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Building Climate-Resilient Agriculture through Conservation Practices: Evidence from Sunamganj Wetland Ecosystem, Bangladesh

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Abstract: Climate change creates major obstacles that threaten both agricultural sustainability and food security in wetlands that are most at-risk in Bangladesh's haor regions where smallholder farmers deal with constant flooding and soil erosion and decreasing crop yields. The research investigates how vermicompost-based conservation agriculture (CA) impacts soil health and carbon storage capacity and crop yield and ecosystem resilience in the haor region of Sunamganj District Bangladesh. A participatory action research framework was implemented to evaluate conservation agriculture (CA) and conventional farming methods on four crops which included amaranth, basella, grass pea, and mustard through a randomized complete block design that used three replications during the Rabi season from October 2025 to February 2026. The study used ANOVA to analyze soil physicochemical properties and crop morphological traits and biomass production together with climatic data from NASA POWER DAV. The results showed that CA plots contained more organic matter and better micronutrient accessibility and higher root biomass which reached 7.29 t ha^{-1} and their carbon sequestration capacity reached 2,916 kg ha^{-1} organic carbon. The CA-grown grass pea varieties achieved greater seed production with stable yields that reached 1.7 t ha^{-1} while intercropping systems enhanced leaf area and biomass distribution which demonstrated better resource use and soil moisture conservation. However, mustard was discarded from recommendation due to the lack of survival capacity in that ecosystem. The research demonstrates that vermicompost-based conservation agriculture increases soil biodiversity while decreasing chemical dependence and improving climate resilience in wetland agroecosystems. The research presents a community-based agricultural transformation model which can be expanded to achieve sustainable farming practices in climate-vulnerable haor regions while providing evidence that agroecological methods create resilient food systems for South Asia.

Keywords: Vermicompost; Conservation agriculture; Haor wetlands; Soil health; Climate-resilient agriculture

INTRODUCTION

Climate change poses unprecedented threats to global food security, particularly in vulnerable agricultural regions where smallholder farmers face mounting challenges from extreme weather events, variable rainfall patterns, salinity intrusion, and rising temperatures (Abebaw, 2025). These climate-induced stressors significantly reduce crop productivity and amplify the vulnerability of farming communities in climate hotspots across South Asia (Aryal et al., 2020, Kabato et al., 2025) .

Bangladesh's haor wetlands represent a unique and highly climate-sensitive agroecological zone characterized by seasonal flooding and dynamic water regimes. These low-lying wetland areas are critical for rice production but face recurrent challenges from flash floods, which cause substantial crop losses and degrade soil quality (Rahman et al., 2022). The haor regions of northeastern Bangladesh, including Sunamgonj District, are particularly vulnerable to climate variability, with Boro rice cultivation experiencing frequent disruptions that threaten the livelihoods of resource-poor farming communities (Rahman et al., 2022). The extreme poverty conditions in these disaster-affected areas, coupled with dependence on traditional cultivation techniques, create an urgent need for innovative, climate-resilient agricultural interventions that can enhance both productivity and environmental sustainability (Hoque et al., 2022).

Soil degradation and declining fertility represent major constraints to sustainable agricultural intensification in wetland rice systems. Organic amendments, particularly vermicompost, have emerged as promising solutions for improving soil health through multiple mechanisms. Vermicompost supplies essential macro- and micro-nutrients (N, P, K), organic matter, humic substances, and biologically active compounds that enhance plant growth, soil structure, carbon storage, and microbial community composition (Team Acrres et al., 2023). Recent field trials in Bangladesh wetland paddy systems have demonstrated that vermicompost application can achieve the highest carbon sequestration rates (approximately 29% increase) compared to other organic amendments such as poultry manure, cow dung, and rice straw (Rahman et al., 2022).

Beyond carbon sequestration, vermicompost applications have been shown to improve soil physical properties, reduce electrical conductivity in saline-alkali soils, optimize pH levels, and increase soil organic matter and available phosphorus (Ai et al., 2023). These improvements in soil chemistry are accompanied by beneficial shifts in microbial community composition, with changes correlated to enhanced pH and organic matter content (Ai et al., 2023). Furthermore, vermicompost has been documented to boost microbial biomass and improve overall soil quality metrics that directly contribute to higher crop output in Bangladesh agricultural contexts (Tudu, 2023).

The comparative assessment of organic and conventional farming systems reveals complex trade-offs between productivity, environmental sustainability, and resource efficiency. While conventional inorganic-only systems often demonstrate higher energy use efficiency (EUE) and system productivity in the short term, organic amendment-based systems provide superior benefits for long-term soil health, carbon sequestration, and ecosystem services (Rahman et al., 2022). A comprehensive multi-season field experiment (2018-2020) in wetland paddy cultivation found that while inorganic-only plots achieved the highest EUE (9.77) and system productivity, vermicompost treatments maximized carbon sequestration but showed lower EUE (8.04), highlighting the inherent trade-offs between yield optimization and environmental benefits (Rahman et al., 2022).

Integrated nutrient management (INM) strategies that combine organic amendments with targeted inorganic fertilizers offer a promising middle path, potentially capturing both soil health benefits and competitive yields (Rahman et al., 2022). Organic systems typically enhance soil biodiversity, reduce synthetic input-related emissions, and improve various ecosystem services, though yield gaps and lifecycle environmental impacts remain context-dependent and require careful evaluation (Seufert & Ramankutty, 2017). The optimization of these integrated approaches is particularly critical in resource-constrained wetland contexts where both productivity and sustainability must be balanced.

Agroecological approaches encompassing diversified cropping systems, conservation tillage, organic manures, integrated pest management, and beneficial microbe utilization are increasingly recognized as essential strategies for building climate resilience and conserving biodiversity in vulnerable agroecosystems (Hoque et al., 2022). These practices not only enhance the adaptive capacity of farming systems to climate variability but also contribute to long-term productivity through improved ecosystem functioning. In saline-alkali land conditions similar to those found in some haor areas, vermicompost combined with soil conditioners has demonstrated measurable ecosystem-level productivity gains, with biomass increases ranging from 6.37% to 19.91% (Ai et al., 2023).

Climate-smart frameworks emphasize the importance of locally tailored technical, institutional, and extension services to support farmer adoption of agroecological measures and enhance overall system resilience (Ma & Rahut, 2024). However, the successful implementation of these practices requires context-specific adaptation and participatory engagement with farming communities to address socio-economic barriers and ensure practical applicability.

Despite growing evidence for the benefits of organic amendments and agroecological practices, significant knowledge gaps remain regarding their implementation in specific wetland contexts such as haor ecosystems. There is limited documentation of participatory action research frameworks that engage farming communities in iterative, collaborative inquiry to co-develop and refine sustainable agricultural solutions (Méndez et al., 2012). Action research approaches, which follow a cyclical process of planning, acting, observing, and reflecting, are particularly well-suited to addressing the complex, context-specific challenges faced by haor communities.

The lack of long-term monitoring studies that assess trade-offs between productivity, energy efficiency, and carbon sequestration outcomes represents another critical gap. Additionally, insufficient attention has been paid to understanding the socio-economic and institutional barriers that constrain the scaling of vermicompost production and agroecological practices in resource-poor wetland settings. Addressing these gaps requires research designs that integrate biophysical measurements with participatory methodologies to generate evidence-based insights that are both scientifically rigorous and practically relevant to community contexts.

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Given the urgent need to enhance climate resilience and improve livelihoods in Bangladesh's haor wetlands, this action research investigates the impact of vermicompost and mulching practices on soil health, vegetable productivity, and biodiversity within the haor ecosystem of Sunamgonj District. By employing a participatory action research framework within the CARITAS Bangladesh ELSRP project, this study aims to (i) assess and compare soil health indicators across organic and inorganic farming systems, identifying key metrics of sustainability and resilience in the haor context, (ii) evaluate the role and functionality of microbial organisms within organic and inorganic agricultural systems, highlighting their contributions to soil fertility and ecosystem balance, (iii) analyze crop production outcomes under agroecological practices versus conventional farming methods, with emphasis on productivity, environmental impact, and long-term viability.

This research addresses critical knowledge gaps by generating community-grounded evidence on the effectiveness of vermicompost and agroecological principles for enhancing climate resilience in smallholder farming systems. The participatory approach ensures that research outcomes are directly informed by local knowledge and priorities, thereby increasing the likelihood of sustainable adoption and scaling. Through this integrated investigation, the study contributes to both scientific understanding and practical pathways for transforming agricultural practices in climate-vulnerable wetland landscapes.

MATERIALS AND METHODS

Study area and site selection

The research was conducted at Badeharipur, located within the Dharmapasha Upazila of Sunamganj district, Bangladesh. This region is geographically significant as part of the northeastern wetland system of the country. The study area is characterized by a typical Haor ecosystem, which is a large, bowl-shaped tectonic depression. The agricultural landscape is predominantly mono-crop, with farmers primarily cultivating rice during the Boro season (winter rice). Historically, this region has lacked the implementation of soil conservation practices or organic farming systems, relying instead on traditional conventional agricultural methods that are often vulnerable to environmental fluctuations. The site was purposively selected to represent a vulnerable wetland ecosystem where the introduction of climate-resilient agriculture is critical. The selection was based on the necessity of introducing climate-smart conservation agriculture and organic farming interventions. By implementing these sustainable practices, the study aims to explore pathways for expanding the livelihoods and strengthening the socio-economic resilience of resource-poor households living in these ecologically sensitive wetlands.

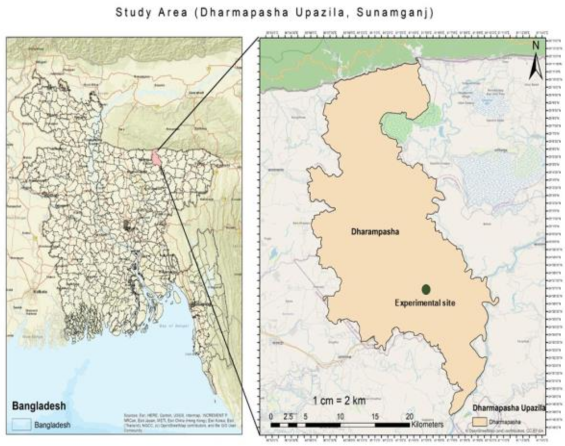

Figure 1: Study area (Dharmapasha, Sunamganj)

Research Design

The experiment was structured to compare the performance of different cultivation systems across four major crops: Amaranth (Datashak), Indian Spinach (Puishak), Grass Pea (Khesari), and Mustard (Sarisha). For each crop, the experimental plots were divided into two primary management systems: Conservation Agriculture (CA), involving two distinct varieties per crop cultivated under CA principles (minimum soil disturbance and organic inputs, especially vermicompost), and Conventional Farming, where one variety per crop was grown using traditional local practices as a control. Additionally, an intercropping system was established, involving the simultaneous cultivation of Puishak and Khesari to evaluate the land-use efficiency and synergistic effects of mixed cropping in wetland ecosystems. The research started October 20, 2025, and ended on 25 February, 2026, covering the primary Rabi (winter) season. The experiment followed a Randomized Complete Block Design (RCBD) with three replications (R1, R2, R3) to ensure statistical headers for the Analysis of Variance (ANOVA) and account for spatial heterogeneity within the Haor study site.

Vermicompost Production and Application

The project prioritized organic nutrient management through the production and application of vermicompost. The production process followed standardized indigenous methods as practiced by the local beneficiaries to ensure sustainability and ease of adoption.

Vermicompost Production Process

The production parameters followed by the farmers utilized the epigeic earthworm species *Eisenia fetida* (Red Wiggler) due to its high efficiency in converting organic waste into nutrient-rich humus. Composting was carried out in cement rings (chari) or plastic containers using a feedstock of semi-decomposed cow dung, foliage, and kitchen waste. Earthworms were introduced at a rate of approximately 1 kg per 100 kg of waste, with the

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transformation process spanning 70–80 days. From every 100 kg of bedding, approximately 55–60 kg of refined vermicompost was harvested using a fine-mesh sieve. Under optimal conditions, the earthworm population increased 4 to 5 times every six months. Precautionary measures were taken to protect units from excessive rainwater and predatory ants.

Application and Dosage

Vermicompost is a potent source of NPK and micronutrients. The application dosage was standardized to ensure optimal soil health and crop yield in the Haor ecosystem. Leafy vegetables (Amaranth/Indian Spinach) received 3.0 – 5.0 ton/ha applied during final land preparation and as top-dressing. Oilseeds (Mustard) received 2.5 – 3.5 ton/ha as a basal application, while Legumes (Grass Pea/Khesari) received 2.0 – 3.0 ton/ha to enhance nodulation and soil structure.

Crop Management

This section details the comparative cultivation techniques employed for both Conservation Agriculture (CA) and Conventional Farming systems, focusing on variety selection and maintenance.

Crop Selection and Cultivation Species

The study selected specific varieties for each management system. For Amaranth, CA plots used "Sobuj data" and "Paloan lal data," while conventional used "Lal data." For Indian Spinach, CA used "Sobuj puishak" and "Kajla puishak," while conventional used "Lal puishak." For Mustard, CA used "BINA sarisha-11" and "BARI sarisha-14" against "Local sarisha." Finally, for Grass Pea, CA used "BINA khesari-1" and "BARI khesari-3" against "Local khesari."

Planting Method and Spacing

Different sowing techniques were applied to distinguish between practices. In Conservation Agriculture, all crops were sown using the Line Sowing (In-Row) method with congested spacing to maximize land-use efficiency and suppress weeds. In Conventional Pracftice, seeds were sown via the Broadcasting method, following traditional local habits which result in random plant distribution.

Figure 2: Line sowing

Irrigation and Water Management

Due to the moisture-sensitive nature of the post-wetland soil, a precise irrigation schedule was implemented. Water was applied using manual watering cans with a sprinkler attachment to ensure even distribution and prevent soil erosion. A strict two-day interval was maintained throughout the vegetative growth stages to ensure the soil remained at field capacity.

Pest, Disease, and Nutrient Management

A clear distinction was made between the two systems regarding chemical inputs. The CA system operated under strictly organic principles using only vermicompost and mulching, with no synthetic fertilizers or pesticides. Conversely, the Conventional Practice followed the farmers' local methods, involving the application of synthetic fertilizers (primarily Urea) and chemical pesticides as needed.

Data Collection Methods

To evaluate the impact of CA versus conventional practices on both the ecosystem and crop productivity, specific protocols were established for monitoring soil and plant development.

Soil Health Assessment

Baseline soil samples were collected from each plot to monitor fertility. Analysis focused on soil pH, nutrient profiles (N, P, K, Mg, S), micronutrients (Zn, B), and Organic Matter (OM) to assess carbon sequestration potential in CA plots.

Crop Performance Indicators

Crop growth was monitored at 33, 54, and 69 Days After Sowing (DAS). For leafy vegetables, measurements included shoot/root length, stem diameter, leaf count, leaf area (cm^2), and biomass. For reproductive crops (Khesari and Mustard), indicators also included the number of branches, flowers, fruits (pods/siliques).

Yield Parameters

Seed yield of grass pea harvests have been documented.

Climate and Environmental Monitoring

To correlate performance with environmental fluctuations, agro-climatological data were integrated using the NASA POWER platform. Data were downscaled to a 2-meter resolution for the specific coordinates in Dharmapasha. Monitored parameters include daily temperature profiles, relative humidity (RH %), precipitation, and soil moisture dynamics (surface and root zone wetness), which are particularly important in the receding water environment of the Haor.

Statistical Analysis

The data were subjected to rigorous processing to evaluate the significance of variations. Initial data entry and cleaning were performed in Microsoft Excel, while Python

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and R Programming were used for advanced manipulation and modeling. Experimental results were analyzed based on the RCBD using a One-Way Analysis of Variance (ANOVA). A significance level of $p < 0.05$ was maintained for all tests to define statistical significance.

RESULTS AND DISCUSSIONS

Environmental and Agro-Climatic Dynamics

The success of agricultural interventions in the Haor ecosystem is inextricably linked to prevailing climatic conditions. Data retrieved from the NASA POWER DAV platform (Table 1) provides a high-resolution snapshot of the environmental stresses during the study period.

Table 1: Summary of climatic data of the experimental site (20 October, 2025- 25 December, 2025)

Mean Temp . Mean	Mean Temp . Min	Mean Temp . Max	RH Mean	Precip. Total	Precip. Mean	Surface Soil Moisture Mean	Surface Soil Moisture Min	Surface Soil Moisture Max	Root zone Soil Moisture Mean	Root zone Soil Moisture Min	Root zone Soil Moisture Max
22.265	13.7	32.88	71.94647059	97.49	1.433676471	0.751764706	0.58	0.89	0.772352941	0.64	0.9

Mean temperatures averaged 22.27°C, while root zone soil moisture remained relatively stable with a mean of 0.77. The temporal dynamics of rainfall and mean air temperature (Figure 3) show that rainfall exhibits a highly episodic pattern, with distinct events concentrated over a short duration while extended periods remain dry. Earlier literature shows that, around the haor basin, rainy days are projected to become fewer but more intense, especially in pre-monsoon, enhancing the episodic character of rainfall and flash-flood risk (Akter et al., 2023). In contrast, mean air temperature shows a gradual declining trend, typical of the seasonal shift from late autumn to early winter and National analyses confirm warming during monsoon and post-monsoon, with cooler trends in parts of winter, matching a gradual decline from late autumn into early winter rather than abrupt shifts (Al Mamun et al., 2023). From an agro-climatic perspective, this combination suggests an increasing dependence on soil moisture retention. Research findings highlight that decreasing/erratic rainfall with warming implies greater dependence on soil moisture storage and retention for dry-season and late-season crops in haor basins (Md. N. Rahman et al., 2023). The interrelationship among rainfall, soil moisture, temperature, and humidity (Figure 4) further clarifies these dynamics; for instance, a very strong correlation was observed between surface soil wetness and root zone soil wetness (r = 0.99), highlighting a strong vertical moisture continuity within the soil profile. Strong coupling among rainfall, evapotranspiration, and humidity reported for Bangladesh supports interpreting tight linkages between surface and root-zone moisture (Md. N. Rahman et al., 2023).

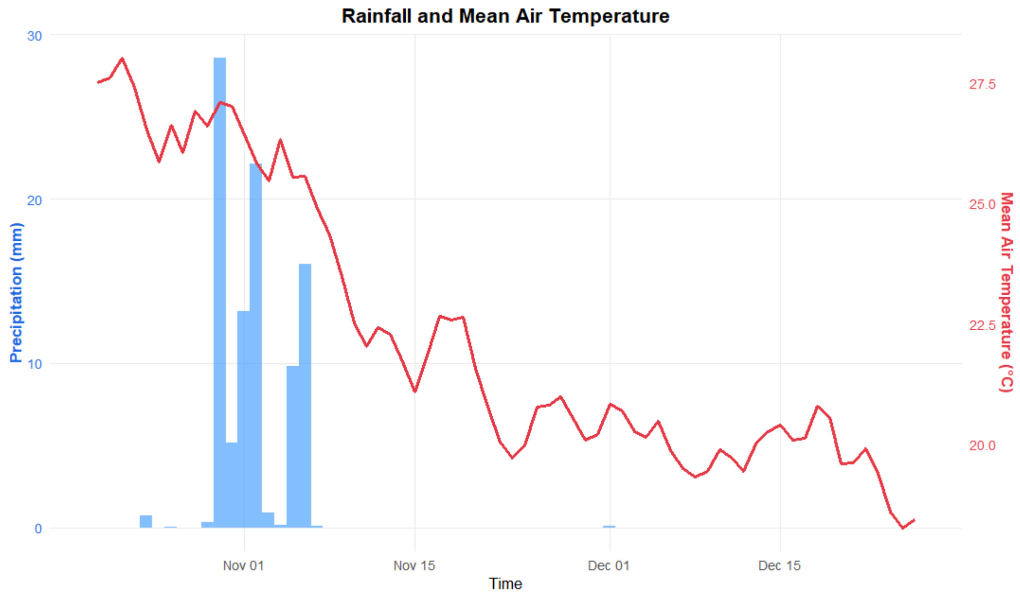

Figure 3: Mean temperature (°C) and Rainfall (mm) of the experimental site

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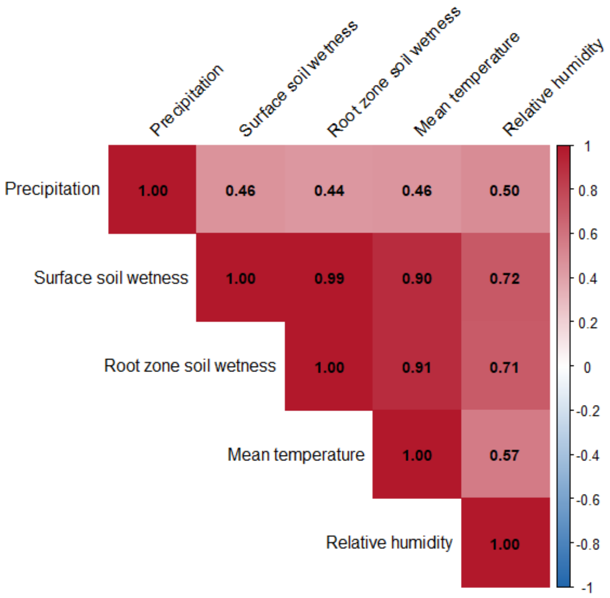

Figure 4: Correlation between the climatic parameters

Baseline Soil Health Status

The baseline Organic Matter (OM) content (Fig. 5) shows a wider distribution in the Organic/CA plots (ranging from ~0.9% to 2.8%) compared to the Conventional plots (~0.5% to 1.5%) and existing study exhibits that Bangladeshi agricultural soils are typically low in organic matter, with many cropped soils having <2.5% OM and often <2.0% in northern and northeastern regions (Islam et al., 2023). This directs that the higher median OM in the CA-designated areas provides a favorable starting point for the vermicompost intervention, which aims to further enhance carbon sequestration and soil structure in this sensitive ecosystem.

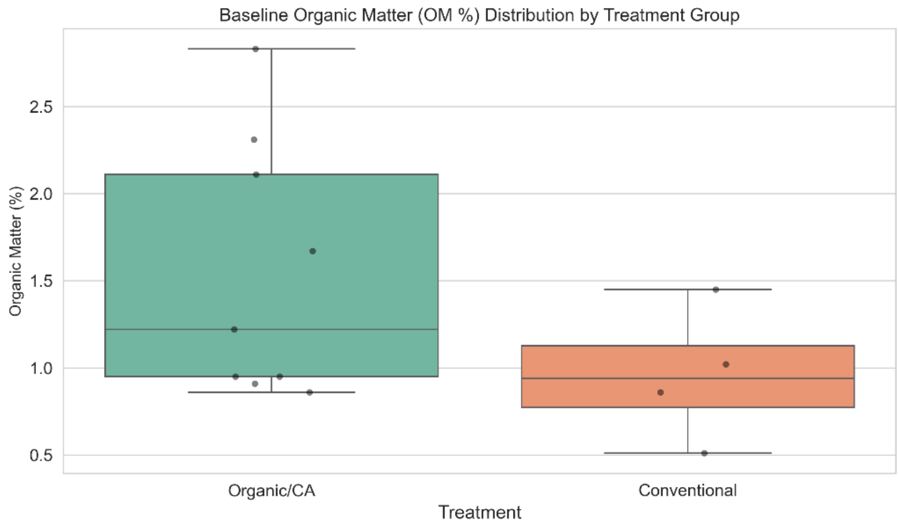

Figure 5: Baseline Organic Matter (OM%) distribution by treatment groups

The baseline data (Fig. 6) reveals that the Conventional plots initially possessed a higher pH (mean ~6.0) and higher levels of available Phosphorus (P) and Sulfur (S) compared to the Organic/CA plots. The lower pH in CA plots (mean ~5.2) suggests a more acidic environment, which is typical for organic-rich wetland soils. Interestingly, while the Total Nitrogen (%) was comparable between both systems, the high variability in the Conventional plots suggests inconsistent prior fertilizer applications by local farmers. It is reported in Sunamganj District that soils were slightly acidic (Mean 5.93 ± 0.42), relatively organic-rich, but low in N (0.025–0.392/total

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nitrogen) and very low in P (0.82 µg g⁻¹ (~0.82 mg kg⁻¹) (Talukder & Huda, 2021).

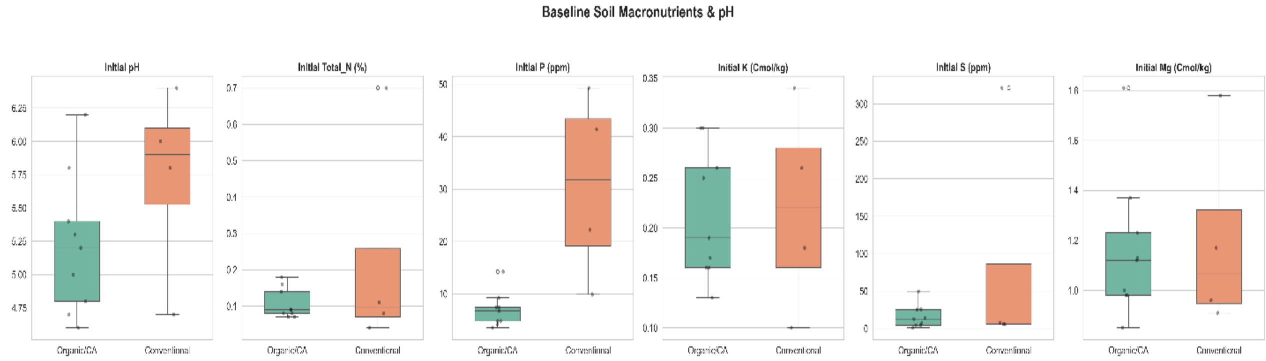

Figure 6: Baseline soil macronutrients and pH

As shown in Fig. 7, initial Zinc (Zn) levels were notably higher in the Organic/CA plots (median ~1.8 ppm) than in the Conventional plots (median <1.0 ppm). Boron (B) levels were low across both groups (0.08–0.22 ppm), falling near the critical deficiency limit for many crops. This justifies the application of vermicompost (Methodology 2.3.2), as it serves as a slow-release source for these vital micronutrients. Earlier study highlights that In Northern & Eastern Piedmont Plains (AEZ 22)**,** Low–medium Zn; trend to further depletion, very low–low B. SRDI notes Sylhet among the most B-deficient regions (Sarker et al., 2020).

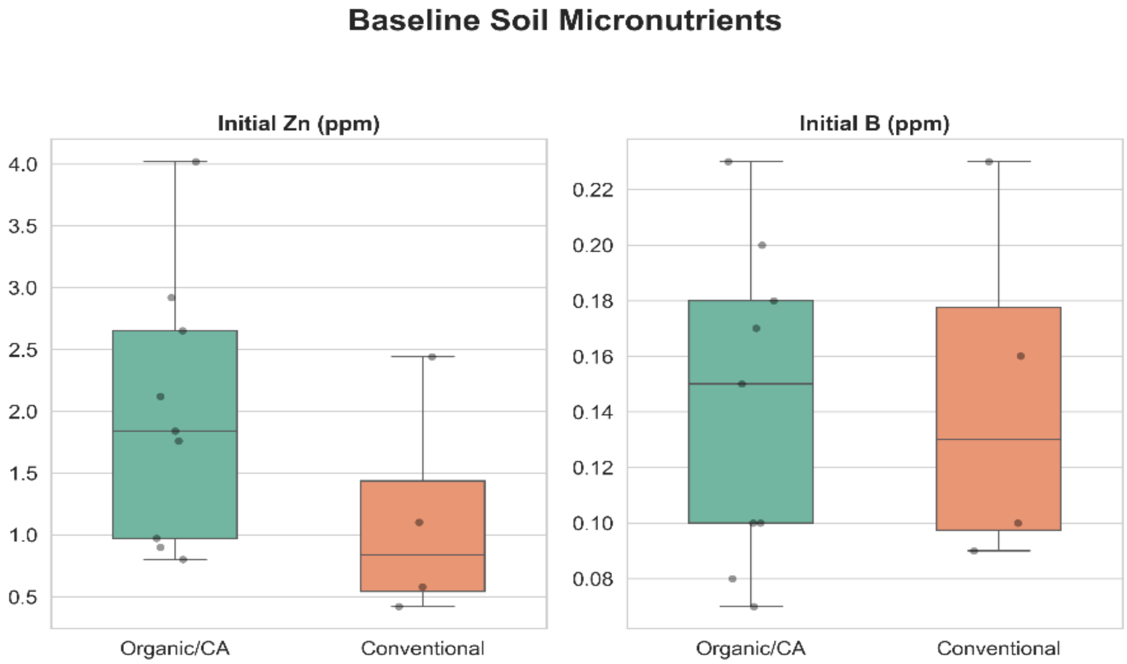

Figure 7: Baseline soil micronutrients

Soil Health Restoration and Carbon Sequestration Potential

One of the primary objectives of this study was to introduce climate-smart Conservation Agriculture (CA) to enhance soil organic matter. The data on root biomass suggests a significant breakthrough in soil health restoration. Among the CA varieties, Paloan lal data (amaranth) and Kajla puishak (basella) emerged as the most efficient contributors to soil organic matter, producing 7.290 t/ha and 7.067 t/ha of biomass respectively. And research shows that, 2–10 t/ha surface residues often needed for key soil functions (Ranaivoson et al., 2017). In terms of carbon sequestration, the estimated Organic Carbon (OC) added to the soil was 2,916 kg/ha for Paloan lal data (amaranth)and 2,827 kg/ha for Kajla puishak (basella). These CA practices represent a massive shift toward "carbon-positive" farming, improving soil aggregation and water-holding capacity in the ecologically sensitive Haor region. This CA practices (reduced/zero tillage, residue retention, diversified crops) increase below-ground biomass and residue return, raising soil organic carbon (SOC) stocks over time (Bai et al., 2019).

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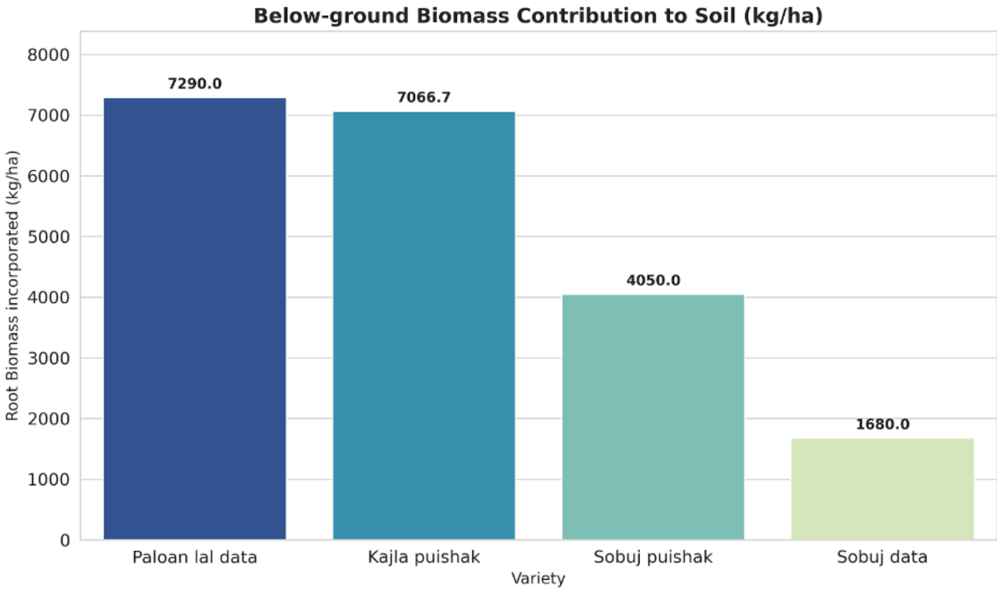

Figure 8: Below-ground biomass contribution by the CA plots' crops

Crop Morphological and Physiological Performance

The performance of different varieties under CA and Conventional management was evaluated through morphological indicators at 69 Days After Sowing (DAS), with statistical analysis confirming that management systems significantly influenced growth.

(a) (b)

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Figure 9: Morphological differences among the varieties; (a) Amaranth, (b) Basella, (c) Grass pea, and (d) Mustard and intercropping Basella-Grass pea

Leaf area (Figure 10), a primary indicator of photosynthetic capacity, was highest in the Conventional Lal data (amaranth), followed closely by CA Sobuj data (amaranth). In the Puishak (basella)varieties, intercropped plants showed significantly higher leaf area, suggesting a synergistic effect from the proximity to nitrogen-fixing Khesari (grass pea). result from maize–legume intercropping study, maize LAI was 31–35% higher than in monoculture, and intercropped soybean also showed higher LAI and specific leaf weight, contributing to yield advantages (Fu et al., 2023).

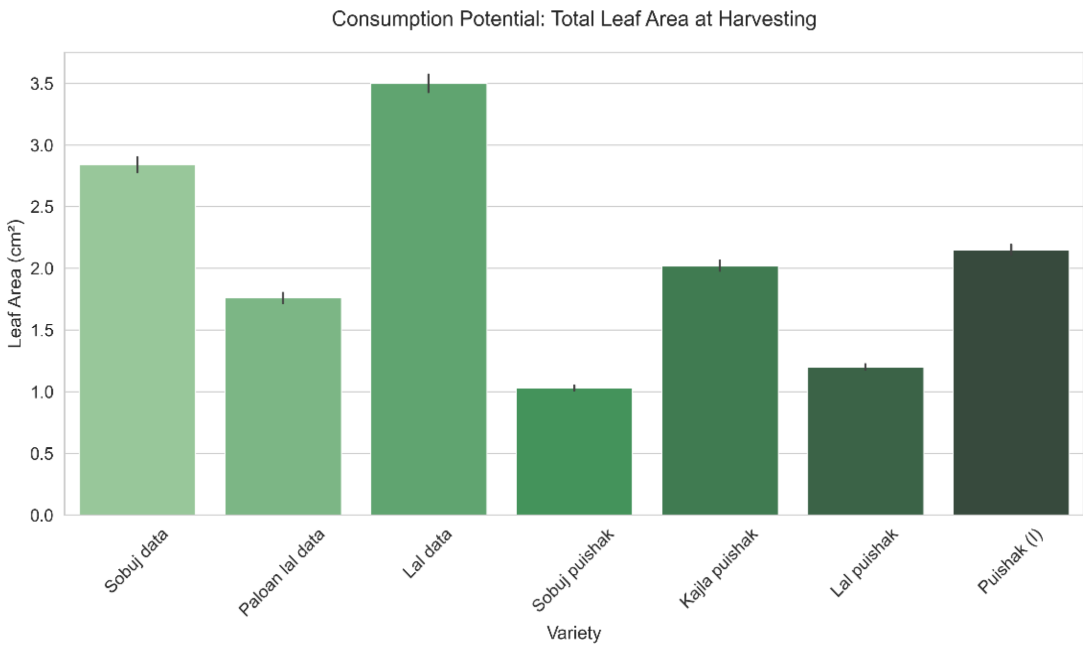

Figure 10: Consumption potential: Total leaf area at harvesting

Analysis of stem diameter (Figure 11) and significant parameters across crops (Table 2) showed that CA systems often matched or neared conventional performance while utilizing organic inputs. Study confirms that Conservation agriculture and intercropping often increase or maintain stem width and structural traits relative to conventional tillage, reflecting adequate resource supply even with reduced synthetic inputs (Kumar et al., 2022).

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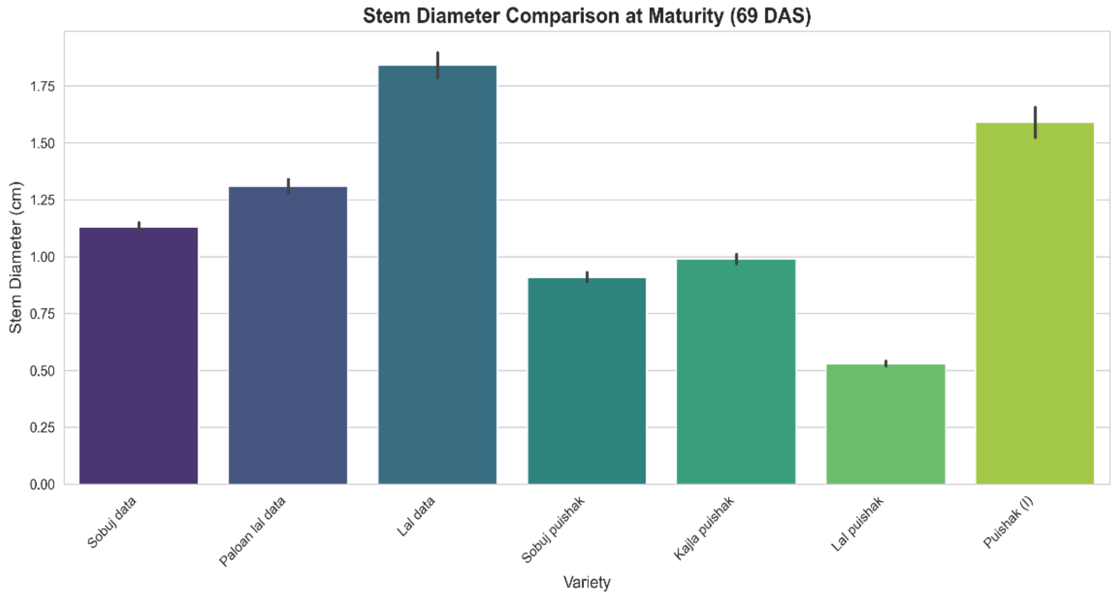

Figure 11: Stem diameter comparison at maturity (69 DAS)

Table 2 shows significance of different morphological parameters for amaranth, grass pea, and basella with their mean value where amaranth shows significant difference for shoot length among all the varieties. Root depth became significant in grass pea between BARI khesari-3 and local varieties. For the basella, leaf numbers are significant for Sobuj puishak variety.

Table 2: Significant parameter in different crops

Crop	DAS	Parameter	Variety	Mean	P-Value
Amaranth	69	Shoot Length	Lal data	152.05	significant
Amaranth	69	Shoot Length	Paloan lal data	59.70	significant
Amaranth	69	Shoot Length	Sobuj data	68.91	significant
Grass Pea	69	Root Depth	BARI khesari-3	12.65	significant
Grass Pea	69	Root Depth	Local khesari	3.45	significant
Basella	69	Leaf Count	Sobuj puishak	12.00	significant

Notably, root nodule dynamics (Figure 12) peaked at 54 DAS, with BARI khesari-3 (CA) exhibiting the highest nitrogen-fixation potential (nearly 18 nodules per plant), confirming that avoiding synthetic urea promotes symbiotic relationships with *Rhizobium* bacteria. Previous study confirms that high mineral N (e.g., synthetic urea) typically suppresses nodule formation and activity through systemic "N-satiety" signals that inhibit organogenesis and promote nodule senescence. When mineral N is low or absent, plants depend more on symbiosis; nodule numbers and functioning increase, supporting greater N_2 fixation (Lepetit & Brouquisse, 2023).

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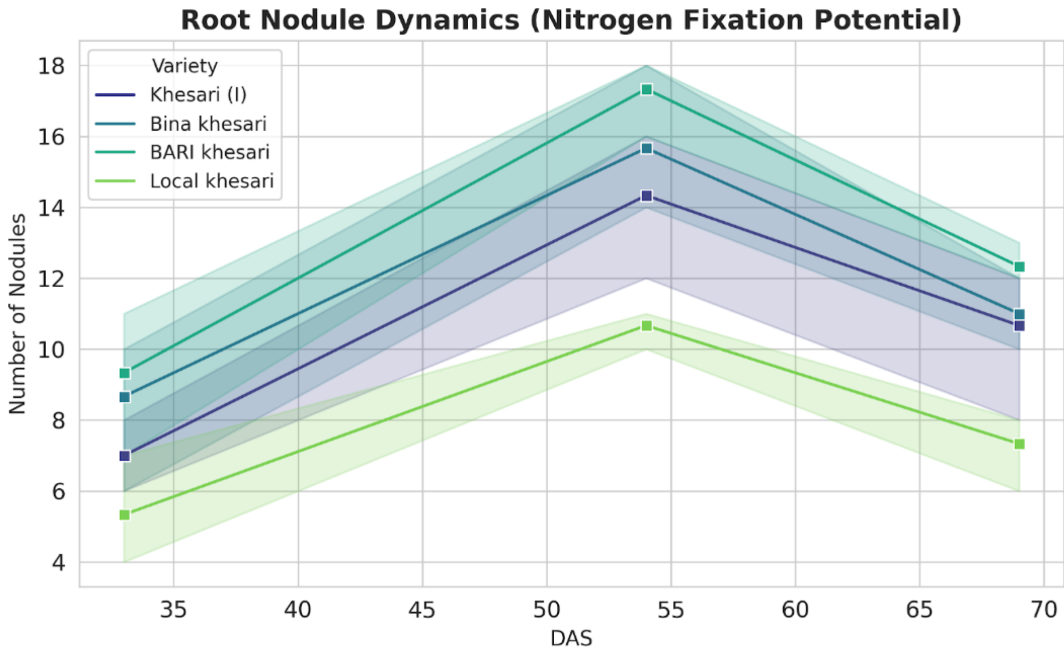

Figure 12: Root nodule dynamics (Nitrogen fixation potential)

Furthermore, the synchronization of flowering and pod formation (Figure 13) and biomass allocation (Figure 14) indicated that CA varieties generally supported higher reproductive yields and superior shoot development in the receding moisture environment, which aligns with this study where CA and cover/mulch systems conserve soil moisture, which sustains canopy development and shoot biomass under limited water, supporting reproductive sinks (Whippo et al., 2024).

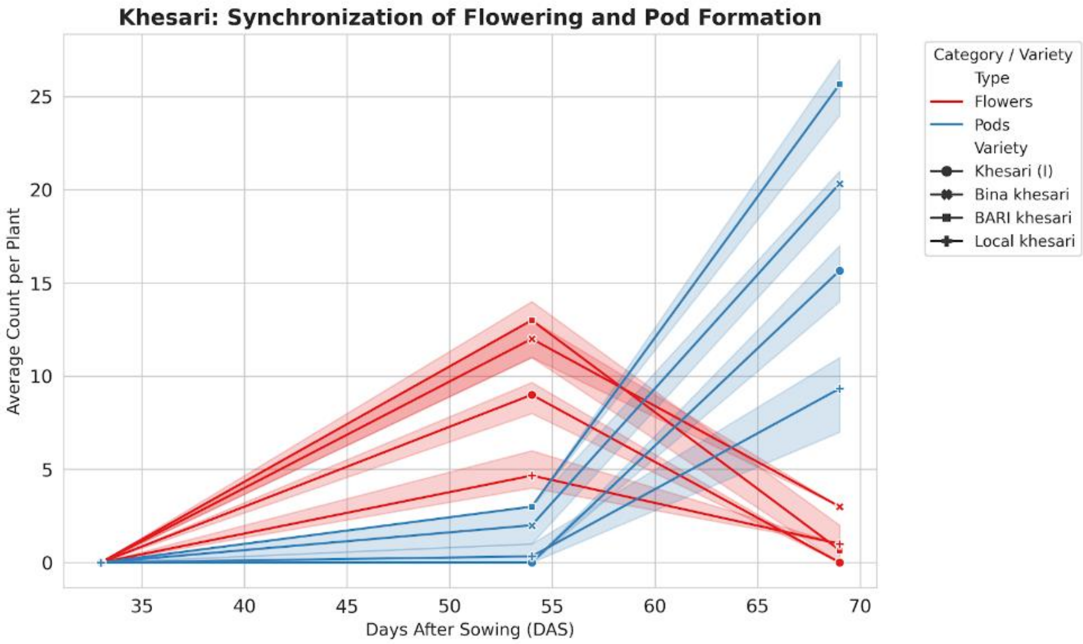

Figure 13: Khesari: Synchronization of Flowering and Pod Formation

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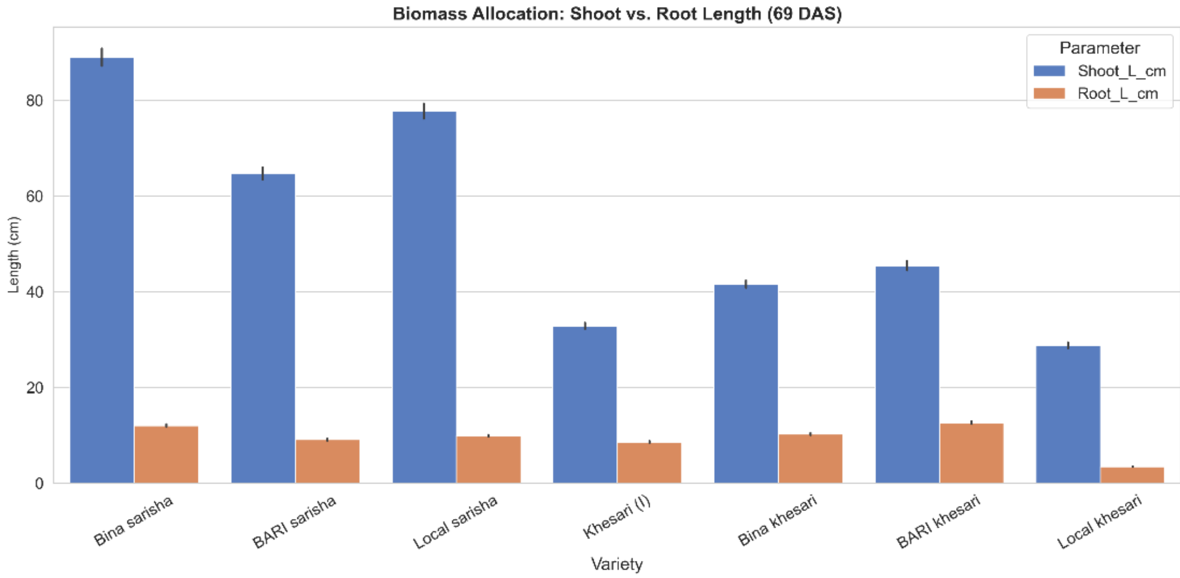

Figure 14: Biomass allocation: shoot vs root length (69 DAS)

However, *Sarisha* (Mustard) has been removed from final recommendations due to poor site-specific performance.

Seed yield of grass pea

The seed yields of three varieties of grass pea are reported 1.7 t/ha, 1.65 t/ha, and 0.9 t/ha for BINA khesari-1, BARI khesari-3, and Local Khesari, respectively. Reviews highlight that *L. sativus* fits minimal/no-tillage, residue-retaining, intercropping and rotation systems, all core elements of conservation agriculture, improving soil structure and fertility while providing stable yields under stress (Solovieva et al., 2025)

Biodiversity and System Resilience

The project aims to strengthen the resilience of resource-poor households through the transition to CA and intercropping. By avoiding pesticides, CA plots maintained higher levels of beneficial soil macro-fauna. The use of *Eisenia fetida* for on-site vermicompost production empowered farmers to become "producers of fertility" rather than just "consumers of chemicals." While conventional systems might offer higher short-term energy use efficiency in terms of growth height, the CA system in Sunamganj maximized ecosystem-level productivity and ensured the soil remains productive for the next cropping cycle, reducing poverty-cycle dependency on external inputs.

CONCLUSION

This action research confirms that in the haor ecosystem of Sunamgonj, vermicompost and conservation agriculture practices significantly outperform conventional methods in terms of root-zone resilience and carbon sequestration. While conventional methods may produce taller plants through chemical stimulation, the CA system builds a robust soil foundation capable of sustaining biodiversity and providing consistent yields for poor wetland households. These findings provide a scalable model to strengthen the climate-adaptive capacity of the region.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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