathogens | Trichoderma mixed with compost for better disease resistance | Agricultural fungi used to fight plant pathogens

4.1.6 Mulching with Organic Residues for Pepper

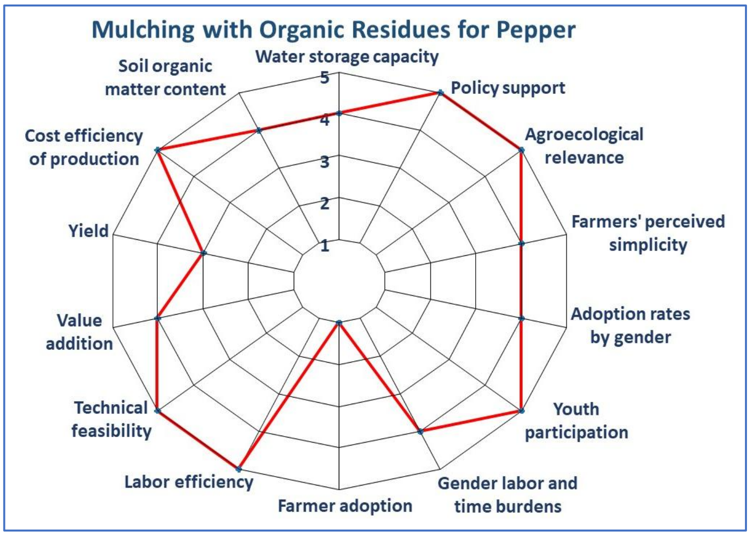
Description

Organic mulching involves covering the soil with biodegradable materials such as crop residues, straw, or paper. For pepper cultivation, this practice reduces evaporation, improves soil structure, and suppresses weed growth. It is commonly used in countries like India and the United States, particularly in the Southeastern region (Ravichandran et al., 2022; Moore & Wszelaki, 2019).

Environmental Sustainability

Organic mulching provides numerous benefits for soil and crop health. It protects the soil from direct sunlight and heavy rainfall, helping to prevent compaction and erosion. By suppressing weeds, it reduces competition for nutrients and decreases the labor required for weeding. Mulching also helps maintain clean crop areas, limits insect habitats, and prevents disease transmission from wild plants. Environmentally, it supports sustainable agriculture by encouraging smart ground cover strategies. As organic materials decompose, they enrich the soil with organic matter, improve moisture retention, and reduce reliance on chemical fertilizers and pesticides. Additionally, mulching helps regulate soil and root temperatures, protecting plants from heat stress.

Economic Viability and Cost Efficiency



Organic mulching is cost-effective as it utilizes low-cost, locally available materials. It supports stable yields by maintaining consistent soil moisture and temperature. By improving crop quality and reducing environmental damage, mulching adds value to production, especially when using biodegradable materials. For pepper, the most effective mulching materials include rice straw, maize stalks, Gliricidia leaves, Chromolaena odorata, and bean residues.

Technical Feasibility and Ease of Adoption

The practice is technically simple and requires only basic tools, making it suitable for smallholders. Labor demand is primarily for mulch collection, application, and periodic replacement as the organic mulch decomposes. While it is widely adopted in many regions due to its benefits for soil health and climate resilience, adoption among some pepper farmers in Cambodia remains limited. Interviews with lead farmers revealed concerns about potential disease risks and the limited availability of suitable mulching materials in some areas. The low interest in using mulch is mainly because they do not fully understand its benefits or proper application. This lack of awareness appears to hinder both adoption and experimentation within their cooperatives or communities, even though mulch materials like rice straw are available locally and can be purchased without difficulty.

Gender, Youth, and Social Inclusion

From a labor perspective, all farmers agreed that youth and family members can assist with mulching activities, and the practice itself was described as easy to implement. Despite being unfamiliar with its benefits, farmers did not find the technique confusing or technically demanding.

Scalability and Agroecological Relevance

Among pepper farmers, mulching is sometimes perceived as complex and may require proper training to ensure correct implementation. Farmers expressed concerns about technical understanding and potential disease risks, making them hesitant to adopt the practice. Additionally, biodegradable materials may degrade quickly, requiring more frequent replacement. Despite these challenges, organic mulching is highly relevant for dry, sandy, and nutrient-poor soils and is beneficial in both tropical and temperate climates, particularly under water stress. National programs support climate-resilient farming practices, including organic mulching.

Mulching with Organic Residues

Rice husk for pepper root mulching

Compost used for mulching

Plant residues for mulching

4.2 Crop Varieties and Genetic Improvement

4.2.1. Disease-Resistant Pepper Varieties

Description

Resilient seeds and disease-resistant pepper varieties are bred to withstand climate stressors and pest pressures. Several black pepper (Piper nigrum) varieties have been developed to enhance resistance to major diseases such as foot rot and nematodes. In India, IISR Shakti and IISR Thevam are known for their resistance to foot rot (Sharangi et al., 2024; Krishnamurthy et al., 2021), while the Pournami variety is recognized for its resistance to root-knot nematodes (Rai & Upadhyay, 2023). Malay-origin varieties such as Natar 1 and Natar 2 offer resistance to pepper stem borers (Karmawati et al., 2024), and traditional Indian cultivars like Narayakodil, Neelamundi, and Thevanmundi have also shown lower susceptibility to foot rot (Krishnamoorthy & Parthasarathy, 2010).

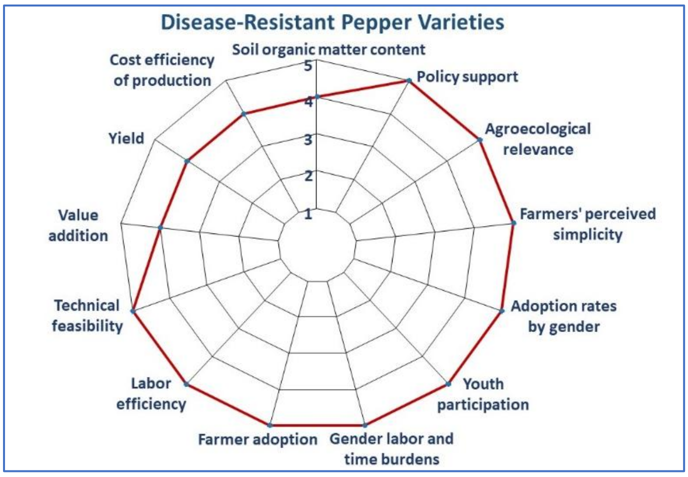
In Cambodia, the largest pepper-growing provinces include Tbong Khmum, Kampot, Kratie, Ratanakiri, Mondulkiri, Battambang, Pursat, Kampong Cham, Koh Kong, Kep, Kampong Thom, and Siem Reap. Pepper farming is largely dominated by smallholders with farms typically under one hectare. Popular varieties include Kamchay (a small-leaf local variety), Lampong or Belantoeng (a large-leaf local variety), Ceylon (originating from Sri Lanka), Panniyur (from India), and Vinh Linh (from Vietnam). Among these, Lampong and Kamchay are notable for their tolerance to diseases and dry conditions. Lampong, in particular, is the most widely cultivated, recognized as a national GI variety (GI 2010), valued for its flavor, high yield, and market price.

Environmental Sustainability

Disease-resistant varieties contribute to environmental sustainability by requiring fewer chemical interventions, which helps preserve soil health and biodiversity. These varieties are often interplanted with ground-cover crops that help retain soil moisture, improve aeration, and increase microbial activity.

Economic Viability and Cost Efficiency

The economic viability of Cambodia's GI pepper is high, supported by a significant price premium and strong export growth following its GI registration. This status prohibits the use of chemical fertilizers and pesticides, reducing input costs and encouraging more natural farming methods. The GI label also attracts investment in processing, branding, and agrotourism. Disease-resistant varieties further reduce costs associated with pest and disease management and contribute to stable and profitable yields.



Farmers noted that variety prices (e.g Kamchay or Lampong) ranged around 3,000–4,000 riels per plant, with an average of 3 plants per pole and about 2,500–3,500 poles per hectare. Despite this, they described the cost as reasonable or "not expensive,".

Technical Feasibility and Ease of Adoption

The development and cultivation of disease-resistant varieties are technically feasible through conventional breeding and existing farm practices. Farmers benefit from reduced pest and disease pressures, which lowers labor needs for intervention. Adoption is considered high when awareness is raised, and extension services are available. During the interview, farmers showed a willingness to adopt disease-resistant pepper varieties, with several expressing personal interest and stating that they are already practicing or ready to implement. The practice was considered easy and practical to integrate into their existing farming routines.

Gender, Youth, and Social Inclusion

Disease-resistant pepper varieties promote inclusion by reducing labor burdens, particularly for women, and increasing the economic returns from farming. This improves food security and income stability, enhancing the roles of women and youth in agriculture and decision-making processes.

Scalability and Agroecological Relevance

In Cambodia, disease-resistant pepper varieties are preserved in farmers' orchards and widely recognized for their quality and resilience. Notably, the GI-registered Kamchay (small leaf) and Lampong (big leaf) cultivars are the two primary varieties produced under the Kampot Pepper label. These varieties have therefore already been adopted by producers in Kampot and Kep, and their longterm field presence underlines their suitability for smallholder cultivation. Given their established local relevance, the emphasis is now on reinforcing their continued use, improving their -term field presence underlines their suitability for smallholder cultivation. Given their established local relevance, the emphasis is now on reinforcing their continued use, improving their diseaseresistance performance through agronomic -resistance performance through agronomic bestpractice, and expanding -practice, and expanding valuechain-chain linkages rather than initial introduction. To support expansion into other suitable agroecological zones and provinces, the approach focuses on maintaining the integrity of existing pepper varieties. For Kamchay and Lampong, this includes ensuring the wide-scale preservation of designated seed and planting material, monitoring disease resilience under evolving environmental conditions, and strengthening GI branding and traceability systems to help farmers capture higher value in export markets.

Disease-Resistant Pepper Varieties

Disease-resistant pepper variety known as "Lampong" is used.

4.3 Crop and Farm Management

4.3.1 Raised Bed Pepper Planting in Flood-Prone Areas

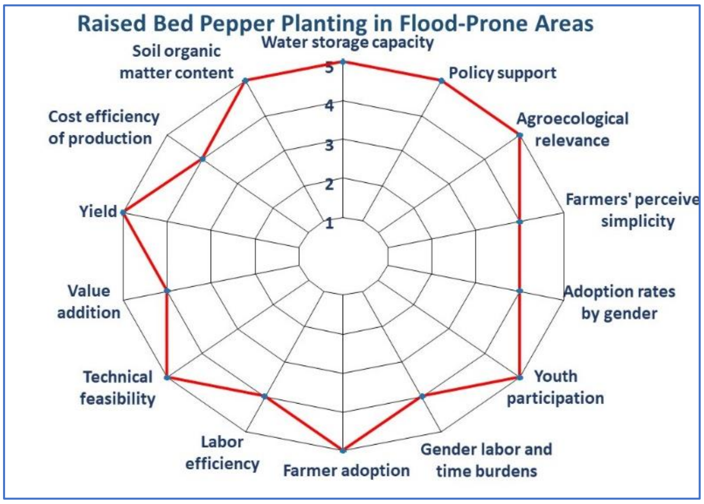
Description

Raised bed planting is a widely used technique in flood-prone or lowland areas to elevate crops above waterlogged soil levels. It improves drainage and soil aeration, making it especially useful in regions with high rainfall or poor natural drainage. In pepper cultivation, this method involves elevating planting rows based on local topography to reduce the risk of flooding and enhance plant health.

The benefits of raised bed planting include preventing runoff and nutrient leaching from compost or soil beds, maintaining soil structure and porosity, and improving root respiration and elongation. It helps prevent root rot in wet conditions and ensures proper water drainage. At the same time, raised beds retain moisture efficiently during dry periods, allowing plants to better tolerate unpredictable weather patterns. This technique has been widely implemented in many countries practicing sustainable agriculture.

Environmental Sustainability

Raised beds do not store water, but they play a crucial role in mitigating waterlogging and improving drainage, which indirectly supports water management. When combined with organic amendments such as compost, they help maintain soil structure and gradually build organic matter. This contributes to better soil moisture retention, nutrient availability, and improved soil aeration. Over time, raised beds support healthier, more resilient soils that are well-suited to sustainable farming.



Economic Viability and Cost Efficiency

While the initial cost of establishing raised beds can be higher due to labor and materials, the investment often pays off by reducing crop losses caused by flooding. Raised beds create a better root environment, which reduces stress from waterlogging and leads to more stable yields. Over the long term, this contributes to improved cost efficiency by protecting crop productivity and reducing the need for replanting or soil repair after floods.

Technical Feasibility and Ease of Adoption

This method is technically feasible for smallholder farmers and can be implemented with basic training. It is compatible with both manual labor using hand tools and small-scale mechanization. Although constructing the beds requires higher initial labor input, the ongoing maintenance is moderate. Interviews with lead farmers in flood-prone areas indicate a high intent to adopt the practice, especially where traditional planting methods frequently result in crop damage due to flooding.

Gender, Youth, and Social Inclusion

Raised bed planting is an inclusive practice suitable for both women and youth. Tasks involved in bed preparation and maintenance are manageable and can be shared among household members. The technique offers equal participation opportunities and contributes to inclusive family farming practices.

Scalability and Agroecological Relevance

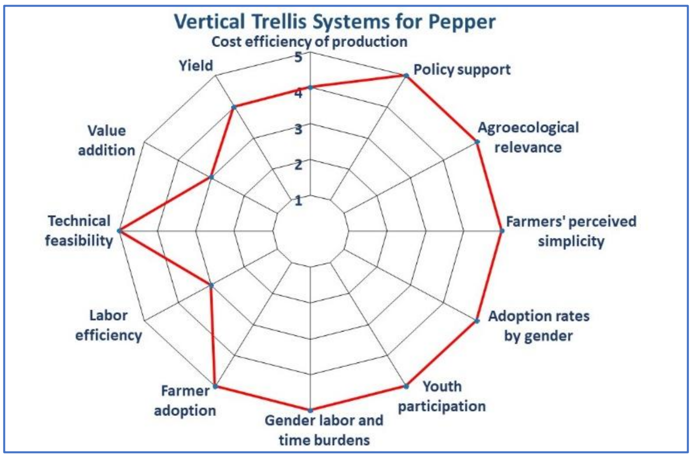
Farmers generally perceive the practice as manageable, especially when supported by extension services or training. Raised bed planting is highly relevant in flood-prone agroecological zones, where it helps manage excess water and supports sustainable cropping systems. It is recommended under climate-smart agriculture strategies and aligns well with national soil and water conservation goals, as well as broader resilience-building programs.

4.3.2 Vertical Trellis Systems for Pepper

Description

Vertical trellis systems provide essential structural support for pepper plants, helping improve air circulation, optimize land use, and increase yields. These systems are particularly important for supporting the vertical growth of pepper vines, which can become tall and heavy due to fruit development. A standard vertical trellis typically measures about 4 meters in height with a diameter of 10 to 15 centimeters. When installed vertically, it allows pepper vines to climb effectively, reducing the risk of ground-level diseases and making harvesting easier. Additionally, this setup keeps fruit off the ground, minimizes spoilage, and improves airflow, contributing to healthier plant development and better-quality produce.

Economic Viability and Cost Efficiency



The vertical trellis system is economically viable because it supports increased pepper yields and improved fruit quality. It also reduces labor costs through easier harvesting and better pest and disease management. Furthermore, the efficient use of vertical space allows farmers to grow more within the same land area, maximizing productivity. Although the initial investment in materials and labor may be relatively high, the returns in terms of yield, quality, and reduced risks make the payback period convincing and the practice cost-effective over time.

Technical Feasibility and Ease of Adoption

Constructing a vertical trellis system requires some labor input, but it is technically simple and has been widely adopted by pepper farmers. While the basic method is accessible, applying best practices—such as correct spacing, secure anchoring, and timely maintenance—is essential to ensure the trellis system effectively supports the plant's growth and maximizes yield potential. With basic guidance and demonstration, smallholders can readily adopt this technology.

Gender, Youth, and Social Inclusion

Vertical trellis systems are inclusive practices that can be implemented by both women and youth. They do not require specialized skills and are suitable for shared labor within farming households. By increasing productivity and reducing labor strain, the system supports equitable participation and contributes to more resilient family farming systems.

Scalability and Agroecological Relevance

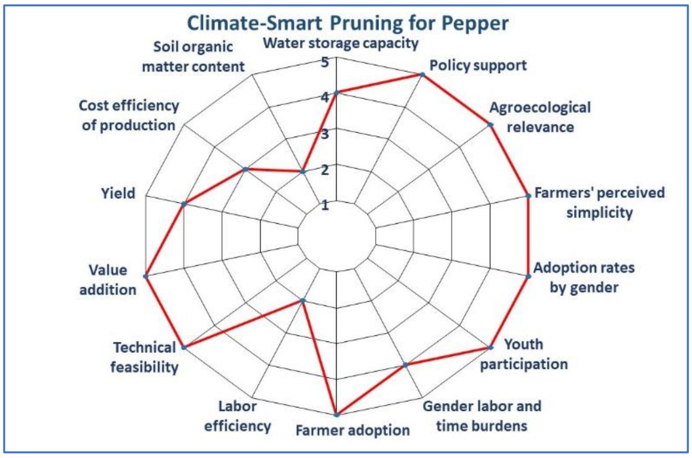
This practice is already widely used and considered simple and effective by many farmers. Its adaptability makes it scalable across provinces and suitable for a variety of agroecological zones. Vertical trellising, alongside horizontal systems, is commonly practiced globally and aligns with national agricultural development and climate adaptation programs. Its relevance in both small-scale and commercial farming contexts further enhances its potential for broader adoption.

4.3.3 Climate-Smart Pruning for Pepper

Description
Climate-smart pruning (CSA pruning) is a targeted strategy that adjusts the timing and intensity of pruning based on local environmental conditions. It helps crops and trees adapt to and mitigate climate stresses such as drought and heat, while maintaining productivity.

In pepper cultivation, climate-smart pruning includes removing lower branches (30–50 cm above the ground), beginning 3–4 months after planting and continuing every 2–3 months. This practice promotes even fruit distribution, eases pesticide application and harvesting, improves airflow, and reduces the risk of pests and fungal diseases. Overall, CSA pruning strengthens plant health, enhances productivity, and supports resilience under climate variability.

Environmental Sustainability
CSA pruning modifies the canopy structure to reduce transpiration and improve water retention in drought-prone conditions. By retaining leaf cover, the soil is shaded, reducing evaporation and preserving soil moisture. Pruned residues can be chipped and used as mulch, enriching the soil with organic matter and contributing to carbon sequestration, thereby supporting long-term soil fertility and ecosystem health.



Economic Viability and Cost Efficiency
Strategic pruning helps maintain productivity by reducing climate-induced stress and supporting stable yields during extreme weather events such as drought or heatwaves. Utilizing pruning waste as mulch adds on-farm value and reduces reliance on external inputs. Although there are some labor and minor equipment costs, the yield benefits typically outweigh the expenses. When done after harvest, pruning can enhance fruit size and quality, further boosting farm income.

Technical Feasibility and Ease of Adoption
CSA pruning is technically feasible for most smallholder farmers and adaptable to a variety of climates. It requires periodic labor input but offers long-term labor savings by reducing the need for intensive pest control. With proper guidance and extension support, the practice is relatively easy to adopt. Its success depends on farmers' understanding of pruning techniques and seasonal timing, both of which can be addressed through community training.

Gender, Youth, and Social Inclusion
Pruning activities can be shared among household members and do not require specialized equipment, making them accessible to both women and youth. When integrated into inclusive training sessions, CSA pruning can contribute to skill development and equitable labor division on farms. It supports greater involvement of youth in agriculture by offering tangible ways to enhance productivity and farm resilience.

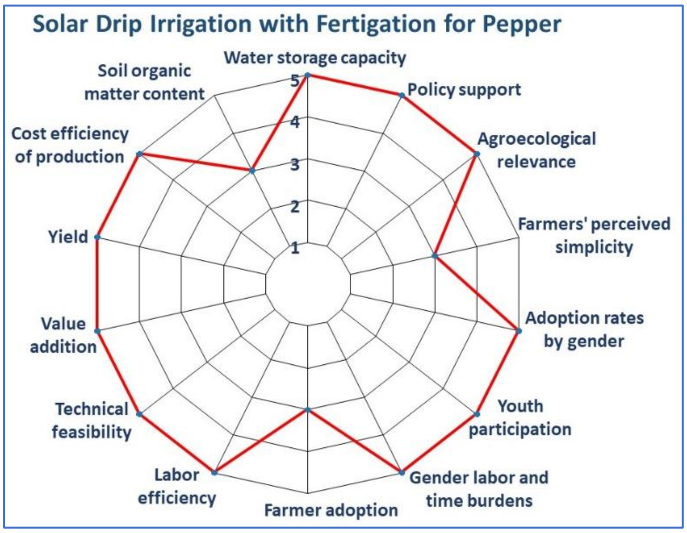
Scalability and Agroecological Relevance
CSA pruning is widely applicable across diverse agroecological zones, especially those prone to water stress and extreme temperatures. It complements broader climate-smart agriculture and agroforestry initiatives. In Cambodia, the practice is aligned with national strategies that promote sustainable land management and climate resilience. As awareness grows, CSA pruning has the potential for widespread replication and integration into pepper and cashew production systems.

4.4 Water Management

4.4.1 Solar Drip Irrigation with Fertigation for Pepper

Description
Drip irrigation combined with fertigation is an efficient method that delivers both water and nutrients directly to the root zone of pepper plants through a drip system. This system uses filters and drip lines to ensure precise delivery of inputs, enhancing resource use efficiency and crop performance. It promotes better plant growth, increases yield, and results in high-quality pepper production. The method also reduces water waste and minimizes the risk of groundwater pollution by targeting the exact area where water and nutrients are needed. This precision leads to both cost savings and environmental benefits for farmers.
When powered by solar pumps, the system becomes independent from unreliable grid or diesel supplies, ensuring continuous irrigation even in remote areas. Solar integration also allows farmers to run irrigation during peak daylight hours without increasing energy costs.

Environmental Sustainability



Drip irrigation can achieve high water use. By delivering water and nutrients directly to the roots, the practice helps retain soil moisture and reduces fertilizer losses. This targeted delivery system not only conserves water but also supports healthier soils and limits nutrient runoff, contributing significantly to sustainable pepper farming in both rainfed and irrigated systems. When powered by solar pumps, the system further reduces environmental impact by replacing diesel or grid electricity with clean, renewable energy. Solar pumping avoids fuel spills and emissions, decreases dependence on fossil fuels, and contributes to national climate-smart agriculture objectives. Combining drip fertigation with solar energy therefore promotes both resource efficiency and low-carbon pepper production.

Economic Viability and Cost Efficiency

Drip irrigation with fertigation allows farmers to optimize water and fertilizer use, reducing unnecessary input costs while improving yield quality and uniformity. More efficient nutrient delivery can translate into healthier plants, fewer losses, and more predictable harvests. Over time, these benefits contribute to improved farm profitability and reduced financial risk.

Integrating solar-powered pumps strengthens the economic case further. Although solar systems require higher initial investment compared to diesel or grid-powered pumps, they eliminate recurring fuel expenses and help protect farmers from rising energy costs. Routine maintenance requirements are also lower, reducing long-term operating expenses. When combined with yield gains from drip fertigation, the avoided energy costs can significantly shorten the pay-back period and make the system financially attractive, especially for remote farmers with limited access to electricity.

Technical Feasibility and Ease of Adoption

Drip fertigation systems are technically manageable for most pepper farmers with only basic training required for maintenance and usage. The main barrier to adoption is the upfront investment cost, but the long-term benefits in terms of labor savings, yield stability, and improved efficiency make it an appealing option. Once established, the system is relatively easy to operate and maintain.

Solar pumping technology can be integrated into drip systems with minimal modification. Standard solar pump kits are modular and connect easily to storage tanks or mainlines, allowing farmers to operate irrigation even in areas with unreliable grid supply. Once installed, farmers primarily need guidance on panel orientation, pump sizing, and simple maintenance routines. Because routine operation remains much like conventional drip systems, the addition of solar energy does not complicate use and can actually make operation more reliable and easier to manage.

Gender, Youth, and Social Inclusion

Drip irrigation with fertigation is inclusive and offers several advantages for women and youth. With proper training, women farmers can manage the technical aspects of the system, and the reduced labor demand lessens the household burden typically borne by women. This improves their resilience and enhances food security at the household level. The technology also presents a platform for youth to engage in agripreneurship, technical skill development, and innovation, making it a valuable practice for inclusive rural development.

When powered by solar pumps, the system eliminates the need to transport diesel, handle fuel containers, or start noisy engines, reducing safety risks and labor burdens typically carried by women. At the same time, the introduction of solar technology creates new opportunities for youth engagement through roles in installation, maintenance, monitoring, and service provision. These emerging “green jobs” help young people participate more actively in agricultural enterprises while building technical skills relevant to future employment.

Scalability and Agroecological Relevance

This practice is highly scalable and applicable across different farm sizes—from smallholder plots to large commercial operations. While some farmers perceive the system as complex, especially during setup and operation, these challenges are easily overcome through training and extension support. Automation tools further simplify decision-making and enhance adoption rates. National agricultural programs widely support drip fertigation for high-value crops like pepper due to its proven ability to increase yield, improve water and fertilizer efficiency, and contribute to climate resilience in regions facing water scarcity.

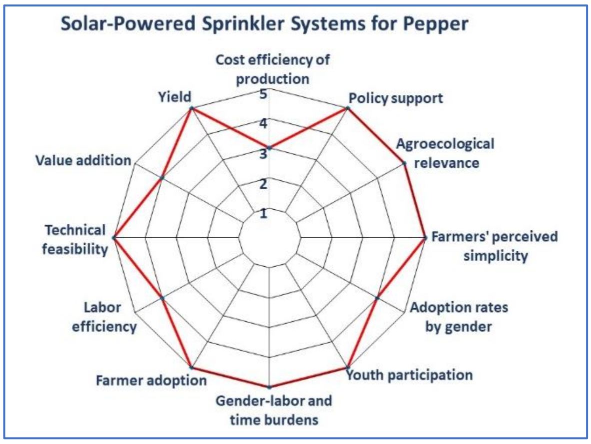
The integration of solar-powered pumps increases scalability further by removing dependence on grid electricity or diesel availability. Because solar units are modular and can be sized to match farm needs, they can be installed first on priority plots and later expanded across the farm as resources allow. This makes the combined solar drip fertigation system particularly relevant in regions facing energy constraints, rising fuel costs, or unreliable rainfall, while supporting broader goals for climate-smart and environmentally sustainable agriculture.

4.4.2 Solar-Powered Sprinkler Systems for Pepper

Description

Solar-powered sprinkler systems are automated irrigation setups powered by photovoltaic energy, designed to distribute water evenly across pepper farms. These systems are particularly effective for mature pepper vines, which benefit from consistent water delivery to manage heat stress and support flowering and fruiting. Sprinklers are favored in pepper systems where uniform canopy coverage and quick water dispersion are required, and they can be adapted to various terrains and planting designs.

Environmental Sustainability-powered systems, solar-powered sprinklers reduce energy-related emissions and eliminate the risks of fuel spills and runoff. In pepper production systems, efficient irrigation helps minimize water waste and reduces nutrient leaching and soil degradation, supporting environmentally responsible farming practices. Research on pepper irrigation shows that proper water management significantly improves -designed irrigation in sustainable pepper cultivation (Vieira et al., 2024).



Compared to traditional diesel or grid-powered systems, solar-powered sprinklers reduce energy-related emissions and eliminate the risks of fuel spills and runoff. In pepper production systems, efficient irrigation helps minimize water waste and reduces nutrient leaching and soil degradation, supporting environmentally responsible farming practices. Research on pepper irrigation shows that proper water management significantly improves **water use efficiency** and reduces overall water and energy demand, highlighting the importance of well-designed irrigation in sustainable pepper cultivation (Vieira et al., 2024).

Economic Viability and Cost Efficiency-powered sprinkler systems are relatively high, farmers recognize strong long-term returns due to labor savings, reduced water wastage, and improved yields. The automation of irrigation through efficient systems like solar-powered sprinklers ensures timely watering, which is critical for high-value pepper crops that are particularly sensitive to water stress during flowering and fruiting stages. Evidence from drip and sprinkler irrigation studies in pepper production shows that improved irrigation management increases water use efficiency and yield, leading to better economic outcomes compared to conventional irrigation methods (Mačkić et al., 2023). In comparative analyses, modern sprinkler and drip systems for pepper also demonstrated higher technical efficiency and output relative to traditional furrow irrigation, suggesting greater potential for profitability when water and labor costs are factored in (-term cost efficiency and improved farm economic performance.
While initial investments in solar-powered sprinkler systems are relatively high, farmers recognize strong long-term returns due to labor savings, reduced water wastage, and improved yields. The automation of irrigation through efficient systems like solar-powered sprinklers ensures timely watering, which is critical for high value pepper crops that are particularly sensitive to water stress during flowering and fruiting stages. Evidence from drip and sprinkler irrigation studies in pepper production shows that improved irrigation management increases water uses efficiency and yield, leading to better economic outcomes compared to conventional irrigation methods (Mačkić et al., 2023). In comparative analyses, modern sprinkler and drip systems for pepper also demonstrated higher technical efficiency and output relative to traditional furrow irrigation, suggesting greater potential for profitability when water and labor costs are factored in (Absanto et al., 2025). These findings support the notion that, in areas with limited labor availability or high irrigation costs, efficient irrigation technologies can translate into long-term cost efficiency and improved farm economic performance.

-growing regions have shown strong interest in solar-powered sprinkler systems because t

Technical Feasibility and Ease of Adoption
Farmers in pepper hey fit easily within existing trellis or vertical vine layouts. Once installed, they require little technical input, and the growing availability of local suppliers, spare parts, and installers in Cambodia further supports feasibility.

Pilots in Kampot and Kep demonstrate that commercial pepper farms can integrate solar-powered cooling and irrigation systems that combine misting or sprinklers with drip irrigation. In the “Kampot Cooling” project, PV-powered systems were installed on two farms and adapted to existing trellis structures, then operated by farm workers using simple controllers and mobile-based monitoring. Farmers reported reduced manual watering, better water-use efficiency, and ease of operation, indicating that the technology is manageable for both smallholders and medium-scale farms (People in Need, 2025).

In Brazil, a microspray irrigation system installed on trellised black pepper achieved high uniformity and strong yields when irrigation depths matched crop water requirements, showing that pressurized sprinkler technologies work reliably in pepper production. In practice, transitioning to solar-powered systems mainly involves substituting the energy source rather than changing farmers' irrigation practices (Vieira et al., 2024).

Because SPIS are built from widely available components such as solar panels, controllers, pumps, and piping or sprinklers, they provide a dependable water source and can be combined with moisture-sensing automation and fertigation. For pepper farms, this translates into technically feasible systems that integrate smoothly with current production methods while improving efficiency and labor savings.

Gender, Youth, and Social Inclusion

By reducing the physical labor associated with manual watering, sprinkler systems improve accessibility for women and older farmers. They also create opportunities for youth engagement through installation, maintenance, and monitoring services. When organized through farmer groups or cooperatives, these systems can encourage more inclusive participation in decision-making and water governance.

Sprinkler systems typically require only a simple switch to operate, which removes the need to carry heavy equipment or fuel containers and significantly reduces physical burden. Women often prefer solar-powered systems over electric pumps because they perceive a lower risk of electrical shock, which contributes to improved safety and confidence in system use. At the same time, the expanding sector generates new green jobs for youth, particularly in technical maintenance, system design, installation services, and extension support, helping to integrate young people more actively into agricultural innovation.

Scalability and Agroecological Relevance

The system is well suited to the sloped and mixed-elevation terrains common in pepper farms, where overhead irrigation helps reduce heat stress and maintain canopy humidity. It is particularly relevant in provinces such as Tboung Khmum and Kampot, where increasing climate variability and longer dry periods threaten pepper quality and yield.

The scalability of solar-powered systems is driven by strong economic and environmental benefits. With near-zero operating costs compared with diesel or grid pumps, farmers can recover investments quickly. Reliable off-grid energy improves production stability, while falling solar prices and simple control technologies make systems easier to manage. Support programs from government and development partners further encourage wider adoption.

From an agroecological perspective, these systems help farmers manage droughts and heatwaves by ensuring dependable water supplies and cooling capacity during critical periods, strengthening resilience and supporting sustainable pepper production in Cambodia.

4.5 Agroforestry and Intercropping

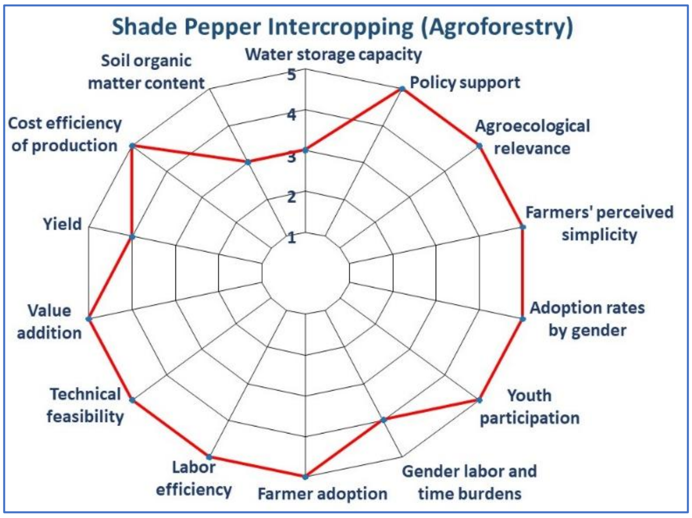
4.5.1 Shade Pepper Intercropping

Description

Shade pepper intercropping involves planting pepper alongside shade trees that offer both structural support and environmental benefits. In Cambodia, the Areca Palm (Areca catechu) is commonly used as a live stake and shade provider. It offers multiple benefits, including partial shading, structural support for pepper vines, and the added economic value of Areca nuts. The palm's deep root system is less competitive with pepper, and its cultural and medicinal significance makes it highly relevant in Cambodian farming systems.

This practice is part of a broader agroforestry system that intercrops pepper with tall trees like Areca trees. Sala trees, for example, provide moderate shade without obstructing pepper plant photosynthesis and require less pruning than other shade-providing crops. The use of live tree trunks as stakes not only lowers long-term costs but also ensures durability and sustainability. As a climate-smart agricultural method, this system offers additional benefits such as natural pest control (e.g., through attracting birds that prey on moths), biodiversity enhancement, reduction of heat stress, and improved growth conditions. Shade pepper intercropping is currently implemented in several countries, including India, Indonesia, Brazil, and nations in Sub-Saharan Africa. In Cambodia, it is increasingly adopted for its role in reducing temperature stress, managing humidity, and improving the overall resilience of pepper crops.

Environmental Sustainability



Shade intercropping systems frequently incorporate compost-based organic fertilizers, particularly in tree-based systems. These not only support nutrient cycling but also enhance organic matter accumulation in the soil. The shaded environment helps maintain soil moisture and reduces evaporation, while tree canopies act as natural regulators of microclimates. Additionally, birds attracted to these systems contribute to soil fertility through their droppings. Together, these elements support a more sustainable and biodiverse ecosystem, improving overall soil and plant health.

Economic Viability and Cost Efficiency

Using live stakes like Areca Palm significantly reduces long-term production costs by eliminating the need for wooden poles and synthetic inputs. Although initial planting requires labor, long-term savings are realized through reduced expenditure on fertilizers and pest management. For example, the cost of purchasing 2,500 Areca seedlings (at 2m x 2m spacing) is approximately $1,750. Pepper grown under shade systems also tends to have more stable yields due to protection from environmental stressors like heat and wind, and benefits from better water use efficiency. Furthermore, shade-grown pepper—especially when cultivated organically—often commands premium market prices due to its quality and environmentally friendly cultivation process. Farmers benefit from dual-income streams: one from pepper production and another from Areca fruit sales. They also avoid costs associated with installing artificial heat-protective systems and benefit from the natural pest regulation provided by biodiversity.

Technical Feasibility and Ease of Adoption

Shade intercropping using live stakes is technically feasible for smallholder farmers and is adaptable across various soil types. While initial labor investment is required for establishing the trees, labor demands decline over time. Maintenance involves manageable tasks like pruning and monitoring, particularly when household or community labor is available. The approach is increasingly being adopted, particularly in areas supported by extension services or demonstration plots. Farmers consistently report that the long-term benefits outweigh the initial effort and investment. Interviews with lead farmers indicate a high intention to adopt the system due to its sustainability and income potential.

Gender, Youth, and Social Inclusion

This system allows for equitable participation among household members. Tasks such as collecting Areca fruits, maintaining shade trees, or managing pepper vines can be shared among men, women, and youth. These activities do not place a significant additional burden on women, and the relatively simple management structure encourages youth participation. Many young farmers are engaging in pepper-agroforestry systems either through family farms or entrepreneurial agroforestry initiatives.

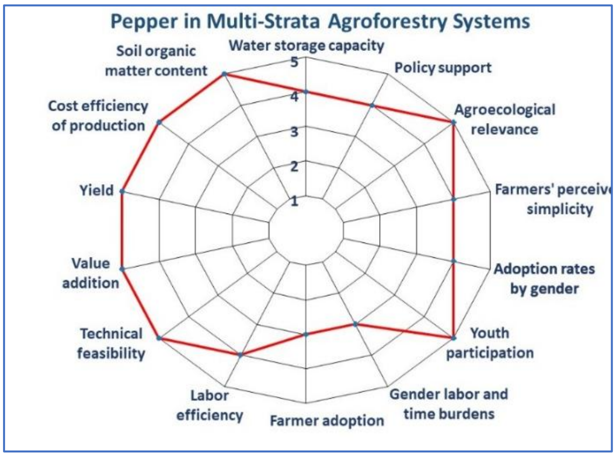
Scalability and Agroecological Relevance

Among Cambodian pepper farmers, this practice is perceived as simple, adaptable, and highly suitable for the country's tropical climate and often-degraded soils. The use of Areca Palm improves soil structure and biodiversity while mitigating heat stress. These attributes make the approach ideal for semi-humid and rainfed conditions. Agroforestry-based systems such as these are already promoted under national climate-resilient agriculture strategies, reinforcing the enabling policy environment for wider adoption.

4.5.2 Pepper in Multi-Strata Agroforestry Systems

Description

Pepper in multi-strata agroforestry systems involves cultivating climbing pepper vines alongside crops of varying heights, including canopy trees, fruit trees, and understory plants. This polyculture mimics natural forest ecosystems, delivering substantial environmental and economic advantages over monoculture systems. The multi-strata design includes several layers: the upper canopy with tall timber or fruit trees like jackfruit, coconut palms, or clove; a middle layer with crops such as bananas, coffee, or cacao; and an understory with shade-tolerant plants like pineapple, ginger, turmeric, and leafy greens. Pepper vines climb living support trees within this setup. Common companion crops include bananas, pineapples, and Gliricidia trees. This system enhances soil fertility, boosts biodiversity, improves moisture retention and temperature regulation, and reduces input costs while increasing yields and pepper plant health.



Environmental Sustainability

Multi-strata agroforestry improves soil structure through root stratification across different depths, enhancing nutrient retention and cation exchange capacity. Decomposing organic matter from diverse plants boosts soil organic matter. Reduced nutrient leaching, subsoil nutrient recycling, and niche complementarity increase efficiency in resource use. Shade from trees helps retain moisture, while leaf litter and mulch add nutrients. These systems also support soil moisture storage, biological health, and maintain a fresher microclimate.

Economic Viability and Cost Efficiency

Multi-strata agroforestry enables diversified income through the integration of pepper and high-value companion crops, creating resilience against market fluctuations. Farmers reduce input costs by leveraging natural pest control from biodiversity and improved soil fertility via organic matter recycling and nitrogen-fixing species like Gliricidia. This approach reduces chemical fertilizer dependency and provides added value through crops like bananas, pineapples, and organic pesticides.

Technical Feasibility and Ease of Adoption

The system is technically feasible and labor-manageable, though initial design and species selection are crucial. While the integration of multiple species can be perceived as complex, proper planning and extension support mitigate this. Interviews with lead farmers show some hesitation, especially due to small land sizes, although implementation is still possible with smart design.

Gender, Youth and Social Inclusion

Women can participate meaningfully in the multi-strata system by engaging in seedling and nursery work (for pepper, shade trees), intercropping, weeding, harvesting pepper berries, postharvest processing (drying, sorting), value-chain tasks (packaging, marketing) and even nursery or tree maintenance tasks. Youth (both young women and men) can be engaged via training, demonstration plots, youth farmer networks, innovation adoption (shade tree intercropping, value add for pepper), monitoring and digital marketing of farm produce. -cropping, weeding, harvesting pepper berries, post-harvest processing (drying, sorting), value-chain tasks (packaging, marketing) and even nursery or tree-maintenance tasks. Youth (both young women and men) can be engaged via training, demonstration plots, youth-farmer networks, innovation adoption (shade-tree intercropping, value-add for pepper), monitoring and digital marketing of farm produce.

Multi-strata agroforestry for pepper provides diversified income streams. Women and youth could thus benefit not only from pepper berries but also from shade trees (fruits, timber, NTFPs) and inter-crops. To ensure equitable access and opportunity, several strategies can be applied. These include training modules tailored for women and youth, and flexible schedules that accommodate domestic responsibilities. Additional approaches involve linking participants to value chains with lower entry barriers, using demonstration sites where women and youth can engage in multi-strata systems, and strengthening extension services that are specifically adapted to gender and youth needs.

Scalability and Agroecological Relevance
Despite perceptions of complexity, multi-strata agroforestry is scalable with adequate technical support. The system aligns well with national strategies promoting climate-resilient agriculture, especially in regions practicing pepper farming. While land size can limit implementation, proper planning enables adaptability even in smallholder settings.

4.5.3 Pepper–Fruit Tree Intercropping

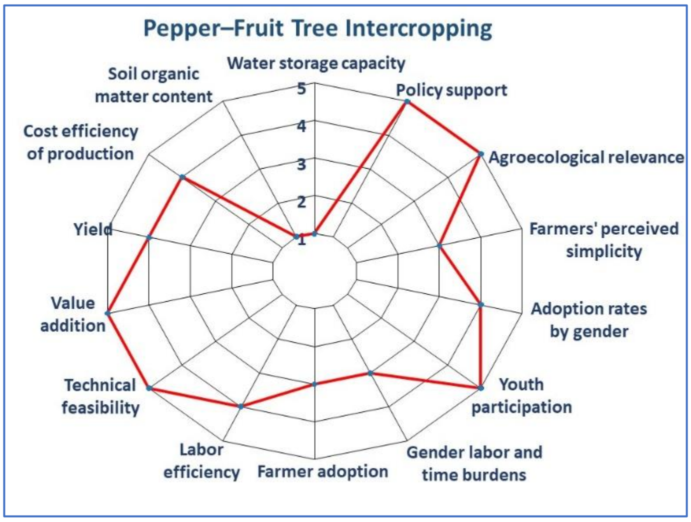
Description
Pepper–fruit tree intercropping is a polyculture system where black pepper vines are cultivated alongside and supported by various fruit trees. This method offers significant ecological and economic benefits, including increased biodiversity, improved soil health, and diversified income for farmers. There are two types of systems: live poles and non-living poles. Live support becomes more practical as deadwood becomes less available. Black pepper plants benefit from partial shades, especially during the hottest parts of the day. Fruit trees with moderate canopies provide this necessary shade, reducing heat and moisture stress on the pepper vines. By using living fruit trees as support standards for climbing pepper vines, farmers can cut costs associated with non-living supports like concrete or wooden poles, while also reducing the need to harvest forest trees for stakes, promoting conservation.

Fruit trees with deep root systems can absorb nutrients from deeper soil layers that are unavailable to the shallow-rooted pepper plants. When fruit trees drop leaves or fruits that decompose, these nutrients become accessible to the pepper vines. Planting fruit trees such as Durian (Durio spp.) or Rambutan (Nephelium lappaceum) between pepper rows improves land-use efficiency. This method enables farmers to earn income from both pepper and fruit crops while the long-term trees mature and provide shade.

Environmental Sustainability
This system absorbs carbon into the soil, reduces greenhouse gas emissions, and contains a high level of organic matter that improves soil quality. Leaf litter from fruit trees moistens the soil and contributes to a healthier soil ecosystem. In Cambodia, where many smallholder farmers use limited fertilizer and water inputs—particularly in rainfed systems—fruit trees intercropped with pepper vines often compete for essential resources. Water competition is particularly evident during the dry season, and soil nutrients must be replenished through compost or fertilizer to avoid depletion.

Economic Viability and Cost Efficiency

Pepper–fruit tree intercropping increases overall farm income by producing multiple crops from the same land. Diversified income streams act as a buffer against the price volatility of a single commodity. Durian and Rambutan intercropping have shown significantly higher net returns and benefit-cost ratios compared to monocropping. If the market price for pepper falls, income from the fruit trees helps stabilize farm revenue.



Technical Feasibility and Ease of Adoption

This system is technically feasible for smallholder farmers and adaptable across pepper-growing soil. Initial labor is required for tree establishment, but maintenance tasks are manageable, especially with community or household labor. Success depends on proper tree selection and management—fruit trees like durian and rambutan must support pepper vines without excessive competition. Interviews with lead farmers highlight concerns about nutrient competition, though the system is considered productive and sustainable with appropriate planning.

Gender, Youth and Social Inclusion

Pepper–fruit tree intercropping is inclusive of women and youth. With appropriate support, both groups can engage in and benefit from the system. Equity in access to resources and decision-making ensures shared economic and social outcomes within households and communities.

Scalability and Agroecological Relevance

Although dual cropping is perceived as slightly complex, with technical guidance and training, it can be scaled across Cambodia's pepper-growing regions. It aligns with national strategies for climate-resilient agriculture and is already promoted through supportive policies.

4.6 Post-Harvest, Processing and Value Addition

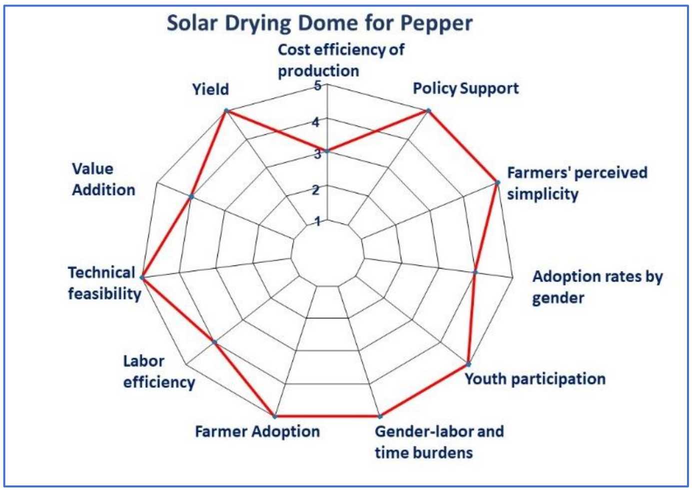
4.6.1 Solar Drying Dome for Pepper

Description

Solar drying uses solar energy to remove moisture from agricultural products, enhancing shelf-life and quality. For black pepper, it significantly improves traditional open-sun drying by speeding up the process and protecting the product from contamination. This results in a higher-quality product with better flavor and color. Under controlled conditions, solar dryers regulate temperature and humidity, enabling a more consistent and predictable drying process.

The solar drying system is designed for optimal sunlight exposure during midday. A heating fan operates to extract moisture, with a built-in timer for efficiency. Its benefits include preventing mold, contamination from soil, and preserving flavor for long-term storage. The system typically includes a loading window, internal shelves, and an exhaust fan. This method is commonly used by collectors and large-scale farmers.

There are three main types of solar dryers. Direct dryers heat peppercorns inside an enclosed chamber via sunlight through a transparent cover—simple and low-cost, but with limited temperature control. Indirect dryers use solar-heated air circulated through a separate chamber, offering gentler and more uniform drying. Mixed-mode dryers combine both methods, providing the fastest solar drying option.



Economic Viability and Cost Efficiency

Despite substantial economic and quality - related benefits, solar drying remains unaffordable for many smallholder pepper farmers in Cambodia due to high initial costs. Nevertheless, it reduces post-harvest losses, accelerates drying, preserves compounds like piperine and volatile oils, and minimizes microbial contamination. These advantages increase usable yield and boost economic return per unit of crop, though widespread adoption requires financial or cooperative support.

Technical Feasibility and Ease of Adoption

Solar drying is technically feasible and proven as a cost-effective alternative to open-sun drying. Farmers recognize its value and express willingness to adopt it, but limited financial resources hinder smallholder implementation.

Gender, Youth, and Social Inclusion

The practice supports inclusive development by empowering women—typically responsible for drying—with time saving, income-enhancing tools. It also promotes youth engagement through entrepreneurial opportunities in food safety, quality improvement, and marketing.

Scalability and Agroecological Relevance

Perceived as practical and beneficial by farmers, solar drying can be scaled across provinces with appropriate financing. It aligns with Cambodia's agricultural and energy strategies and supports sustainable development goals.

4.7 Pest and Disease Management

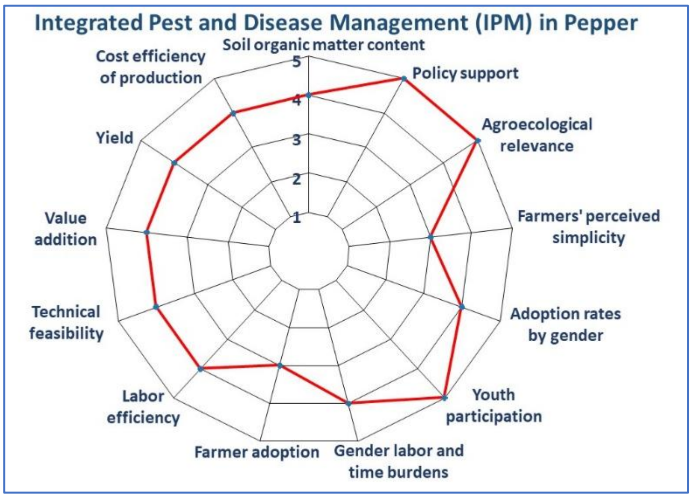
4.7.1. Integrated Pest and Disease Management (IPM) in Pepper

Description

Integrated Pest and Disease Management (IPM) in pepper is an approach that integrates biological, cultural, mechanical, and chemical methods to manage insect pests and diseases while minimizing environmental harm. Its primary objective is to reduce the over-reliance on chemical pesticides and conserve beneficial insects that naturally suppress pest populations. These beneficial organisms, acting as natural enemies, play an increasingly vital role in pest control. The approach also emphasizes the use of disease- and pest-resistant pepper varieties to enhance crop resilience.

Environmental Sustainability

By minimizing the excessive use of chemical inputs, IPM contributes to the protection of the environment, biodiversity, and the health of natural resources. Its effect on water storage capacity depends on the specific practices applied. For example, when farmers use biopesticides such as Trichoderma, they often mix them with compost before application. This practice enhances soil nutrient availability, maintains adequate moisture, and improves the soil's ability to retain water.



Economic Viability and Cost Efficiency

Economically, IPM in pepper is cost-effective, with relatively low input costs per hectare. The approach has shown strong potential to deliver high yields, thereby improving farmers' incomes. However, to fully realize its benefits, farmers and communities need technical training on how to properly implement and maintain IPM strategies. With adequate knowledge and application, IPM can significantly enhance productivity and profitability.

Technical Feasibility and Ease of Adoption

Similar to its application in cashew, IPM in pepper is technically feasible but not entirely straightforward to adopt. Farmers must be able to recognize and respond to various pests and diseases, which can present initial challenges. Nevertheless, once in practice, IPM tends to reduce pest and disease incidence and does not require considerable labor input for continued use.

Gender, Youth, and Social Inclusion

IPM is inclusive and accessible to men, women, and youth. The tasks involved can be performed equally by all groups, without placing a significant burden on their time or labor. This makes the approach suitable for promoting gender equality and youth engagement in agriculture.

Scalability and Agroecological Relevance

The practice is scalable across provinces and adaptable to different agroecological zones. While some farmers may initially perceive it as somewhat complex, most find it manageable after receiving proper training. Furthermore, national agricultural strategies support the reduction of synthetic pesticide use and promote the production and adoption of biological alternatives.

4.8 Information, Training and Advisory Systems

4.8.1. Farmer Field Schools for Pepper

Description

Farmer Field Schools (FFS) are group-based experiential learning programs designed to empower farmers through season-long, hands-on education conducted directly in their own fields. Although not inherently climate-specific, FFS curricula can be tailored to include climate-smart agriculture practices such as the use of drought-tolerant seeds, water-saving techniques, integrated pest management, and sustainable soil management. These programs use real-time observation, experimentation, and collaborative problem-solving to foster informed decision-making and enhance crop management.

In pepper farming, FFS guides participants through the entire production cycle; including pruning, fertilizing, harvesting, and post-harvest storage. It emphasizes sustainable practices, adaptive techniques, and peer collaboration. The goal is to strengthen decision-making capacity, improve technical knowledge related to planting, maintenance, and pest/disease control, and to foster stronger farmer networks.

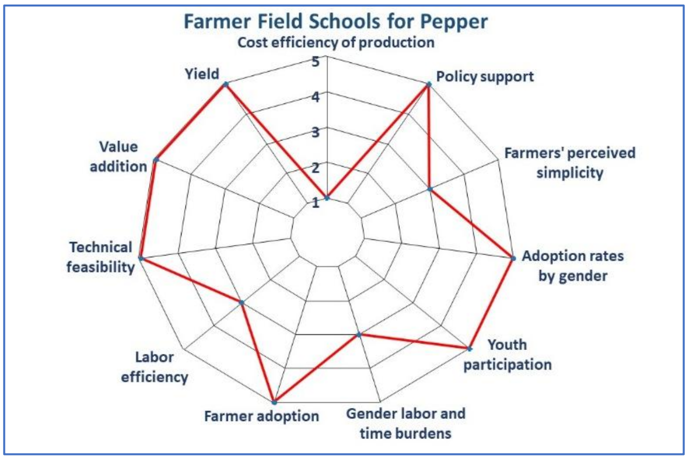
FFS has been widely implemented in Africa, Asia, and Southeast Asia, including Cambodia, where it has supported numerous agricultural sectors.

Economic Viability and Cost Efficiency

FFS reduces reliance on expensive chemical inputs by promoting alternatives such as biological control and composting. This knowledge-sharing approach can lower production costs over time. It promotes adaptive, locally relevant strategies like improved seed selection and disease management, which help stabilize yields under variable climatic conditions. Modules often include training on post-harvest handling, processing, and marketing, and enhancing value addition. However, the implementation of FFS requires significant investment in facilitation, demonstration plots, and monitoring. Continued support from extension services is critical, particularly for long-duration crops like peppers. Many FFS programs face challenges due to limited financial and technical resources.

Technical Feasibility and Ease of Adoption

FFS is technically feasible in rural settings because of its participatory nature and adaptability across crop systems. While it may temporarily increase labor demands during group activities and trials, it ultimately boosts labor efficiency through knowledge transfer. Adoption rates are high when programs are facilitated effectively, as farmers tend to trust practices co-developed through local experimentation and peer validation.



Lead farmer interviews show a strong willingness to participate, particularly when adequate support is provided.

Gender, Youth, and Social Inclusion
FFS can be highly inclusive when designed thoughtfully. It supports gender-sensitive participation and can be aligned with women's time availability. It also offers opportunities for youth engagement, especially when topics include technology, innovation, or agribusiness. With built-in gender-disaggregated data collection, FFS programs can monitor and address gender-specific barriers and outcomes in adoption and participation.

Scalability and Agroecological Relevance
FFS's perceived complexity depends on the facilitator's capacity and the relevance of selected topics, but peer-to-peer learning helps lower these perceived barriers. The model is highly adaptable to different agroecological zones and farming systems. In Cambodia, FFS has a long-standing presence and has been successfully applied across various crops. It is well supported under national strategies and agricultural development policies.

Participatory Farmer Consultation And Prioritization

5.1 Farmer Feedback on Proposed Practices

As part of the participatory consultation process, farmers from cashew- and pepper-growing provinces participated in focus group discussions to reflect on which of the proposed CRPs they had previously implemented. This feedback provides a baseline understanding of farmer familiarity and experience with key practices, helping to guide priority settings, training needs, and demonstration planning.

Table 3. Farmer Reported Use of Climate Resilient Practices Across Cashew and Pepper Production Areas

No.	Practice	Cashew		Pepper	
		Kratie	Kampong Thom	Tboung Khmum	Kampot
1	Biochar Application	Yes	Yes	Yes	No
2	Climate-Smart Pruning	Yes	Yes	Yes	Yes
3	Cover Cropping	Yes	Yes	Yes	Yes
4	Local Biofertilizer/Compost Production	Yes	Yes	Yes	Yes
5	Cooperative-Led Nursery Systems	Yes	Yes	Not applicable	Not applicable
6	Drought-Tolerant / Disease-Resistant Varieties	Yes	Yes	Yes	Yes
7	Legume Intercropping	No	Yes	Not applicable	Not applicable
8	Integrated Pest & Disease Management (IPM)	Yes	Yes	Yes	Yes
9	Mulching with Organic Residues	Yes	Yes	Yes	No
10	Organic Production	Yes	Yes	Not applicable	Not applicable

11	Pesticide-Free Pest Traps	No	Yes	Not applicable	Not applicable
12	Agroforestry / Shade Intercropping	Yes	Yes	Yes	Yes
13	Bee Keeping	No	Yes	Not applicable	Not applicable
16	Site-Specific Nutrient Management (SSNM)	Not applicable	Not applicable	Yes	Yes
17	RaisedBed Planting (Flood Prone Areas)-Bed Planting (Flood-Prone Areas)	Not applicable	Not applicable	Yes	Yes
18	Vertical Trellis Systems	Not applicable	Not applicable	Yes	Yes
20	Farmer Field Schools (FFS)	Not applicable	Not applicable	Yes	Yes
21	Mycorrhizal Inoculation	Not applicable	Not applicable	Yes	Yes
22	Solar-Powered Irrigation Sprinkler Systems	No	Yes	Yes	Yes
23	Solar Drying	Not applicable	Not applicable	Yes	Yes

5.1.1 Cashew Farming Systems (Kratie, Kampong Thom)

Farmers in the cashew-producing provinces of Kratie and Kampong Thom reported a wide and diverse range of climate-resilient practices already in use to varying degrees, particularly those related to soil fertility improvement, ecological pest control, and climate-smart field management. Their feedback suggests that cashew cultivation in both provinces is increasingly shaped by practices that emphasize soil regeneration, reduced chemical dependency, and resilience to climate variability.

In terms of soil and nutrient management, farmers in both provinces described the use of practices that enhance soil structure and sustain organic matter. Biochar application, used to improve soil texture and carbon retention, was commonly reported, along with cover cropping, which enhances soil protection and supports organic matter cycling. Farmers also described applying mulching with organic residues to reduce evaporation losses and suppress weed growth. In addition, local biofertilizer production was noted, reflecting a preference for low-cost, locally available nutrient inputs. Many farmers characterized their systems as organic cashew production (non-certified), highlighting their low synthetic fertilizers and pesticides. Moreover, both provinces reported the use of drought-tolerant and disease-resistant varieties (e.g. M23), indicating growing awareness of genetic resilience and availability at many local nurseries.

Nursery systems were also described as active in both provinces, supporting farmer access to improved planting materials. While many households continue to manage small informal nurseries at the farm level, more structured cooperative-led propagation remains limited. However, this widespread on-farm practice can serve as a strong foundation for scaling improved varieties and good planting techniques through enhanced technical support. Although Farmer Field Schools were not widely accessed by cashew growers, the strong reliance on peer learning and cooperative exchanges suggests significant opportunity to introduce structured training platforms focused on key aspects of the production cycle. This could help accelerate the uptake of more technical climate-resilient practices in future phases.

By contrast, water-related practices were less commonly implemented. Although solar-powered irrigation systems were known in both provinces, they were not widely used, and drip irrigation with fertigation was largely absent. This reflects the broader perception of cashew as a low water-demand crop, combined with the high capital and maintenance costs associated with irrigation investments, particularly among smallholders.

Agroforestry and intercropping practices were widely acknowledged, especially shade-based agroforestry systems, which were reported across both provinces. These systems help stabilize microclimates, reduce heat stress, and strengthen overall farm resilience. In Kampong Thom, farmers also described cashew–legume intercropping, using nitrogen-fixing plants to improve soil fertility while providing additional ground cover.

In the area of pest and disease management, farmers demonstrated strong familiarity with climate-smart pruning and IPM in both provinces. These practices emphasize good canopy structure, pest monitoring, and reduced reliance on chemical pesticides. Pesticide-free pest traps were mentioned specifically in Kampong Thom, while bee keeping was reported in both provinces, reflecting an understanding of ecosystem services such as pollination. These examples suggest that farmers are increasingly integrating ecological approaches into their existing farm management systems.

5.1.2 Pepper Farming Systems (Tboung Khmum, Kampot)

Farmers in the pepper-producing provinces of Tboung Khmum and Kampot reported a diverse set of climate-resilient practices already implemented, with particularly strong engagement in areas such as soil health, water management, agroforestry, and peer learning systems.

In terms of soil and nutrient management, both provinces adopted biochar application, cover cropping, and compost production and use, indicating broad application of practices that support organic matter enhancement. SSNM and mycorrhizal inoculation were also practiced in both provinces, reflecting the adoption of precision fertilization strategies and efforts to improve soil microbiology. Additionally, drought-tolerant varieties were integrated across both provinces as part of broader climate adaptation strategies.

Regarding water management, both Tboung Khmum and Kampot reported the use of solar-powered sprinkler systems, alongside raised-bed planting, which helps improve drainage and mitigate the impact of floods. These systems are particularly effective for pepper, a vine crop sensitive to water stress and root zone saturation.

In the area of agroforestry and intercropping, both provinces practiced shade-based pepper intercropping. Some farmers also implemented agroforestry with fruit trees, although the practice remains limited. For pest and disease management, both provinces implemented climate-smart pruning, IPM, and mycorrhizal inoculation as part of disease suppression strategies. These practices show a shift toward more ecological management approaches. As part of crop and farm management, the use of vertical trellis systems was widespread. These systems support optimal vine growth, improve airflow and light penetration, and reduce disease incidence in dense plantings.

Knowledge and extension systems were more prominent in pepper production. Farmers in both provinces reported previous participation in Farmer Field Schools, which provided hands-on training and facilitated the exchange of technical knowledge. Finally, under post-harvest and value addition, solar drying systems were reported as adopted in both provinces, although adoption varied. Some farmers had fully integrated these systems to preserve product quality, while others noted plans to adopt solar drying once financial resources become available.

5.2 Results of Participatory Prioritization Exercises

5.2.1 Cashew Systems (Kratie, Kampong Thom)

The results of the farmer prioritization exercises for cashew-based CRPs are presented in Figure 1. Farmers in both Kratie and Kampong Thom expressed generally strong interest in the proposed practices, with the majority of CRPs receiving "Willing to Adopt" responses. However, variation in adoption preferences was observed between the two provinces.

In Kampong Thom, where cashew is widely cultivated as a primary crop and often on larger, drier plots, farmers showed a higher willingness to adopt a broader range of practices. Their responses indicate a strong interest in scaling up production and improving productivity, likely driven by commercial motivations and the need to manage more challenging soil conditions.

In contrast, Kratie farmers were more selective. The province's more fertile soils and diverse farming systems may reduce the perceived need for certain CRPs. For example, cover cropping received a "Not Willing to Adopt" response, suggesting that farmers in Kratie view the benefits of this practice as less relevant in their context. When soils are already productive or land is used for multiple cropping, the added labor and land commitment required for cover cropping may not be justified from their perspective.

Additionally, Kratie farmers marked several practices as "Undecided," including Local Biofertilizer Production, Cooperative-Led Nursery Systems, and Climate-Smart Pruning. These responses suggest that further extension support and demonstration activities may be needed to improve understanding and confidence in implementing these options. Unlike Kampong Thom, Kratie farmers may base adoption decisions more on the perceived ease of integration into existing systems, rather than production scaling potential alone.

These findings reinforce the need for province-specific extension strategies. In Kampong Thom, efforts may focus on technical support for scaling and efficiency, while in Kratie, messaging should emphasize compatibility with existing systems, long-term benefits, and ease of adoption.

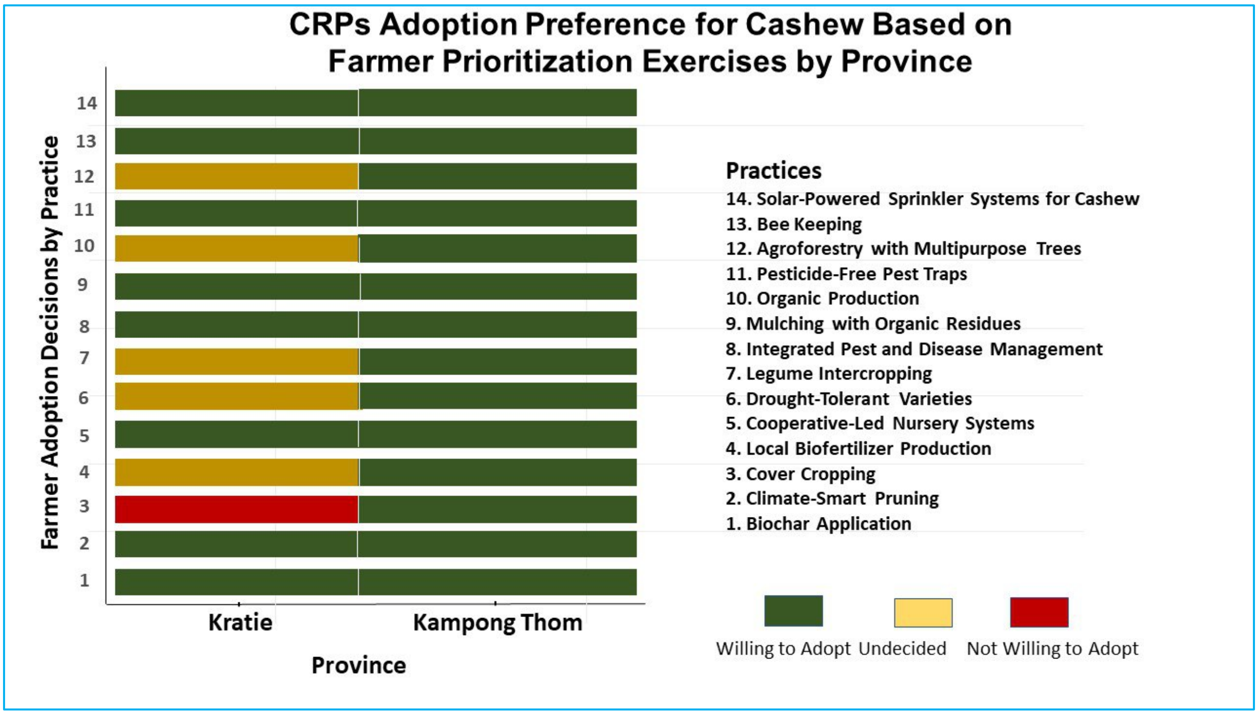


Figure 1. CRP Adoption Preferences for Cashew

5.2.2 Pepper Systems (Tbong Khmum, Kampot)

The results of the farmer prioritization exercises are presented in the figure below. Farmers in Tboung Khmum expressed a uniformly positive response to all 18 proposed CRPs, with each practice receiving a "Willing to Adopt" vote through the participatory exercises. This strong interest suggests that pepper farmers in Tboung Khmum are highly motivated to adopt new practices to scale up their production and transition toward more commercially oriented systems.

In contrast, farmers in Kampot demonstrated more selective decision-making. While most CRPs were supported, at least six practices received "Not Willing to Adopt" responses, and two practices (Compost Use and Biochar Application) were marked as "Undecided" and identified as requiring further information and support. These contrasting results highlight differing levels of readiness and prioritization between the two provinces. Farmers in Kampot appeared more cautious, expressing concerns that unfamiliar practices might negatively impact their current productivity or product quality.

The strong interest across all CRPs in Tboung Khmum may reflect greater exposure to innovation or more coordinated support from extension services. Meanwhile, lower adoption intentions in Kampot, particularly for practices such as Integrated Pest and Disease Management and Multi-Strata Agroforestry Systems, may be linked to cost-benefit concerns, labor requirements, or land constraints. These findings suggest that further clarification, demonstration, or validation of economic feasibility is needed before farmers in Kampot are ready to adopt certain CRPs.

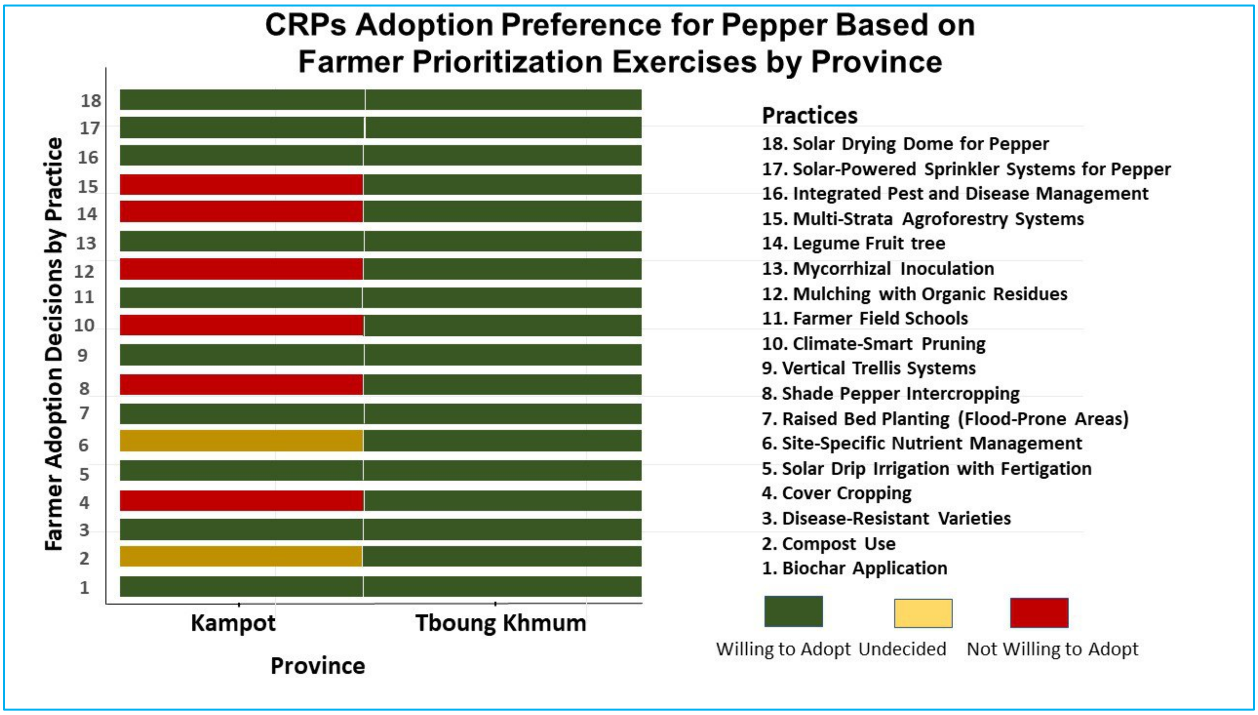


Figure 2. CRP Adoption Preferences for Pepper

5.3 Final Climate Resilient Practices

Following the farmer prioritization exercises, 15 CRPs were finalized, including seven for cashew and eight for pepper. This final selection was informed by a combination of farmer preferences across the two main provinces for each crop, with emphasis placed on practices selected by both provinces. Further considerations included thematic diversity across the production cycle (e.g., from nutrient management to post-harvest), the replicability of practices across different farm contexts, potential for scalability, and overall expected impact. The process also integrated inputs from project staff and provincial stakeholders to ensure alignment with ongoing extension services and project priorities.

For cashew, the seven selected practices focus on improving resilience during the production phase through enhanced nutrient management, ecological services, and pest control. These are:

- Local Biofertilizer Production (Soil and Nutrient Management)
- Cashew–Legume Intercropping (Agroforestry and Intercropping)
- Biochar Application with Cashew (Soil and Nutrient Management)
- Cover Cropping in Cashew Orchards (Soil and Nutrient Management)
- Solar-Powered Irrigation System (Water Management)
- Bee Keeping for Cashew (Ecosystem Services)
- Integrated Pest and Disease Management (IPM) (Pest and Disease Management)

Table 4. Farmer Prioritization Results on Climate Resilient Practice for Cashew

N.	Practices	Thematic Areas	Production Stage	Farmer Prioritization	
				Kampong Thom	**Kratie**
1	Local Biofertilizer Production for Cashew	Soil and Nutrient Management	Production	X	X
2	Cashew–Legume Intercropping	Agroforestry and Intercropping	Production	x	
3	Biochar Application with Cashew	Soil and Nutrient Management	Production	X	X
4	Cover Cropping in Cashew	Soil and Nutrient Management	Production	X	X
5	Solar-Powered Irrigation System for Cashew	Water management	Production	X	X
6	Bee Keeping for cashew	Ecosystem Service	Production	X	X
7	Integrated Pest and Disease Management (IPM)	Pest and Disease Management	Production		X

For pepper, the eight selected practices span critical stages of the production system, from field management to post-harvest. These include:

- Cover Cropping in Pepper Orchards (Soil and Nutrient Management)
- Raised Bed Pepper Planting in Flood-Prone Areas (Crop and Farm Management)
- Site-Specific Nutrient Management for Pepper (FP-SSNM) (Soil and Nutrient Management)
- Solar Drip Irrigation with Fertigation (Water and Nutrient Management)
- Compost-Based Organic Fertilizers (Soil and Nutrient Management)
- Biochar Application in Pepper Fields (Soil and Nutrient Management)
- Solar Drying Dome for Pepper (Post-Harvest, Processing and Value Addition)
- Solar-Powered Sprinkler Systems (Water Management)

Table 5. Farmer Prioritization Results on Climate Resilient Practice for Pepper

N.	Solutions/Technologies	Thematic Areas	Production Stage	Farmer Prioritization	
				Tbong Khmom	**Kampot**
1	Cover Cropping in Pepper Orchards	Soil and Nutrient Management	Production	X	X
2	Raised Bed Pepper Planting in Flood-Prone Areas	Crop and Farm Management	Production	X	X
3	Farmers' Participatory Site-Specific Nutrient Management for Pepper	Soil and Nutrient Management	Production	X	
4	Solar Drip Irrigation with Fertigation for Pepper	Water Management and Soil and Nutrient Management	Production	X	X
5	Compost-Based Organic Fertilizers for Pepper	Soil and Nutrient Management	Production	X	
6	Biochar Application in Pepper Fields	Soil and Nutrient Management	Production	X	X
7	Solar Drying Dome for Pepper	Post-Harvest, Processing and Value Addition	Post Harvest		X
8	Solar-Powered Sprinkler Systems for Pepper	Water management	Production	X	X

Guidelines For Field Demonstration Of Climate-Resilient Practices

This section provides brief implementation guidelines for smallholder farmers on how to apply the selected climate-resilient practices at the field level, along with an overview of demonstration site selection. A detailed implementation protocol will be provided in a separate document.

6.1 Field on Implementation Guides for Climate-Resilient Practices

As previously mentioned, cashew farmers in Kratie and Kampong Thom identified several CRPs as priorities for adoption and field demonstration. The practices chosen include local biofertilizer production, cashew–legume intercropping, biochar application, and cover cropping, all of which contribute to improved soil and nutrient management. Water-related practices such as solar-powered irrigation systems were also prioritized to address increasing water stress, especially in more degraded or drier zones. Additionally, bee keeping was selected to enhance ecosystem services, while Integrated Pest and Disease Management (IPM) was identified to support more sustainable pest control strategies. The selected CRPs reflect farmer's interest in approaches that combine productivity gains with long-term sustainability.

In Tboung Khmum and Kampot, pepper farmers focus on soil health, water management, and post-harvest improvements. Practices such as cover cropping, raised bed planting in flood-prone areas, and compost-based organic fertilization were selected to enhance soil structure, nutrient retention, and climate resilience. Site-specific nutrient management and biochar application were also included to improve soil microbiome functioning and nutrient-use efficiency. To address water limitations, farmers prioritized solar drip irrigation with fertigation and solar-powered sprinkler systems. Additionally, post-harvest practices such as solar drying domes were highlighted in Kampot, given the importance of maintaining pepper quality for market access. These choices reflect farmer's interest in improving not only production but also value addition and climate adaptation across the full production cycle.

To support implementation, detailed demonstration protocols were developed as separate documents for both cashew and pepper. These protocols will guide farmers and project staff in applying the selected practices, with adaptations based on local soil conditions, community structures, and farming systems. Each protocol provides step-by-step instructions, timelines, materials needed and expected outcomes to ensure consistency and replicability. The protocols are intended to be living documents, updated as needed to reflect changes in production systems, community dynamics, and national agricultural policies. This flexible approach will help ensure that demonstration sites serve as effective learning hubs for both current and future scaling efforts.

6.2 Selected Demonstration Sites

After the participatory prioritization exercises, 15 CRPs were presented, and cashew and pepper farmers participated in group discussions to identify appropriate sites for demonstration. These discussions considered factors such as community structure, land size and location, water availability, and the commitment of host farmers. Below are the results of demonstration sites voluntarily offered by farmers for the implementation of selected practices.

6.2.1 Demonstration Sites for Cashew

Kratie

In Chhlong district, demonstration activities for cashew will focus on the following CRPs: Biochar Application. The district benefits from relatively fertile soils and diverse farming systems, which influence the local interest in practices that are perceived as easily adoptable.

In Praek Prosob district, demonstration activities for cashew will focus on the following CRPs: Biochar Application, Solar-Powered Sprinklers. In Snoul district, demonstration activities for cashew will focus on the following CRPs: Biofertilizer Production, Solar-Powered Sprinkler, Bee Keeping. In districts of Chet Borey, Sambo, O'Kraeng Mean Chey, demonstration activities for cashew will focus on the following CRPs: Solar-Powered Sprinkler and IPM.

These practices collectively support the following thematic areas: soil and nutrient management, pest and disease management, agroforestry systems, and ecosystem services.

The area’s relatively fertile soils and diverse cropping systems suggest readiness for CRPs focused on organic soil enrichment and ecological pest control.

There is also an abundance of uncultivated land that is increasingly affected by climate variability and contains *Prey Khmer* soil, a coarse sandy soil with relatively better drainage and moderate moisture retention during the dry season. Although slightly deeper than *Prateah Lang*, *Prey Khmer* soils are still nutrient-poor, low in organic matter, and prone to iron toxicity, making soil and nutrient management focus on an appropriate and promising intervention.

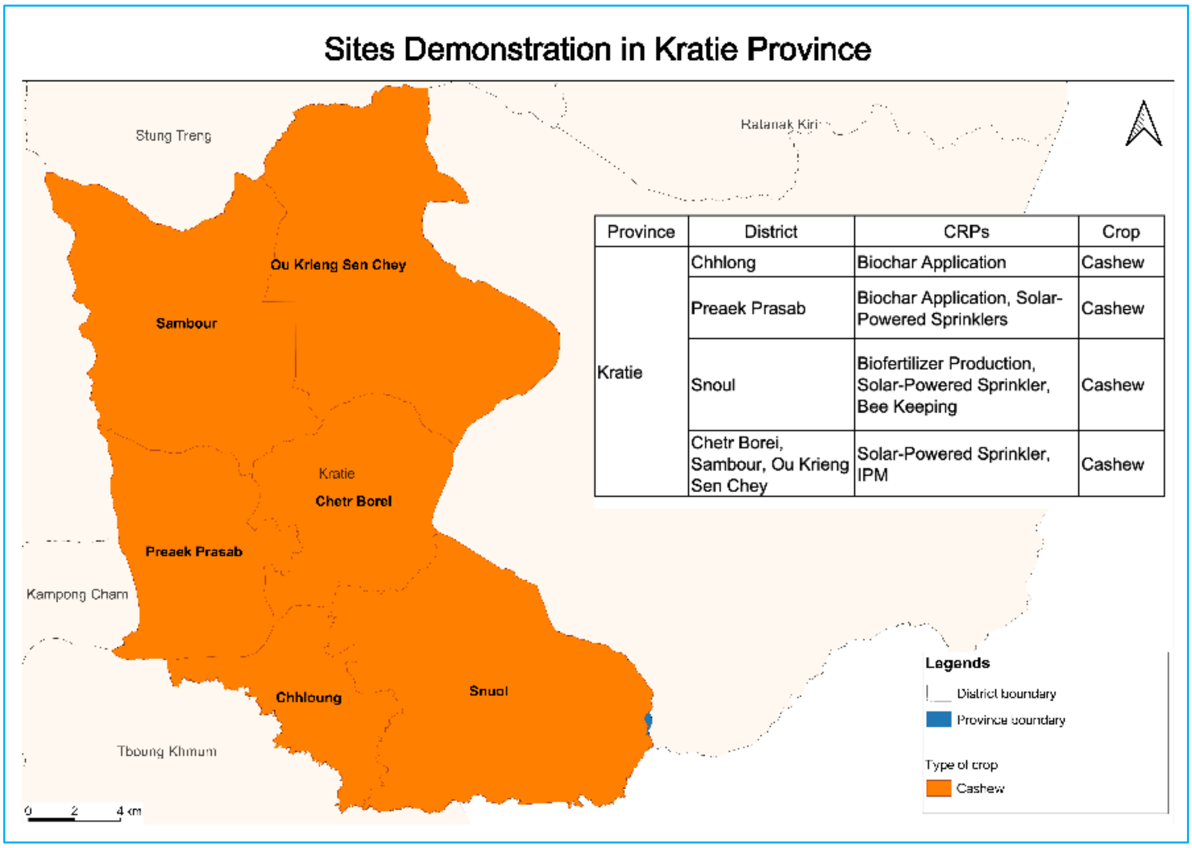


Figure 3. Site demonstration for cashew in Kratie

Kampong Thom

In Santuk district, demonstration activities for cashew will focus on the following CRPs: Solar-Powered Sprinklers, Bee Keeping, IPM, Biofertilizer Production, Biochar Application. Kampong Thom farmers cultivate cashew at a larger scale and in more degraded or drier conditions, which drives stronger interest in practices that support soil health and climate adaptation.

In Sandan district, demonstration activities for cashew will focus on the following CRPs: Cover Cropping, Bee Keeping. In Prasat Balang district, demonstration activities for cashew will focus on the following climate-resilient practices: Solar-Powered Sprinklers, Bee Keeping. In Sambor Preykuk district, demonstration activities for cashew will focus on the following climate-resilient practices: Solar-Powered Sprinklers, Bee Keeping, IPM, Biofertilizer Production.

Kampong Thom farmers cultivate cashews at a larger scale and in more degraded or drier conditions, which drives stronger interest in practices that support soil health and climate adaptation. In Ponnhakraek and Dambae districts, demonstration activities for cashew will focus on the following climate-resilient practices: Solar Drip Irrigation, Compost Use, Solar-Powered Sprinklers.

These practices address key thematic areas including soil and nutrient management, water, pest and disease management and ecosystem services. Given the district’s large-scale cashew production under nutrient-depleted and dry conditions, the selected CRPs will target soil improvement, water conservation, and disease resistance.

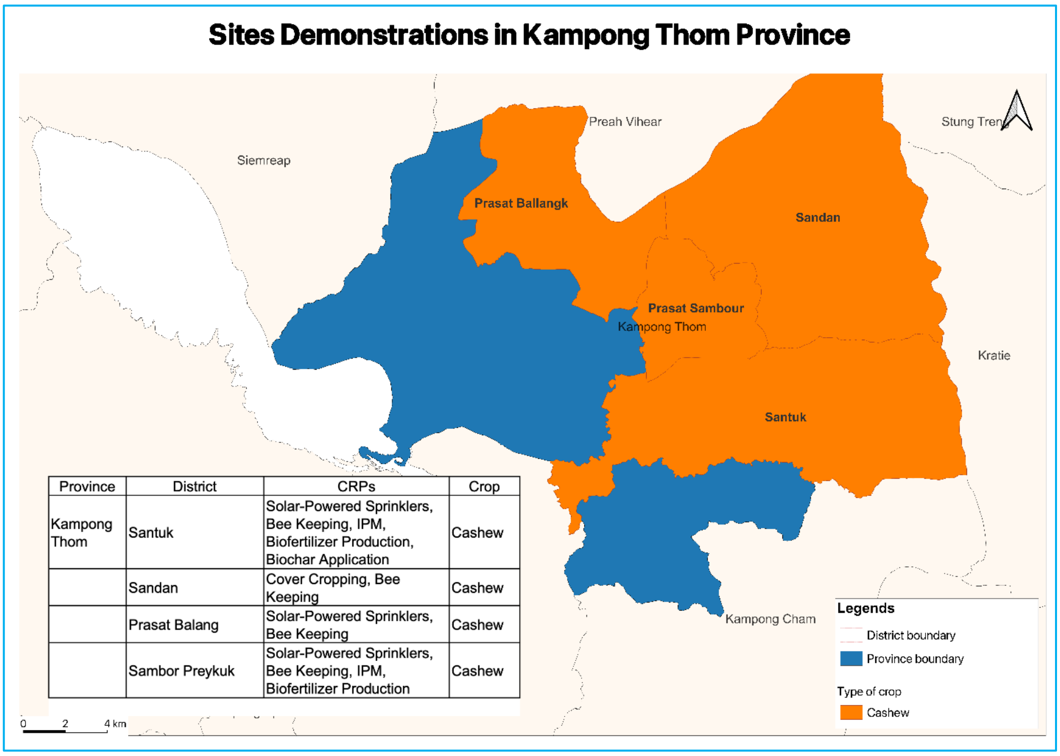


Figure 4. Site demonstrations for cashew in Kampong Thom

6.2.2 Site Demonstrations for Pepper

Tboung Khmum

In Memot district, demonstration activities for pepper will focus on the following CRPs: Solar Drip Irrigation, Cover Cropping, Compost Use and Solar-Powered Sprinklers. In Krouch Chhma district, demonstration activities for pepper will focus on the following climate-resilient practices: Solar Drying Dome, Solar-Powered Sprinklers.

These practices collectively support key thematic areas including water management, soil health, nutrient efficiency, and Post-Harvest, Processing and Value Addition. Tboung Khmum's pepper-growing zones are increasingly affected by erratic rainfall, requiring enhanced irrigation efficiency and soil moisture conservation. The introduction of compost use is particularly relevant for improving soil structure and nutrient retention in these pepper systems.

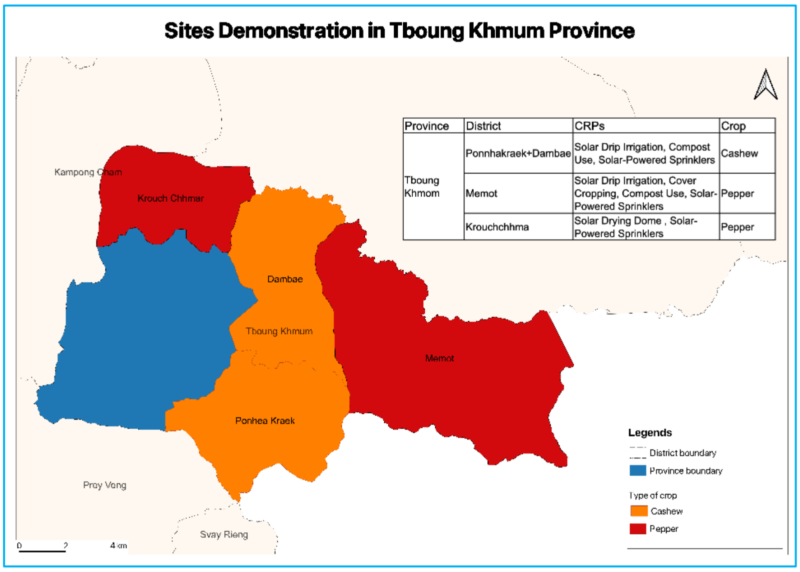


Figure 5. Site demonstration for pepper in Tboung Khmum

Kampot and Kep

In Angkor Chey1 district, demonstration activities for pepper will focus on the following CRPs: Solar Drying Dome, Solar-Powered Sprinklers, IPM. In Angkor Chey 2 district, demonstration activities for pepper will focus on the following climate-resilient practices: Biochar Application, Solar-Powered Sprinklers, Solar Drying Dome. In Trapang Chrey district, demonstration activities for pepper will focus on the following climate-resilient practices: Solar Drying Dome, Solar-Powered Sprinklers, IPM, Raised Bed Planting. In Antong Sor district, demonstration activities for pepper will focus on the following climate-resilient practices: Biochar Application, Solar Drying Dome, Solar-Powered Sprinklers.

Kampot is also predominance of Prey Khmer soil, making the site ideal for testing soil improvement methods such as organic fertilization and introducing efficient irrigation solutions to mitigate water scarcity driven by climate change.

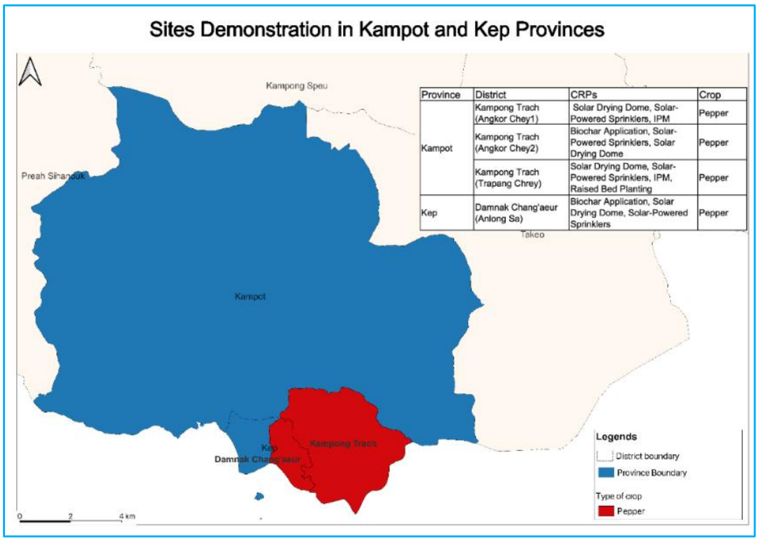


Figure 6. Site demonstration for pepper in Kampot and Kep

APPENDICES

A. Guide on Scaling of Indicators

1. Environmental Sustainability (*Water storage capacity (WSC), Soil organic matter content (SOM)*)		2. Economic Viability & Cost Efficiency (*Cost efficiency of production (CEP) , Yield (Y), and Value addition(VA)*)	
Score	**Meaning for Participants**	**Score**	**Meaning for Participants**
1. Very Poor	The practice harms soil or wastes water.	**1. Very Poor**	Too costly; farmers lose money.
2. Poor	Small benefit; still causes some soil or water problems.	**2. Poor**	Expensive; small or uncertain profit.
3. Fair	Helps soil or water sometimes but not always.	**3. Fair**	Average benefit; some gain, some loss.
4. Good	Clearly improves soil or water; small issues remain.	**4. Good**	Profitable most of the time.
5. Excellent	Very good for soil and water; protects environment well.	**5. Excellent**	Very profitable and low cost.
3. Technical Feasibility & Ease of Adoption (*Technical feasibility (TF), Labor efficiency (LE), Farmer adoption (FA)*)		**4. Gender, Youth & Social Inclusion** (*Gender — labor and time burdens (GB), Youth participation (YP), Adoption rates by gender (ARG)*)	
Score	**Meaning for Participants**	**Score**	**Meaning for Participants**
1. Very Hard	Too difficult or needs experts.	**1. Very Unequal**	Women/youth excluded or overworked.
2. Hard	Difficult without help or training.	**2. Unequal**	Some inclusion but still unfair.
3. Medium	Can learn with some support.	**3. Fair**	Shared work; still small gaps.
4. Easy	Simple; farmers already familiar.	**4. Equal**	Balanced; both benefits.
5. Very Easy	Very simple; anyone can do it.	**5. Empowering**	Strongly benefits women and youth.

5. Scalability & Agroecological Relevance (*Farmers' perceived complexity (FPC), Agroecological relevance (AR), Policy support (PS)*)	
Score	**Meaning for Participants**
1. Not Suitable	Only works in one area or for few farmers.
2. Low	Works for some, not for others.
3. Moderate	Works in several places with adjustment.
4. High	Easy to spread to nearby farms.
5. Very High	Works everywhere; all farmers can use.

B. List of Agricultural Producers Consulted

N	Name	Sex	Province	District	Commune
1	Try Aun	M	Tboung Khmum	Memot	Tramoung
2	Eng Raneth	F	Tboung Khmum	Memot	Tonlung
3	Leang Sokhna	M	Tboung Khmum	Memot	Memorng
4	Sang Thorn	M	Tboung Khmum	Memot	Korki
5	Son Tha	M	Tboung Khmum	Memo	Dar
6	Loeung Hoeun	M	Tboung Khmum	Ponheakrek	Porpel
7	Toem Rathy	M	Tboung Khmum	Dambae	Sromor
8	Sarun Sophea	M	Tboung Khmum	Krochmar	Toul Snoul
9	Ngoun Sopheak	M	Kampot	Kampong Trach	Damnak Kantuot Khang Tboung
10	Torn Puthtry	M	Kampot	Kampong Trach	Damnak Kantuot Khang Tboung

11	Ma Nary	F	Kompong Thom	Santuk	Kor Koh
12	Pin Sreipos	F	Kompong Thom	Prasat Sambo	Tipo
13	Kong Dorn	M	Kampong Thom	Sandan	Ngorn
14	Sorn Sopheap	F	Kampong Thom	Prasat Balang	Salavisai
15	Vann Sokoeun	F	Kampong Thom	Prasat Balang	Tul Kreul
16	Lorm Srey	M	Kratie	Prek Prasab	Saob
17	Un Simon	M	Kratie	Orkrieng	Orkrieng
18	Chun Siphai	M	Kratie	Prek Prasab	Chroybeanteay
19	Chhorn Dina	M	Kratie	Snoul	Pithnoo
20	Teth Ratha	M	Kratie	Chhlong	Kampongdomrei

C. Climate-Resilient Practice Scoring Matrix for Pepper

N	CRS	Environment Sustainability			Economic Viability and Cost Efficiency				Technical Feasibility and Adoption				Gender, Youth and Social Inclusion				Scalability and Agroecological Relevance				Total
		WS C	SOM	Total	CEP	Y	VA	Total	TF	LE	FA	Total	GB	YP	ARG	Total	FPC	AR	PS	Total	
Pepper																					
1	Cover Cropping in Pepper Orchards	5	4	4.5	5	4	5	4.66	5	5	5	5	5	5	5	5	5	5	5	5	4.83
2	Disease-Resistant Pepper Varieties	0	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	4.6
3	Raised Bed Pepper Planting in Flood-Prone Areas	5	5	5	4	5	4	4.33	5	4	5	4.66	4	5	4	4.33	4	5	5	4.66	4.6
4	Site Specific Nutrient Management	5	5	5	3	5	4	4	5	4	5	4.66	5	5	5	5	3	5	5	4.33	4.6
5	Solar Drip Irrigation with Fertigation	5	3	4	5	5	5	5	5	5	4	4.66	5	5	5	5	3	5	5	4.33	4.6
6	Compost-Based Organic Fertilizers	5	5	5	4	5	5	4.66	5	3	5	4.33	3	5	5	4.33	4	5	5	4.66	4.6
7	Vertical Trellis Systems	0	0	0	4	4	3	3.66	5	3	5	4.33	5	5	5	5	5	5	5	5	4.5
8	Shade Pepper Intercropping	3	3	3	5	4	5	4.66	5	5	5	5	4	5	5	4.66	5	5	5	5	4.46
9	Biochar Application	5	5	5	4	4	4	4	5	5	5	5	5	5	4	4.66	4	4	4	4	4.53
10	Solar Drying Dome	0	0	0	3	5	4	4	5	4	5	4.66	5	5	4	4.66	5	0	5	5	4.58
11	Pepper in Multi-Strata Agroforestry Systems	4	5	4.5	5	5	5	5	5	4	3	4	3	5	4	4	4	5	4	4.33	4.36
12	Mycorrhizal Inoculation	0	4	4	4	5	3	4	4	4	4	4	5	5	5	5	4	5	5	4.66	4.33

13	Mulching with Organic Residues	4	4	4	5	3	4	4	5	5	1	3.66	4	5	4	4.33	4	5	5	4.66	4.13
14	Climate-Smart Pruning	4	2	3	3	4	5	4	5	2	5	4	4	5	5	4.66	5	5	5	5	4.13
15	Farmer Field Schools	0	0	0	1	5	5	3.66	5	3	5	4.33	3	5	5	4.33	3	0	5	4	4.08
16	Integrated Pest and Disease Management (IPM)	0	4	4	4	4	4	4	4	4	3	3.66	4	5	4	4.33	3	5	5	4.33	4.06
17	Pepper–Fruit Tree Intercropping	1	1	1	4	4	5	4.33	5	4	3	4	3	5	4	4	3	5	5	4.33	3.53
18	Solar-Powered Irrigation Systems	0	0	0	4	5	4	4.33	5	4	5	4.66	5	5	4	4.66	5	5	5	5	4.66

D. Climate-Resilient Practice Scoring Matrix for Cashew

N	**CRS**	**Environment Sustainability**			**Economic Viability and Cost Efficiency**				**Technical Feasibility and Adoption**				**Gender, Youth and Social Inclusion**				**Scalability and Agroecological Relevance**				**Total**
		WSC	SOM	Total	CEP	Y	VA	Total	TF	LE	FA	Total	GB	YP	ARG	Total	FPC	AR	PS	Total	
Cashew																					
1	Drought-Tolerant Cashew Varieties	0	0	0	5	4	4	4.33	4	5	4	4.33	5	5	4	4.66	5	4	5	4.66	4.5
2	Local Biofertilizer Production for Cashew	0	0	0	5	5	5	5	5	4	5	4.66	4	5	5	4.66	5	5	5	5	4.83
3	Cooperative-Led Nursery Systems for Cashew	0	0	0	5	5	5	5	5	3	3	3.66	5	5	3	4.33	5	5	5	5	4.5
4	Pesticide-Free Pest Traps for Cashew	0	0	0	5	5	5	5	5	4	3	4	5	5	4	4.66	3	5	5	4.33	4.5

5	Cashew–Legume Intercropping	5	5	5	5	4	5	4.66	4	4	5	4.33	4	5	4	4.33	3	5	5	4.33	4.53
6	Biochar Application with Cashew	5	5	5	4	4	4	4	5	5	5	5	5	5	4	4.66	4	4	4	4	4.53
7	Mulching with Organic Residues for Cashew	4	4	4	5	3	4	4	5	5	5	5	4	5	4	4.33	4	5	5	4.66	4.4
8	Organic Cashew Production	3	5	4	5	5	5	5	4	5	3	4	3	5	4	4	4	5	5	4.66	4.33
9	Cover Cropping in Cashew	5	5	5	5	5	4	4.66	4	4	4	4	4	4	5	4.33	4	5	5	4.66	4.53
10	Cashew Climate-Smart Pruning Practices	4	2	3	3	4	5	4	5	2	5	4	4	5	5	4.66	5	5	5	5	4.13
11	Integrated Pest and Disease Management (IPM) in Cashew	0	4	4	4	4	4	4	4	4	4	5	5	5	5	5	4	5	5	4.66	4.53
12	Cashew Agroforestry with Multipurpose Trees	1	2	1.5	3	3	4	3.33	3	3	2	2.66	2	5	3	3.33	4	5	5	4.66	3.1
13	Solar-Powered Irrigation Systems for Cashew	0	0	0	4	5	4	4.33	5	4	5	4.66	5	5	4	4.66	5	5	5	5	4.66
14	Bee Keeping for cashew	0	0	0	4	5	5	4.66	4	5	5	4.66	5	5	4	4.66	4	5	5	4.66	4.66

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