

GREENING AGRICULTURE 2026



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

15 Climate-Resilience Practices

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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.

Background

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), 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.

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 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.

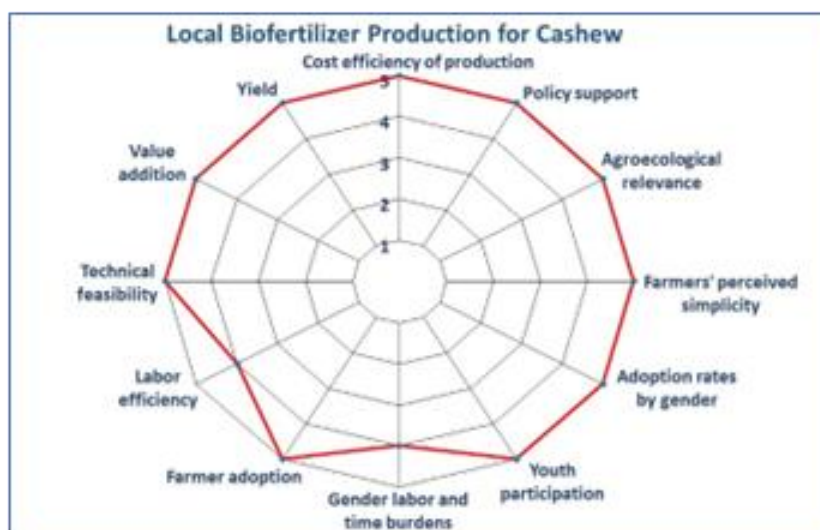
Objectives

This assessment aims to identify, evaluate, and prioritize climate-resilient green agricultural solutions with high potential for adoption and scalability within Cambodia's cashew nut and pepper value chains. The assignment also assists in establishing a robust evidence base to inform the selection of demonstration sites and guide strategic engagement with farmers, cooperatives, and other stakeholders.

Climate-Resilient Practices for Cashew

1. Local Biofertilizer Production for Cashew

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.

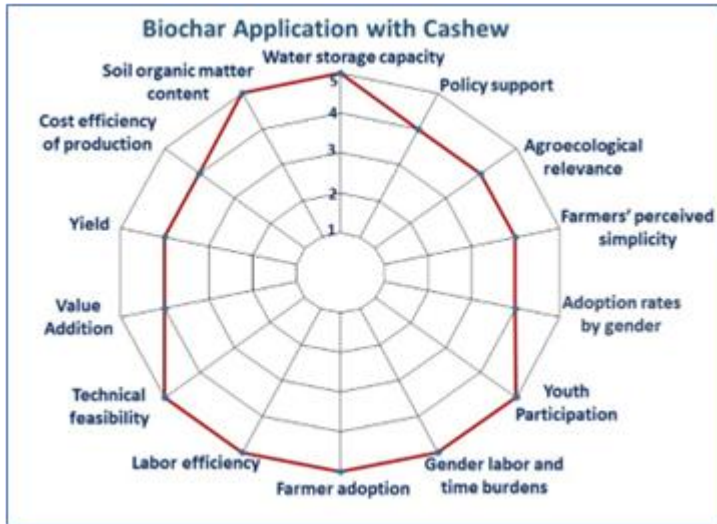


Specifically for cashew, local biofertilizer production uses biofertilizers made from readily available community resources such as fallen cashew leaves, green plant residues, kitchen waste, animal manure, and poultry droppings. The process includes collecting organic waste and composting it into nutrient-rich 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.

2. Biochar Application for Cashew

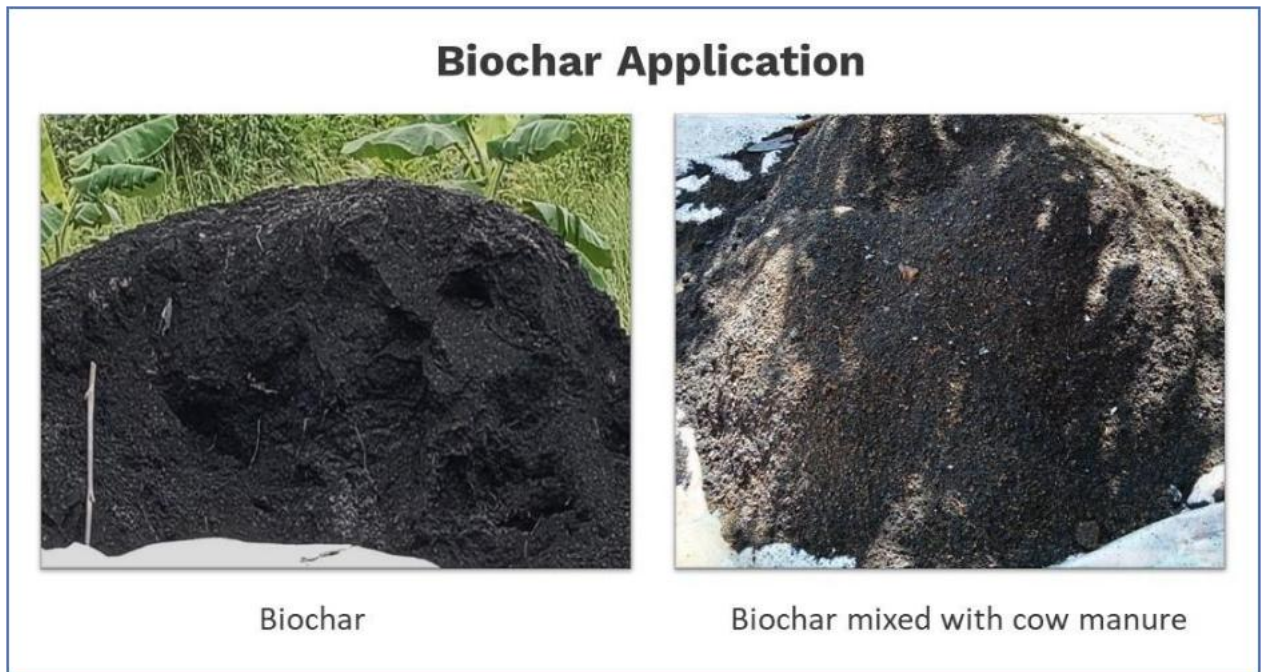
Biochar is a carbon-rich material produced through the thermal decomposition of organic matter in the absence of oxygen (pyrolysis). It is widely recognized for its benefits in improving soil fertility, water retention, and crop productivity, while also reducing greenhouse gas emissions. Countries such 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 through the use of 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

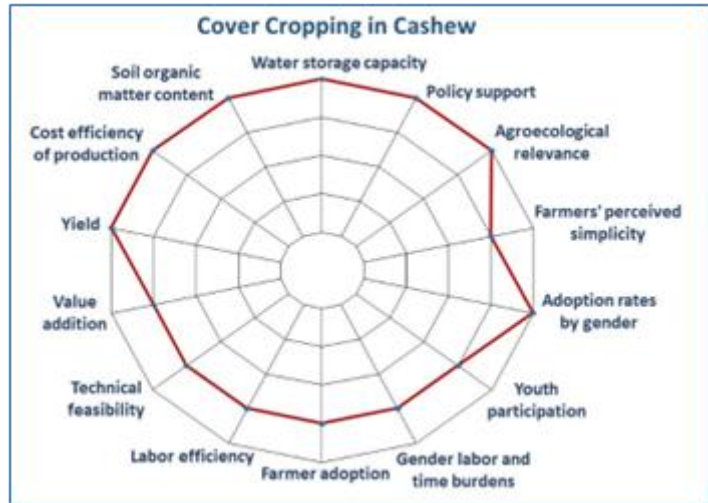
generation. On August 7, 2025, the first BIOCHAR HUB Roundtable at the Institute of Technology of Cambodia gathered over 40 participants from government, academia, NGOs, and the private sector to discuss biochar's potential. In parallel, the V-BIOCHAR project in Pursat Province (March 2025–March 2026), 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.



3. Cover Cropping in Cashew

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.

Cover Cropping in Cashew



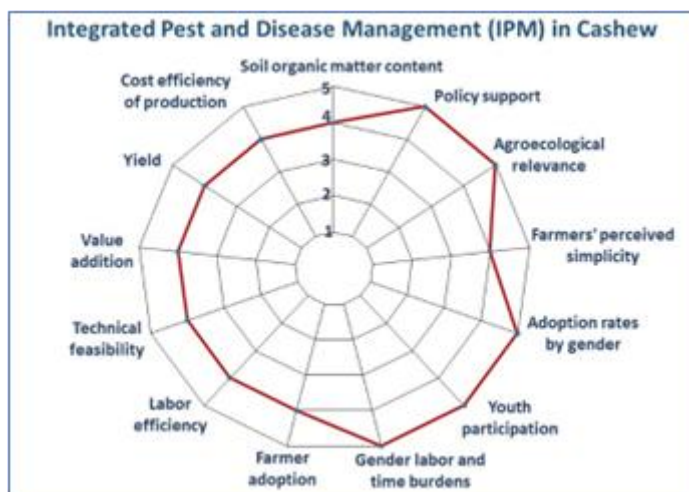
Planting Stylo as a cover crop in cashew plantation



Harvesting Stylo grass as fodder for cows

4. Integrated Pest and Disease Management (IPM) in Cashew

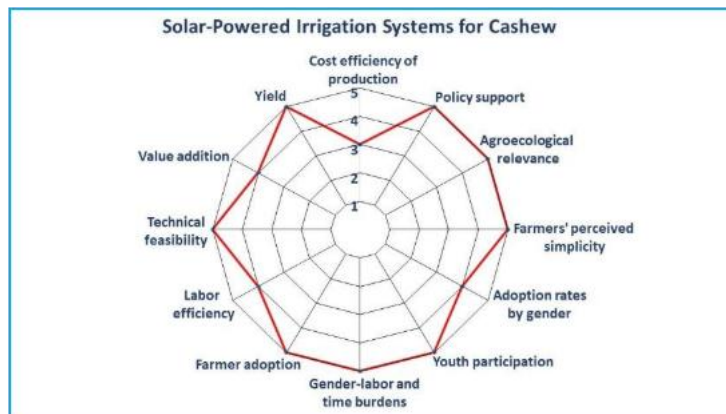
Integrated Pest and Disease Management (IPM) is a sustainable agricultural approach that combines biological, cultural, mechanical, and need-based chemical methods to manage pests and diseases while minimizing risks to human health and the environment. In cashew cultivation, IPM typically involves monitoring 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.



5. Solar-Powered Irrigation System

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.

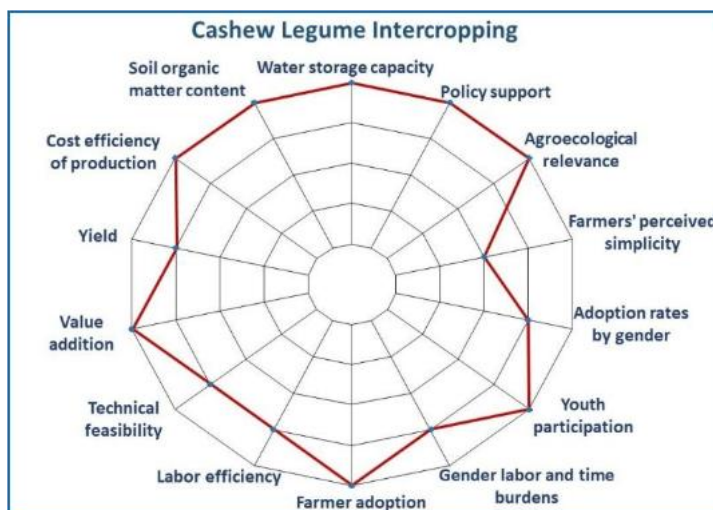
SPIS offers a sustainable way to improve cashew yields while reducing fuel and electricity costs. Systems typically combine solar panels with efficient delivery methods such as drip or micro sprinklers, adapted to orchard age, soil type, and water availability. Solar panels power either surface or submersible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



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.

6. Cashew-Legume Intercropping

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.



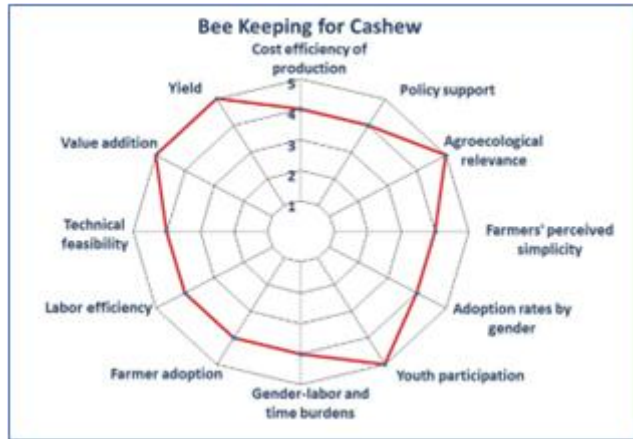
This practice has been adopted in countries like Nigeria, Ghana, and Mozambique, where cashew farming is prevalent (Ajayi et al., 2021).



7. Bee Keeping for Cashew

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.



Beekeeping for Cashew



Honey bee harvesting



Bee keeping

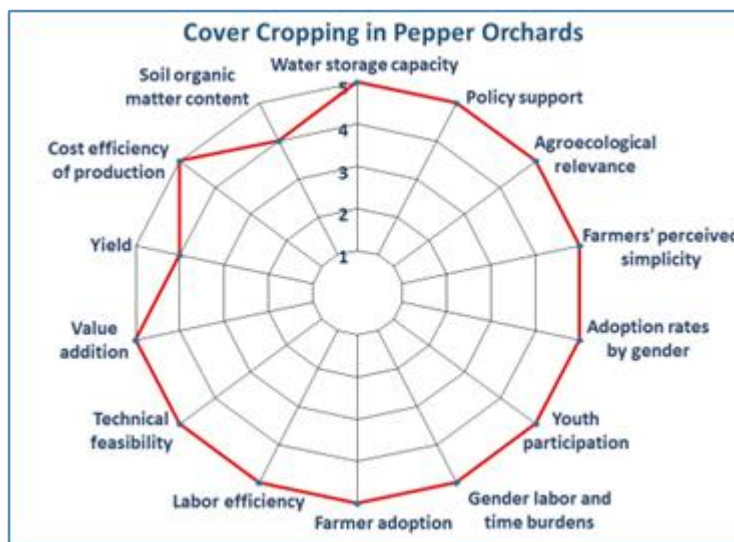
Climate-Resilient Practices for Pepper

8. Cover Cropping in Pepper Orchards

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.

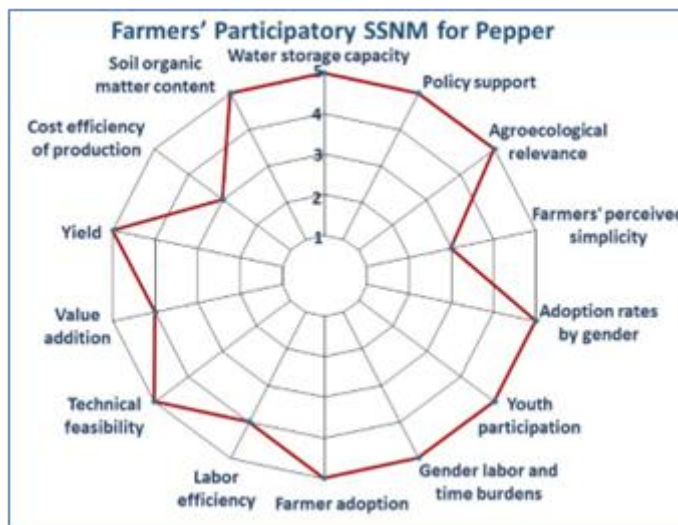
Common leguminous cover crops, such as green beans or cowpeas, are typically planted at a rate of 30 kilograms per hectare, with an approximate cost of 75 US dollars per hectare. These species are adaptable to various soil types and show strong tolerance to diverse weather conditions.



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

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.

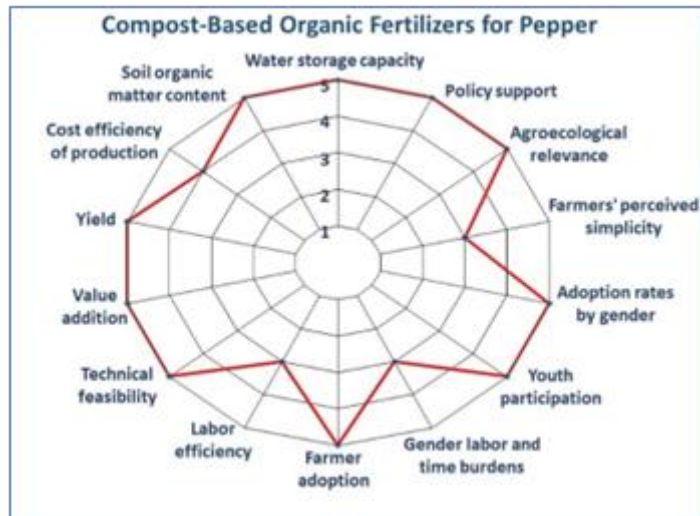
FP-SSNM is a structured method wherein farmers co-develop or validate nutrient management practices in collaboration with researchers or extension workers, typically through trials, demonstrations, and localized learning. The level of technology or digital tool usage varies depending on the farmers' 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.

10. Compost-based Organic Fertilizers for Pepper

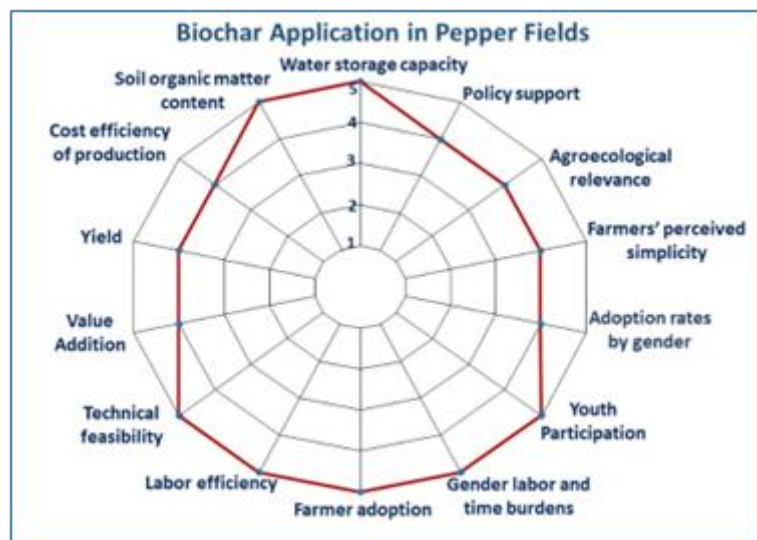
Compost-based organic fertilizers are created by decomposing organic materials such as crop residues, animal manure, and green waste. This decomposition process produces a nutrient-rich substance that enhances soil fertility and promotes healthier plant growth. In pepper cultivation, compost applications have 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.



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11. Biochar Application in Pepper Fields

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.



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.

Biochar Application in Pepper Fields



Biochar



Biochar mixed with animal manure

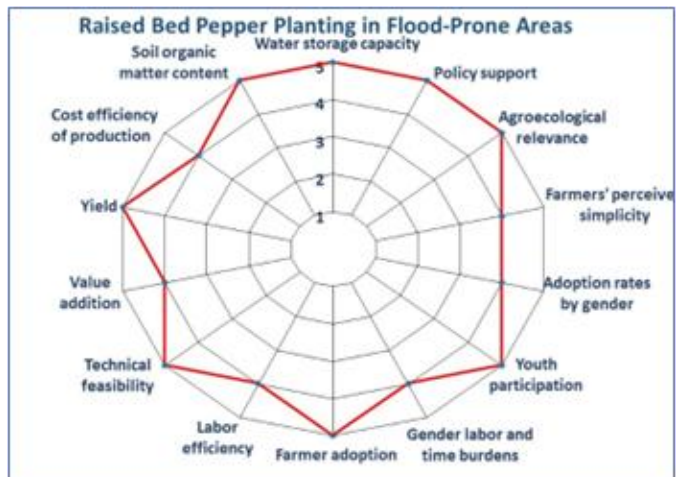


Compost application

12. Raised-Bed Pepper Planting in Flood-Prone Areas

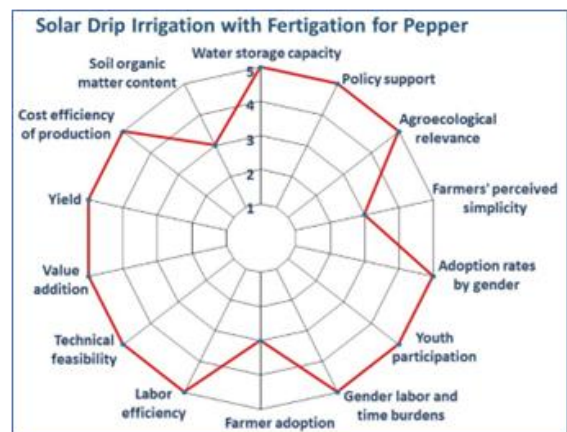
Raised bed planting is a widely used technique in flood-prone or lowland areas to elevate crops above waterlogged soil levels. It improves drainage and soil aeration, making it especially useful in regions with high rainfall or poor natural drainage. In pepper cultivation, this method involves elevating 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.



13. Solar Drip Irrigation with Fertigation for Pepper

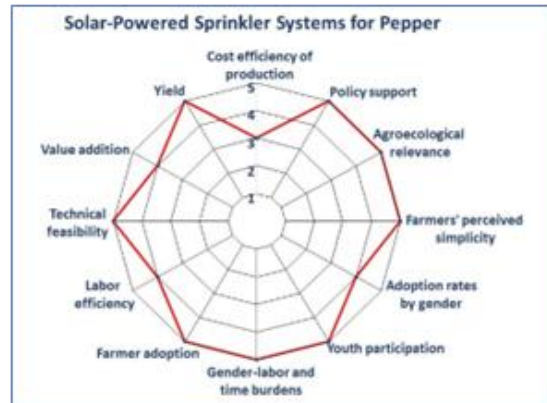
Drip irrigation combined with fertigation is an efficient method that delivers both water and nutrients directly to the root zone of pepper plants through a drip system. This system uses filters and drip lines to ensure precise delivery of inputs, enhancing resource use efficiency and crop performance. 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.

14. Solar-Powered Sprinkler Systems for Pepper

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.



Solar-Powered Sprinkler System



Pepper Farm Irrigation

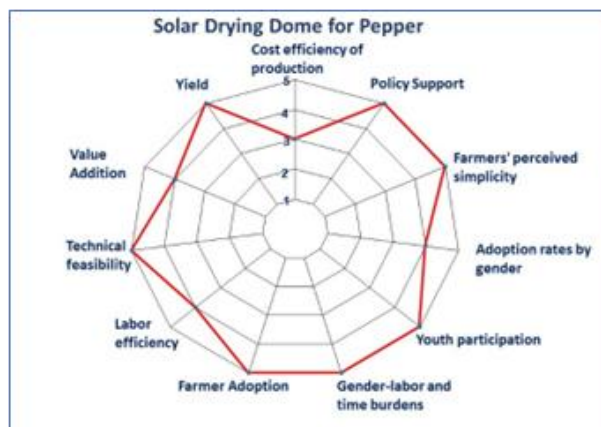


Sprinkler System

15. Solar Drying Dome for Pepper

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.

Results of Participatory Prioritization Exercises

Cashew Value Chain (Kratie and Kampong Thom)

Farmers in both Kratie and Kampong Thom expressed generally strong interest in the proposed practices, with most 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 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.

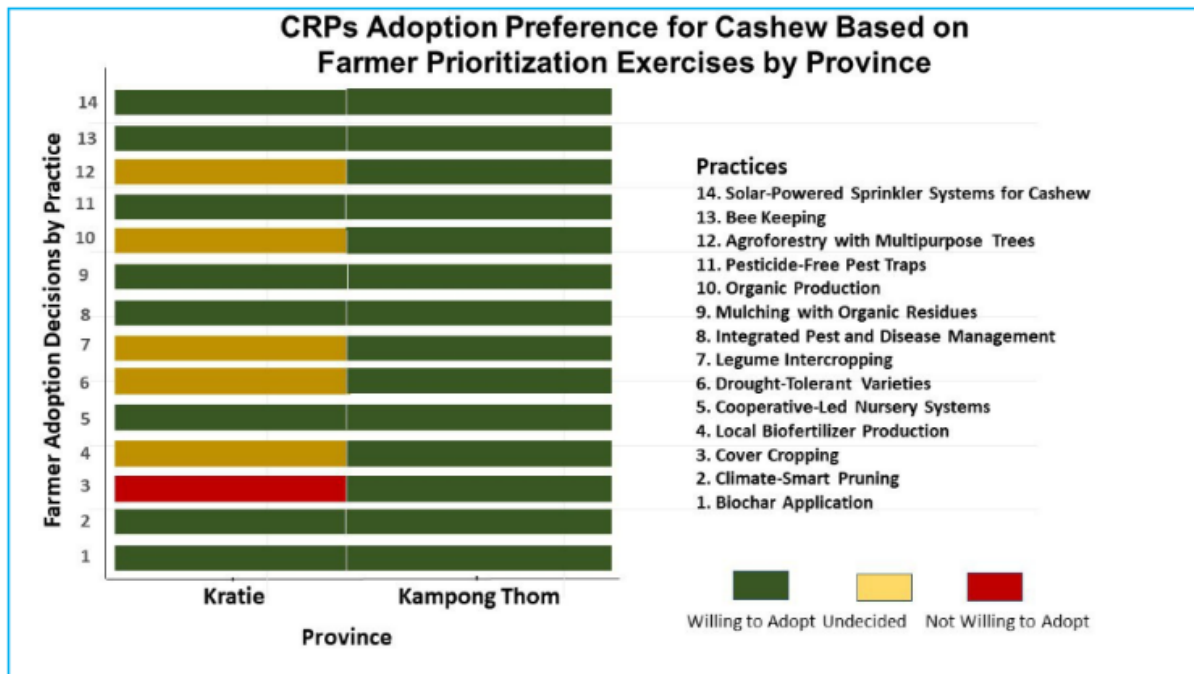


Figure 1. CRP Adoption Preferences for Cashew

Sites Demonstrations in Kampong Thom Province

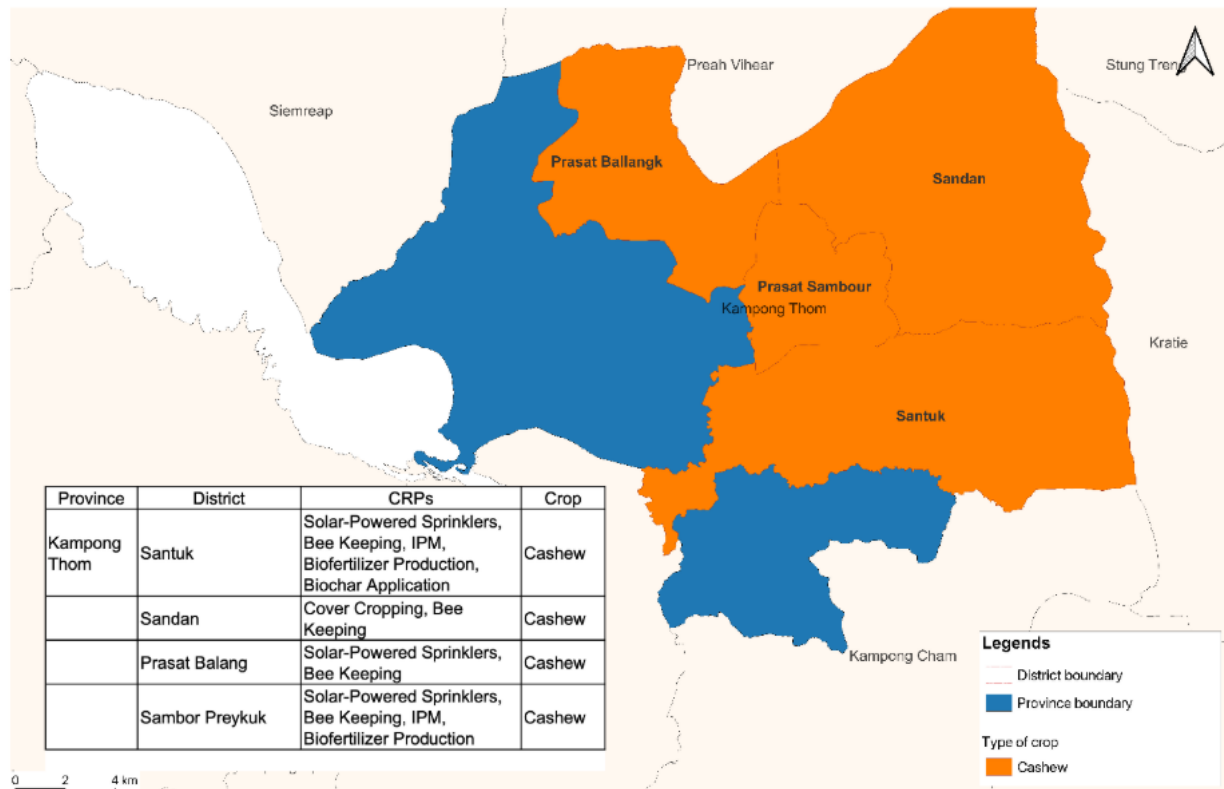


Figure 2. Site demonstration for cashew in Kratie

Sites Demonstration in Kratie Province

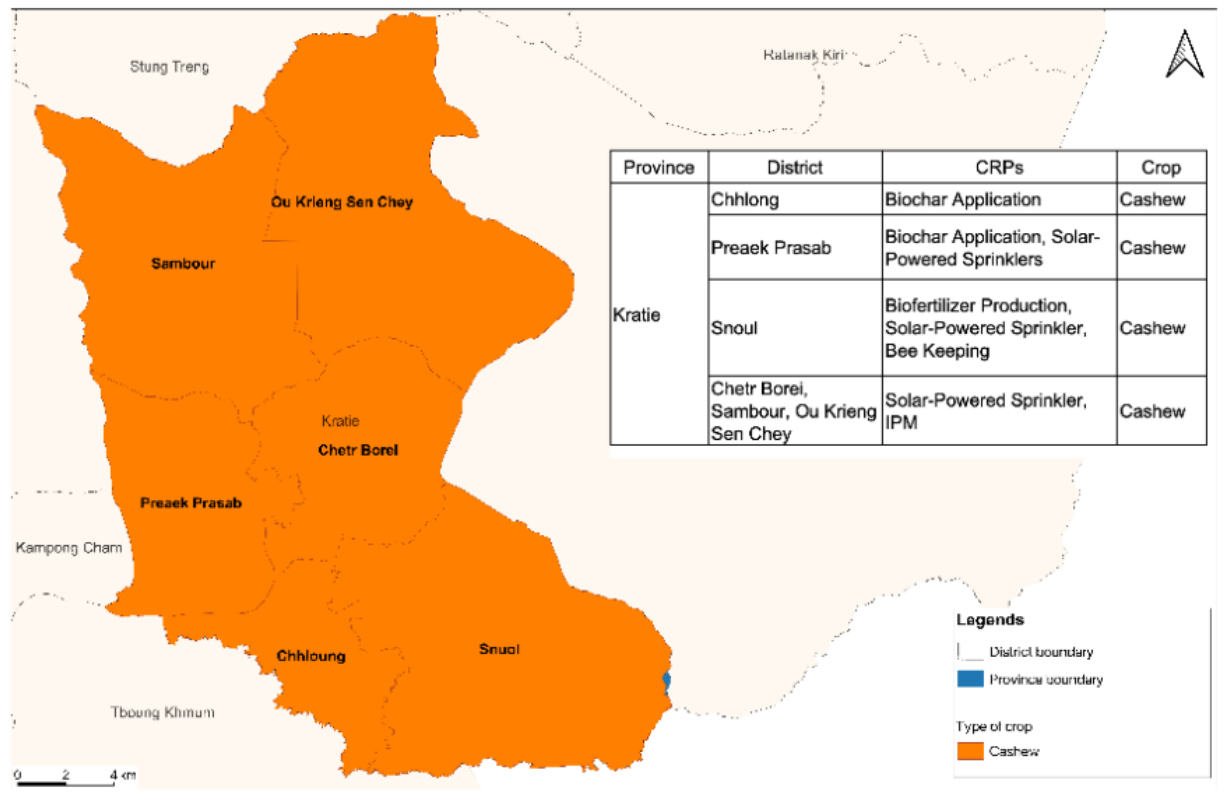


Figure 3. Site demonstrations for cashew in Kampong Thom

Pepper Value Chain (Tboung 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.

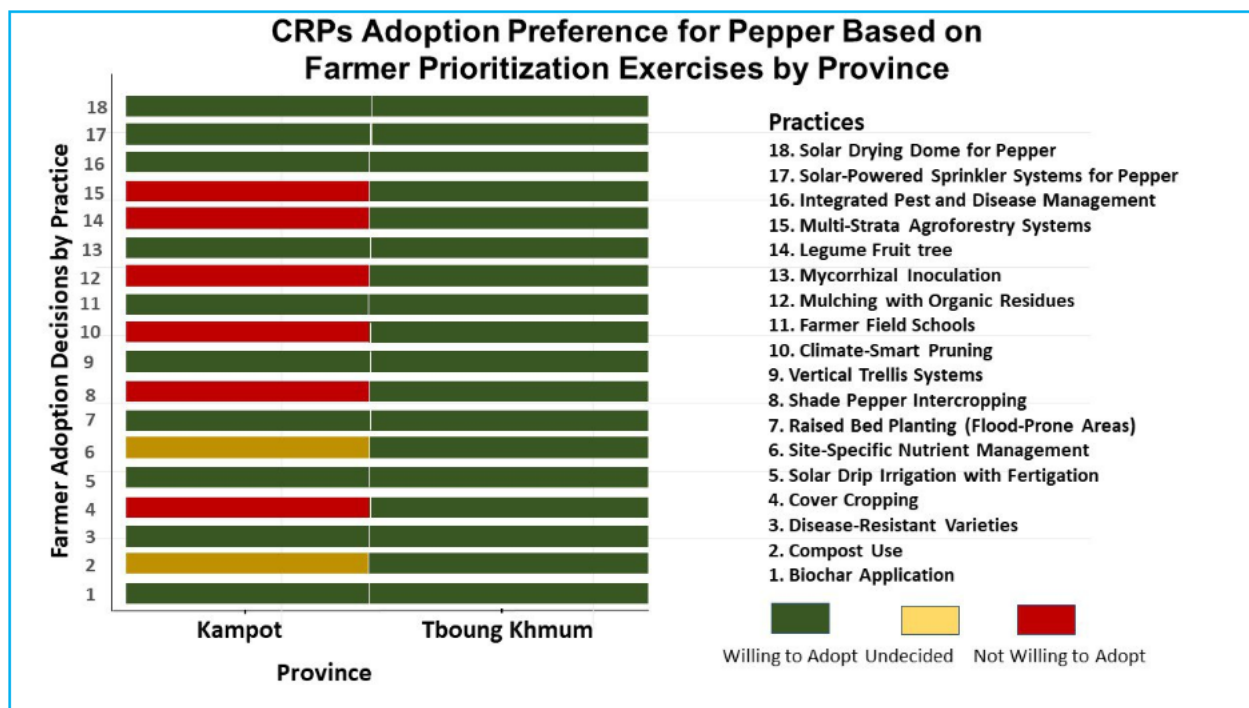


Figure 4. CRP Adoption Preferences for Pepper

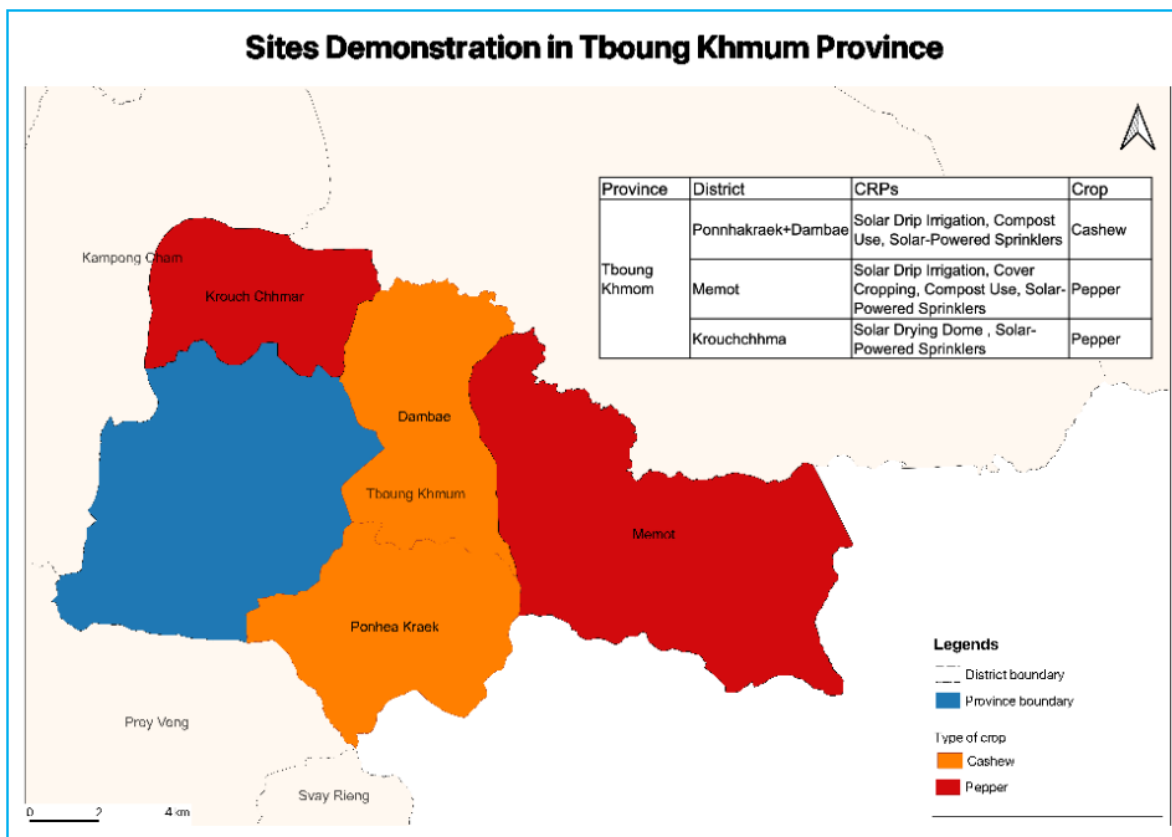


Figure 5. Site demonstration for pepper in Tboung Khmum

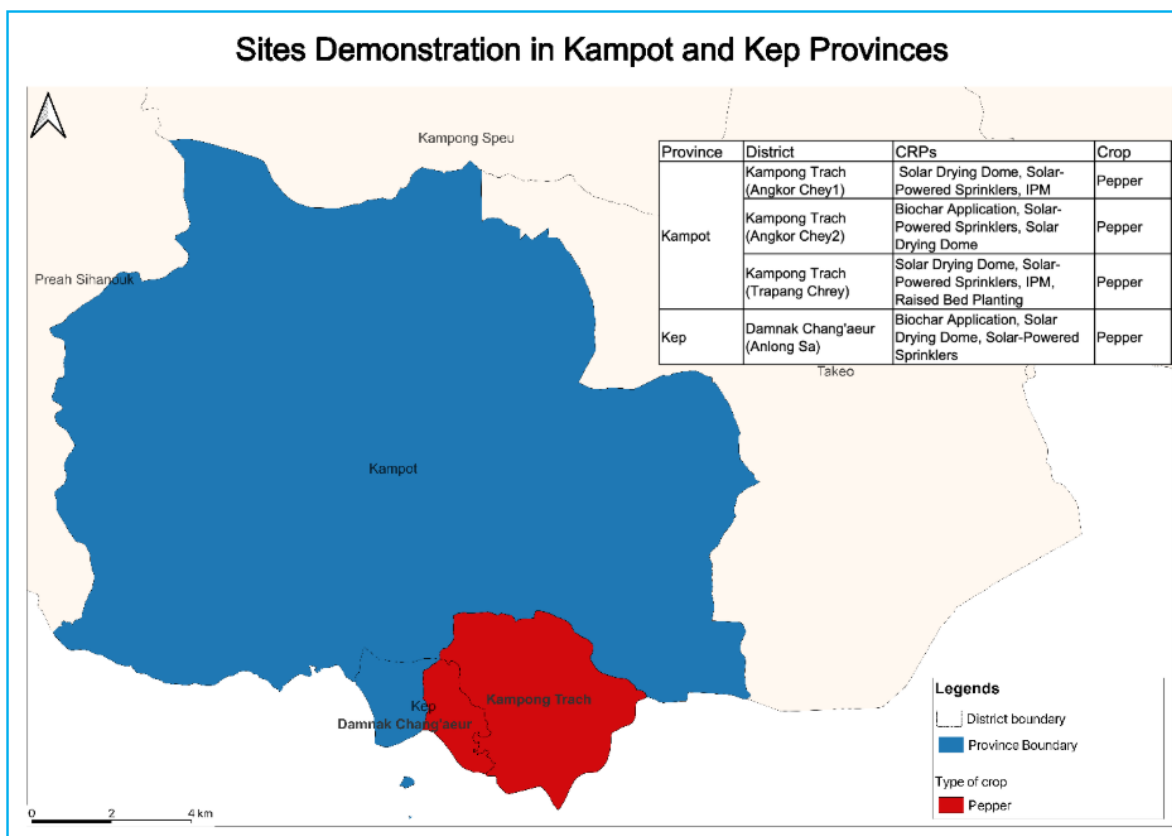


Figure 6. Site demonstration for pepper in Kampot and Kep

