International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

# Sowing Sustainability: A Comprehensive Review of Upland Kangkong Cultivation and the Role of Carbonized Rice Husk in Soil Fertility and Yield Enhancement

Krisza Joy C. Vasallo.[1], Cyril John C. Nagal[1]
[1]College of Agriculture, University of Science and Technology of Southern Philippines, Claveria, Misamis Oriental, Philippines
Email address: cyriljohn.nagal@ustp.edu.ph

***Abstract*****—***Upland kangkong, a widely cultivated leafy vegetable in Southeast and South Asia, plays a crucial role in food security and rural livelihoods due to its rapid growth and adaptability to diverse environments. However, productivity constraints in upland systems, primarily arising from poor soil fertility and suboptimal agronomic practices, limit its full potential. This comprehensive review synthesizes current knowledge on upland kangkong cultivation and evaluates the role of carbonized rice husk (CRH) as an innovative soil amendment to enhance soil fertility and crop yield. CRH, produced via pyrolysis of rice husks under controlled conditions, exhibits unique physical and chemical properties including high surface area, nutrient retention capacity, and stability conducive to improving soil structure, water holding capacity, and microbial activity. Integration of CRH into upland soils has been shown to ameliorate soil constraints such as compaction, acidity, and nutrient deficiencies, thereby promoting sustained growth and biomass accumulation in kangkong. Field trials underscore the importance of optimizing CRH application rates tailored to specific soil types to avoid adverse effects such as salinity buildup. Furthermore, combining CRH with organic amendments and conventional fertilization within an integrated soil fertility management framework offers synergistic benefits, supporting sustainable and resilient production systems. The review also highlights the imperative of farmer education on postharvest handling and explores economic models to facilitate broader adoption of CRH technologies. Future research directions include long-term impact assessments on soil health, crop quality, and economic viability for smallholder farmers. This synthesis affirms that CRH represents a promising strategy to boost upland kangkong productivity while advancing sustainable agricultural practices in tropical and subtropical agroecosystems.*

***Keywords*****—** *Upland kangkong, water spinach, carbonized rice husk, biochar, sustainable agriculture, integrated soil fertility management.*

## I. INTRODUCTION

Kangkong (*Ipomoea reptans* Poir), commonly known as water spinach, is a vital leafy vegetable widely cultivated across Southeast and South Asia. It is an important source of nutrition and income for smallholder farmers due to its rapid growth cycle and adaptability to varied environmental conditions. In the Philippines, two commonly grown types are land water spinach and water spinach, thriving both on dry land and in aquatic environments such as paddy fields and river water. Favorable traits such as bright, attractive green leaves and crispy stalks make them a popular choice in both local and international markets. Furthermore, kangkong's presence extends beyond food use into pharmaceutical applications, highlighting its multifunctionality.

Globally, the demand for kangkong has been rising, with China being the dominant exporter and the United States the primary importer. As of 2021, global trade in kangkong was estimated at about USD 2.61 billion, with prices ranging between USD 0.30 and 1.60 per kilogram, reflecting its commercial importance. This growing demand is an opportunity and challenge for countries like the Philippines to optimize production, especially in upland areas where traditional rice farming is less feasible.

Soil fertility and nutrient availability play a critical role in the productivity of kangkong and other vegetable crops. Among emerging soil amendments, Carbonized Rice Husk (CRH) has gained increasing attention for its potential to improve soil physical, chemical, and biological properties. CRH is a biochar-like material produced through pyrolysis of rice husks under limited oxygen conditions at temperatures between 350 and 700°C. Unlike conventional organic amendments, CRH is more stable and exhibits a high surface area with abundant micropores, making it an ideal medium for nutrient retention and microbial habitat. It acts as a reservoir of nutrients such as nitrogen (N), phosphorus (P), and others, improving plant uptake and enhancing soil moisture retention.

This review aims to consolidate current knowledge on upland kangkong cultivation practices and comprehensively explore the impacts of Carbonized Rice Husk on soil fertility and crop yield. It integrates findings from recent agronomic studies, soil science research, and crop management reports to offer insights into sustainable approaches for improving kangkong productivity, particularly in upland and resource-limited contexts.

## II. METHODOLOGY

This review applied a structured and multi-methodological approach to critically assess and synthesize existing knowledge on upland kangkong cultivation and the effects of carbonized rice husk (CRH) on soil fertility and crop productivity.

### A. *Literature Review*

A comprehensive literature review was conducted to



Krisza Joy C. Vasallo and Cyril John C. Nagal, "Sowing Sustainability: A Comprehensive Review of Upland Kangkong Cultivation and the Role of Carbonized Rice Husk in Soil Fertility and Yield Enhancement," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 7, Issue 12, pp. 83-90, 2025.

IJMRAP
International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

identify peer-reviewed journal articles, institutional reports, and technical papers that explored the cultivation of upland kangkong and the use of CRH as a soil amendment. The review focused on identifying: Physiological characteristics of the crop; Agronomic practices in tropical and subtropical environments; Nutritional profiles and growth responses of kangkong; and Effects of CRH on soil properties (physical and chemical) and crop yield.

*B. Comparative Case Study Analysis*

To provide contextual depth, a comparative case study method was employed. This involved analyzing research outputs from regions with significant upland kangkong production (e.g., the Philippines, Malaysia, Indonesia) and correlating them with case studies on CRH applications in other crops under similar soil and climate conditions. This enabled the identification of: Regional practices and varietal preferences; Common constraints and adaptive strategies in upland kangkong farming; and Measurable outcomes following CRH applications across different crops.

This triangulated approach helped elucidate broader applicability and limitations of CRH as a soil amendment in upland kangkong systems.

*C. Secondary Data Analysis*

Secondary data from existing studies were extracted and subjected to qualitative synthesis. Soil physical properties (e.g., porosity, bulk density, compaction resistance), crop performance indicators (e.g., yield), and soil fertility indicators (e.g., pH, organic matter content, nutrient levels) were some of the variables assessed.

Meta-analytical interpretations allowed identification of trends and divergences across the reviewed studies (Travero et al., 2025; Nagal et al., 2024). Data reliability was ensured by prioritizing studies with defined controls, replicability, and statistical significance.

## III. Results and Discussion

*A. Upland Kangkong Cultivation and Growth Characteristics*

Kangkong's remarkable adaptability to a wide range of environmental conditions is largely attributed to its phenotypic plasticity, which allows the plant to adjust its growth and development in response to varying moisture levels, soil types, and climatic factors. This adaptability enables kangkong to tolerate both wet and dry conditions, making it a versatile crop suitable for diverse agricultural landscapes. Specifically, land kangkong is typically cultivated on well-drained soils and can also be found growing in paddy fields, showcasing its ability to thrive in moderately moist and aerated environments. In contrast, the water spinach cultivar is more specialized, flourishing predominantly in aquatic or heavily saturated conditions such as riverbanks, ponds, and flooded fields. Scientific research has demonstrated that upland kangkong, which is often grown in less fertile and sometimes degraded upland soils, stands to gain substantial benefits from the application of improved soil amendments. These amendments, including innovative materials like carbonized rice husk, enhance soil physical properties, nutrient availability, and microbial activity, thereby mitigating the challenges of poor soil fertility and degradation commonly encountered in upland farming systems. As a result, such interventions can lead to more robust growth, higher yields, and greater sustainability in upland kangkong cultivation, supporting the livelihoods of smallholder farmers in these vulnerable environments.

The nutritional requirement and water use efficiency of upland kangkong reveal a need for balanced fertilizer management and soil moisture conservation. Studies on other vegetable crops under varied irrigation regimes emphasize the importance of water and nutrient optimization for yield maximization. Incorporation of amendments such as biochar and organic manures has shown promising results in enhancing growth parameters of leafy vegetables and tomatoes, suggesting similar benefits for kangkong.

Upland kangkong thrives in moist, organically rich soils and can be cultivated in full sun to partial shade. It is a fast-growing, vine-like plant that spreads horizontally and is reluctant to climb (Lyons et al., n.d.). Two major types are identified: upland and aquatic kangkong, with the upland type adapted to dry soil conditions typical of the Pacific and Southeast Asian regions (Lyons et al., n.d.).

Kangkong is nutritionally dense, with 100g of edible parts containing 10740 µg carotene, 107 mg calcium, 3.9 mg iron, and 42 mg vitamin C (Akand et al., 2015). Its medicinal benefits are also notable, including hepatoprotective properties against heavy metals and potential anti-diabetic effects due to bioactive compounds like flavonoids and alkaloids (Nur Hanis Syuhada, 2019).

Kangkong propagation is predominantly through stem cuttings rather than seeds, offering faster establishment and uniformity (Lyons et al., 2010). For optimal growth, the crop requires consistently moist soil and freedom from competitive weeds.

The compiled data from multiple studies highlights the significant role of biochar amendments in improving the growth performance and physiological characteristics of water spinach (Ipomoea aquatica) across diverse agroecological zones and soil types. Studies surveyed encompass a broad spectrum of soil types, including acidic clayey Ultisol (Taiwan), paddy soils under subtropical conditions (China), acidic sandy loam (Philippines), and acidic soils with low fertility (Lao PDR). The biochars applied ranged from rice husk biochar (RHB), wood biochar (WB), hydrochar derived from wheat straw to carbonized rice hull (CRH), with application rates spanning from 0.5 kg/m³ to as high as 50 g/kg soil or approximately 40 t/ha in field settings.

A consistent observation across these studies is the enhancement of soil properties critical for plant growth. For example, Southavong et al. (2012) reported that rice husk biochar application elevated soil pH from a highly acidic 4.68 to a more favorable 6.22 and enhanced water holding capacity (WHC), indicating improved soil chemical and physical conditions conducive to water spinach growth. Similarly, Wang et al. (2023) connected increases in stem size with biochar's capacity to improve soil water holding capacity and silt content, demonstrating a linkage between soil structure modifications and plant morphological responses.



Krisza Joy C. Vasallo and Cyril John C. Nagal, "Sowing Sustainability: A Comprehensive Review of Upland Kangkong Cultivation and the Role of Carbonized Rice Husk in Soil Fertility and Yield Enhancement," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 7, Issue 12, pp. 83-90, 2025.

Biochar treatments had varying impacts on various aspects of plant development. In the Taiwan study (2013), rice husk biochar preferentially increased stem size and leaf length, while wood biochar showed a pronounced effect on root size and leaf width, illustrating that biochar feedstock types modulate plant development through distinct mechanisms. Biomass production notably increased by up to 124.6% compared to control treatments, underscoring the substantial yield potential of biochar amendments.

Sun et al. (2022) demonstrated that hydrochar application at a higher rate (2.0 wt%) significantly increased biomass yield by 12-14% under reduced nitrogen fertilization regimes (120-160 kg N/ha). This result highlights biochar's potential to enhance nutrient use efficiency, particularly nitrogen recovery, thus suggesting a role in sustainable nutrient management strategies.

TABLE I. Effects of Biochar on the Growth Characteristics of Water Spinach

| Author(s) | Country | Study Type | Soil Type / Conditions | Biochar Type and Application Rates | Growth Characteristics / Results |
|---|---|---|---|---|---|
| Southavong et al. (2012) | Lao PDR | Field experiment | Acid soil, initial pH 4.68; low fertility | Rice husk biochar applied at 40 tonnes/ha (16 kg/4 m2) | Biochar increased soil pH from 4.68 to 6.22 and improved water holding capacity; increased foliage yield for both first and second harvests. No apparent effect of effluent level on foliage growth. Biomass yield with biochar ~18 tons/ha |
| Varela Milla et al. (2013) | Taiwan | Field experiment | Acidic clayey Ultisol (0-20 cm horizon) | Rice husk biochar (RHB) and Wood biochar (WB), at 0.5 to 4.0 kg/m³ | Rice husk biochar increased stem size and leaf length; Wood biochar increased root size and leaf width; biomass production increased up to 124.6% compared to control; stem size proportional to WHC/silt ratio; root size proportional to OM/OC ratio |
| Wang et al. (2023) | China | Field experiment, subtropical | Paddy soil (subtropical) | Industrial and agricultural waste-derived biochar; rates not detailed | Reduced surface-water nutrient loss, decreased dissolved greenhouse gases storage |
| Sun et al. (2022) | China | Soil column experiment | Anthrosol from vegetable production site, pH 5.83, 0-20 cm soil layer | Hydrochar from wheat straw, 0.5 wt% (~12.5 t/ha) and 2.0 wt% (~50 t/ha) applied to topsoil (0- 20 cm) | High hydrochar rate (2.0 wt%) increased biomass yield under reduced N (120-160 kg/ha) by 12-14%; total N recovery increased at 2% hydrochar with 120 kg N; no effect on total N content of plants; low rate (0.5 wt%) showed no significant yield increase |
| Sarong and Orge (2015) | Philippines | Experimental pot study | Sandy loam soil: 71.22% sand, acidic (pH_KCl ~4.93) | Rice hull biochar (carbonized rice hull, CRH); applied at 0, 10, 20, 30, 40, 50 g kg^-1 soil | Significant increases in dry biomass with increasing biochar levels; highest biomass at 50 g kg^-1; no significant effect on plant N, P, K concentration; biochar improved soil nutrient retention and pH |

The pot study in the Philippines (Sarong & Orge, 2015) revealed significant increases in dry biomass with escalating biochar concentrations, achieving maximum biomass at 50 g/kg soil. Despite these biomass gains, concentrations of key nutrients (N, P, K) in plant tissues remained largely unchanged, indicating that biochar may enhance biomass through improved nutrient retention and soil pH adjustments rather than direct nutrient enrichment. Beyond plant growth, Wang et al. (2023) documented reductions in surface-water nutrient loss and dissolved greenhouse gases following biochar amendment, illustrating ancillary environmental benefits linked to biochar use in rice paddie

*B. Impact of Carbonized Rice Husk on Soil Fertility*

The integration of CRH into agricultural soils has been shown to substantially improve soil structure, reduce compaction, and enhance nutrient availability (Atkinson et al., 2010; Lehmann & Rondon, 2006). It improves aggregate stability, water- holding capacity (WHC), and penetration resistance (PR), which are vital for healthy root systems.

The use of carbonized rice husk (biochar) as a soil amendment has emerged as a sustainable strategy to enhance soil fertility and crop productivity. The diagram illustrating the impacts of carbonized rice husk on soil fertility consolidates findings from Varela et al. (2013) and Sarong & Orge (2015), highlighting physical, chemical, and biological improvements in soil properties, and their consequential effects on plant growth and crop yield.

The application of carbonized rice husk significantly ameliorates soil acidity by raising the soil pH from approximately 4.7 to 6.2 (Fig. 1). This pH shift is critical because many nutrients become more bioavailable in near-neutral pH conditions, enhancing nutrient uptake efficiency by plants. Acidic soils often impair root development and microbial activity; thus, biochar-mediated pH moderation creates a more favorable environment for root growth and soil biota.

The incorporation of carbonized rice husk has been shown to increase the soil's water holding capacity by around 10%. This physical improvement is attributable to the porous nature of biochar, which improves soil structure and porosity. Enhanced water retention mitigates drought stress and supports consistent water availability for crop roots, which is fundamental for physiological processes and maintaining plant turgor.

A prominent chemical benefit includes increased availability of essential macro-nutrients such as potassium (K), calcium (Ca), magnesium (Mg), and phosphorus (P). These nutrients are vital for various plant functions, including enzyme activation, photosynthesis, and cell wall development. The carbonized rice husk likely acts as a slow-release nutrient source and enhances nutrient retention in soils, limiting leaching losses.

From a biological perspective, the amendment enhances soil microbial activity and organic matter content. Due to its large surface area and porous structure, biochar supports nutrient cycling, improves soil health, and fosters the growth of helpful microorganisms. Additionally, carbonized rice husk contributes stable organic matter (biochar carbon), which improves soil fertility in both immediate and long-term contexts.

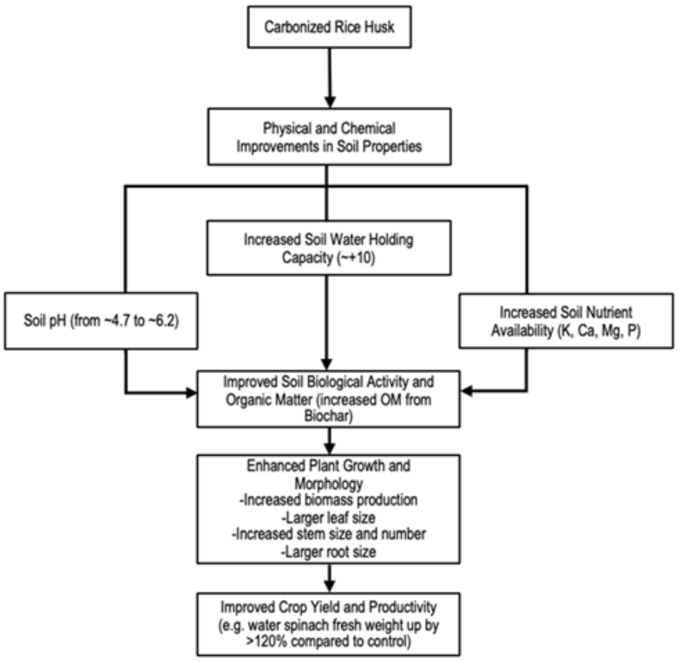


Fig. 1. Effects of Biochar Application on Soil Physical, Chemical, and Biological Properties.

Consequent to improved soil conditions, plants exhibit significant morphological enhancements— increased biomass production, larger leaf size, thicker and more numerous stems, and more extensive root systems. These changes reflect better nutrient and water uptake, improved photosynthetic capacity, and overall vigor, corroborating the efficacy of carbonized rice husk as a growth stimulant.

These integrated benefits culminate in tangible yield improvements, exemplified by a greater than 120% increase in fresh weight yield of water spinach compared to untreated controls. This underscores the practical value of carbonized rice husk in boosting both the quantity and quality of crop production, especially in regions with degraded or acidic soils. Moreover, its use in combination with other organic inputs like cocopeat or chicken manure further improves soil fertility. For example, mixtures of 70% cocopeat and 30% burnt rice hull produced the best results in flowering and yield of Celosia cristata due to a balanced aeration-moisture profile (Awang et al., 2009).

CRH is produced via pyrolysis of biomass materials such as rice husks under limited oxygen at temperatures between 350–700°C (Enders & Lehmann, 2017). The pyrolysis process creates a porous structure, increasing soil surface area and providing micropores that facilitate nutrient retention and enhance soil water-holding capacity. The physical attributes of CRH, including lowered bulk density by 3 to 31%, improve soil aeration and reduce compaction, critical factors for root growth and overall plant health. Its unique characteristics include a high surface area, microporosity, neutral pH, and low bulk density (Kampf & Jung, 1991). These features make it ideal for improving soil aeration, water retention, and nutrient-holding capacity (Lehmann & Joseph, 2015).

Studies demonstrate that CRH enhances key soil nutrients, including nitrogen and phosphorus, and significantly reduces soil bulk density by an average of 12%, which is critical for root development and water infiltration (Blanco-Canqui, 2017). CRH also supports microbial activity by acting as a habitat, thus improving organic matter decomposition and nutrient cycling (Ephraim & Rebbeca, 2024; Wangdi & Intanon, 2021).

Application of CRH in soils has been reported to increase soil nutrient content, particularly nitrogen and phosphorus, depending on the feedstock and pyrolysis conditions. CRH acts as a slow-release nutrient reservoir, reducing leaching losses and promoting sustained nutrient availability. Such characteristics make it advantageous for upland soils, which frequently suffer from low fertility and moisture retention challenges. Additionally, CRH enhances biological activity, encourages soil organic matter breakdown, and supports beneficial soil microorganisms by providing habitat and substrate. This enhanced microbial environment contributes to nutrient mineralization and cycling, further benefiting plant growth.

### C. *Effect of CRH on Crop Yield and Nutrient Uptake*

Several studies have demonstrated positive effects of biochar and CRH applications on crop biomass, yield, and nutrient uptake. Rajkovich et al. (2012) reported improved corn growth and nitrogen nutrition following biochar additions to temperate soils. Similarly, when combined with rice husk biochar, rice genotypes showed higher biomass output and nutrient absorption, according to Win et al. (2019).

The synthesized data from multiple studies highlight the substantial positive effects of rice hull biochar on water spinach productivity and nutrient dynamics across diverse agroecological contexts (Table 2). The studies reviewed encompass field and pot experiments conducted in Cambodia,

Vietnam, China, and Laos, employing varying rates and combinations of biochar and organic fertilizers, reflecting a consistent trend toward enhanced crop yield and improved nutritional quality.

Hu et al. (2014) and Khoi (2024) demonstrated that integrating biochar with organic fertilizers significantly increases yield components such as fresh plant weight, shoot length, diameter, and leaf number. Notably, Khoi's work in Vietnam revealed that the highest fresh plant weight and superior shoot quality were achieved with combined application of 7 t organic fertilizer/ha and 3 t biochar/ha (treatment T6), underscoring the synergistic effect of biochar with balanced nutrient management. Additionally, an improved leaf SPAD chlorophyll index in treatment T4 at 15 days after planting indicated enhanced chlorophyll content and potentially improved photosynthetic efficiency, likely contributing to observed yield gains.



Krisza Joy C. Vasallo and Cyril John C. Nagal, "Sowing Sustainability: A Comprehensive Review of Upland Kangkong Cultivation and the Role of Carbonized Rice Husk in Soil Fertility and Yield Enhancement," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 7, Issue 12, pp. 83-90, 2025.

Ty et al. (2013) reported a 39% increase in biomass dry matter yield in Cambodia at a biochar application rate of 5 kg/m², albeit less pronounced relative to other vegetable crops such as cabbages. The increase in crude protein content from 13.7% to 18.1% coupled with a concomitant decrease in crude fiber from 14.5% to 9.27% in water spinach leaves implies an improvement in forage nutritional quality, which is essential for both human consumption and livestock feed applications. This demonstrates biochar's role not only as a yield enhancer but also as a modulator of crop quality parameters.

TABLE II. Influence of Rice Hull Biochar on the Yield and Nutrient Uptake Effect of Water Spinach

| Author(s) | Country | Crop Yield Effect | Nutrient Uptake Effect | Notes/Additional Info |
|---|---|---|---|---|
| Ty et al. (2013) | Cambodia | 39% increase in biomass dry matter yield at 5 kg/m² application. Yield increase less pronounced compared to cabbages. | Increase in crude protein from 13.7% to 18.1% in leaves; crude fiber decreased from 14.5% to 9.27%. Nutrient uptake improvement implied via biomass protein increase. | Biochar produced from rice husks combusted at ~500°C, applied with biodigester effluent fertilizer; soil pH improved from 5.8 to 6.82-7.13 after trial; trial lasted 35 days. Water spinach responded differently in biomass composition with increased stem proportion. |
| Khoi (2024) | Vietnam | Highest fresh plant weight at 15 days and first harvest in treatment T6 (7 t organic fertilizer/ha + 3 t biochar/ha). Yield significantly improved in T6 and T4 vs control. | Improved leaf SPAD chlorophyll index in T4 at 15 days; shoot quality (length, diameter, leaf number) better in T6; no severe pests/diseases noted. | Experiment used six treatments (T1 to T6) varying amounts of organic fertilizer and biochar; biochar pyrolyzed at 300°C for 2 hours; random complete block design; regular monitoring for pests and diseases. Yield and quality positively correlated with increased rates of fertilizer and biochar applying up to T6. |
| Hu et al. (2014) | China | Increased upland kangkong shoot yield by approx. 25-38% with biochar application (1B) | Increased P acquisition by kangkong; decreased Cd concentration and uptake | Biochar increased soil pH and available soil P; reduced DTPA-extractable Cd; biochar effect additive with intercropping and fungal inoculation; biochar application did not affect mycorrhizal colonization of stonecrop |
| Jiang et al. (2021) | China | Increased dry weight in shoots and roots; synergistic effect with exogenous calcium | Significant reduction in Pb uptake by roots (67.1%) and shoots (80.8%); Ca uptake slightly increased with biochar alone | Biochar increased soil pH, soil organic carbon content and cation exchange capacity; Pb immobilization was a major factor in reducing Pb uptake, |
| Southavong et al. (2012) | Lao PDR | Biochar increased foliage yield significantly in first and second harvests; charcoal had no apparent effect on yield. Curvilinear response to biodigester effluent with biochar peaked at 50-75 kg N/ha. | Soil pH increased from 4.7 to 6.6 with biochar; improved water holding capacity (27.4% to ~39%); nutrient dynamics inferred from yield increase but explicit nutrient uptake data not detailed. | Biochar produced by pyrolysis of rice husks at 40 t/ha; biodigester effluent applied as N source; experiment conducted in acidic soil (pH 4.7). Biochar was more effective than charcoal as soil amender on soil properties and crop growth. |

At the mechanistic level, biochar amendments consistently improved soil chemical properties critical for nutrient availability and metal immobilization. Jiang et al. (2021) and Hu et al. (2014) reported increases in soil pH and available phosphorus content following biochar application. Soil pH improvement is particularly significant in tropical and subtropical acidic soils, where nutrient solubility is often limited. For instance, Southavong et al. (2012) observed soil pH elevation from 4.7 to 6.6 upon biochar application in acidic upland conditions, enhancing water holding capacity (from 27.4% to ~39%), which collectively improves root growth environments and nutrient uptake efficiency. These soil ameliorations underpin the improved biomass accumulation reported in all studies.

Biochar's role in reducing uptake and accumulation of toxic heavy metals is also evident. Hu et al. (2014) and in water spinach tissues, Jiang et al. (2021) observed considerable reductions in the amounts of cadmium (Cd) and lead (Pb) in the water. These effects are primarily attributed to biochar- induced increases in soil pH and cation exchange capacity, facilitating immobilization of heavy metals and reducing their bioavailability to plants. Furthermore, the synergistic interaction between biochar and exogenous calcium application reported by Jiang et al. (2021) resulted in a pronounced reduction of Pb uptake by 67.1% in roots and 80.8% in shoots, alongside a slight increase in Ca uptake. This finding suggests a potential strategy for mitigating heavy metal contamination in vegetable production systems through combined soil amendments.

It is noteworthy that biochar application did not adversely affect beneficial symbiotic associations, such as mycorrhizal colonization (Jiang et al., 2021), preserving essential soil biological functions while improving plant growth and safety. The studies collectively indicate that rice hull biochar serves as a multifunctional soil amendment, improving physical, chemical, and biological soil properties, thereby enhancing yield and nutritional quality of water spinach while mitigating risks associated with heavy metal contamination.

Rice hull biochar application consistently improves water spinach yield and quality by enhancing soil fertility parameters—particularly pH and available phosphorus—and reducing toxic metal uptake. These benefits are amplified when



Krisza Joy C. Vasallo and Cyril John C. Nagal, "Sowing Sustainability: A Comprehensive Review of Upland Kangkong Cultivation and the Role of Carbonized Rice Husk in Soil Fertility and Yield Enhancement," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 7, Issue 12, pp. 83-90, 2025.

biochar is applied in combination with organic fertilizers and micronutrient amendments such as calcium. Future investigations should focus on optimizing biochar application rates under different soil and cropping conditions, elucidating long-term impacts on soil microbiota and nutrient cycling, and integrating biochar with other sustainable agronomic practices for maximizing their agronomic and environmental benefits.

In vegetable crops, biochar amendment has shown to improve lettuce, cabbage, and kangkong growth by increasing soil fertility and moisture retention. The use of rice husk biochar in upland cultivation similarly led to increased water use efficiency and higher leaf area indices, indicators of enhanced photosynthetic capacity. Studies involving livestock manures such as cow dung and poultry manure also confirm increased yields and growth parameters in tomato crops, suggesting that integrating organic amendments with CRH could provide synergistic benefits.

Additionally, pest and disease incidences in kangkong can be mitigated through improved soil health and nutrient management, reducing the vulnerability of plants and enhancing their resilience. The application of CRH has been found to enhance plant height, leaf area index (LAI), and biomass production across various crops, including water spinach (Ipomoea aquatica), maize, and tomato (Ty et al., 2013; Islam et al., 2018; Joshi & Vig, 2010). In sandy soils, CRH increased nutrient-holding capacity and significantly improved yield performance (Sarong & Orge, 2015; Hossain, 2019).

Furthermore, integrating CRH with poultry manure boosts macro-nutrient concentrations in the soil, resulting in improved plant growth and flowering (Warman, 1986; Hassan, 2002; Ismaeil et al., 2012). However, caution must be exercised to avoid excessive salinity due to over-application of soluble organic materials.

### *D. Postharvest and Market Implications*

Kangkong presents unique challenges and opportunities in postharvest management due to its perishable nature. Postharvest storage practices primarily involve bundling the harvested shoots followed by refrigeration, a method that has been demonstrated to extend shelf-life significantly, typically up to seven days under optimal conditions (Lyons et al., n.d.). This relatively short shelf-life necessitates efficient handling protocols to minimize postharvest losses, maintain product quality, and ensure market competitiveness.

The global economic footprint of kangkong underscores its importance within the horticultural sector. In 2021, the worldwide market value of kangkong was estimated at USD 2.61 billion, reflecting robust consumer demand and market expansion intervals influenced by urbanization, rising income levels, and increased health consciousness amongst consumers (Tridge, n.d.). This escalating market value highlights the crop's role as not only a staple food item but also a significant contributor to agribusiness and rural livelihoods.

Within the Philippine context, the integration of value-added processes further magnifies kangkong's economic potential. One notable innovation is the utilization of carbonized rice husk (CRH) in soil amendment practices, enhancing crop yield and quality. This approach translates directly into increased production volumes and, consequently, higher revenue streams. Philippine Rice Research Institute. (2005) projects that the adoption of such value-added interventions could generate annual revenues up to PhP 9.6 billion. This figure emphasizes the dual benefit of technological advancements—improving agronomic performance while fostering agricultural entrepreneurship and financial empowerment among local farmers.

Moreover, value addition through efficient postharvest management and soil fertility improvements presents a strategic avenue for the Philippine agriculture sector to meet both domestic consumption demands and export market requirements. As global interest in sustainable agricultural inputs like biochar grows, leveraging CRH as a low-cost, eco-friendly soil enhancer may catalyze wider adoption, enhancing the sustainability and profitability of kangkong production.

## IV. Conclusion and Recommendations

The reviewed literature converges to affirm that Carbonized Rice Husk is a highly promising soil amendment for upland kangkong cultivation. Its unique physical and chemical properties contribute to significant improvements in soil structure, water-holding capacity, nutrient retention, and microbial habitat. These benefits translate into enhanced crop growth, biomass production, and nutrient uptake, addressing key constraints of upland farming systems with typically poor soil fertility.

For sustainable upland kangkong production, the integration of CRH with conventional fertilization and organic manures appears most beneficial. Future research should focus on optimizing application rates of CRH for different soil types, understanding long-term impacts on soil health, and evaluating economic viability for smallholder farmers.

Moreover, enhancing post-harvest handling and storage techniques remains crucial to maintain the quality and marketability of kangkong. Given the growing global demand, improved agronomic practices supported by innovative soil amendments like CRH can significantly contribute to food security and rural livelihoods in Asia and similar agroecological zones.

Further, this comprehensive review underscores the agronomic, nutritional, and economic value of upland kangkong, particularly when integrated with sustainable soil amendments like carbonized rice husk. CRH not only enhances soil fertility and structure but also significantly boosts crop yield and health.

*Promoting CRH as a Substitute for Chemical Fertilizers*

One of the key recommendations emerging from this review is the promotion of carbonized rice husk as a partial substitute for conventional chemical fertilizers in upland vegetable cropping systems. The incorporation of CRH into soil management practices can provide a more sustainable and environmentally friendly alternative to synthetic inputs. CRH improves soil structure, increases water retention, and supplies essential macro- and micronutrients in forms more accessible to plants. These characteristics make it particularly valuable in tropical and subtropical agriculture, where soil degradation and nutrient leaching are persistent issues. Promoting CRH use can help reduce dependence on costly chemical fertilizers and promote healthier, more productive agroecosystems.

*Field Trials for Optimal Application Rates*

While the benefits of CRH are well documented, determining the most effective application rates for upland kangkong cultivation remains a priority. Over-application may lead to nutrient imbalances or altered soil pH, while under-application may fail to deliver desired productivity outcomes. Field-based experimental trials should be conducted across diverse soil types and climatic conditions to fine-tune CRH application protocols. These trials should also evaluate the long-term effects on soil health, crop quality, and yield sustainability. Findings from such studies can guide extension services and inform evidence-based recommendations for farmers.

*Integrated Soil Fertility Management*

Encouraging the integration of CRH with other organic soil amendments, such as poultry manure, compost, and green manures, can offer synergistic benefits for soil fertility. This integrated soil fertility management approach ensures a balanced nutrient supply, enhances microbial activity, and fosters sustainable crop production. Combining CRH with organic inputs can address multiple soil constraints simultaneously, such as compaction, low organic matter, and nutrient deficiencies. This holistic strategy aligns with sustainable agriculture principles and can be customized to local resource availability and cropping patterns.

*Farmer Education on Postharvest Handling*

Postharvest losses remain a significant barrier to the profitability and quality of kangkong in local and export markets. Therefore, educating farmers on proper postharvest handling practices is crucial. This includes training on harvesting techniques, washing, bundling, refrigeration, and packaging methods that preserve freshness and nutritional value. Reducing spoilage during storage and transportation will not only enhance marketability but also contribute to food security by minimizing waste. Agricultural extension services should prioritize capacity-building programs focused on postharvest management for upland vegetable growers.

*Economic Models and Market Strategies*

Finally, exploring innovative economic models and market strategies is essential for scaling up the adoption of CRH technologies. Business models that support local production and distribution of CRH can stimulate rural entrepreneurship and reduce input costs for farmers. Value chain assessments can identify market entry points, consumer preferences, and price incentives for sustainably produced crops. Policymakers and development agencies should also consider subsidies, carbon credit incentives, and public-private partnerships to make CRH technologies more accessible and attractive to smallholder farmers. Enhancing market access and profitability will ultimately drive wider adoption and reinforce the sustainability of upland vegetable farming systems.

## ACKNOWLEDGMENT

The authors express their heartfelt gratitude to everyone who has been part of this purposeful endeavor.

## REFERENCES

[1] Akand, M. H., Mazed, H. K., Pulok, M. A. I., Chowdhury, M. S. N., & Moonmoon, J. F. (2015). Influence of different dose of fertilizers management on growth and yield of Gimakalmi (Ipomoea reptans Poir). IJAR, 1(5), 98-101.

[2] Atkinson, C. J., Fitzgerald, J. D., & Hipps, N. A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: a review. Plant and soil, 337, 1-18.

[3] Awang, Y., Shaharom, A. S., Mohamad, R. B., & Selamat, A. (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of *Celosia cristata*. *American Journal of Agricultural and Biological Sciences, 4*(1), 63–71. Retrieved from https://www.researchgate.net/publication/237439195_Chemical_and_Physical_Characteristics_of_Cocopeat-Based_Media_Mixtures_and_Their_Effects_on_the_Growth_and_Development_of_Celosia_cristata

[4] Blanco-Canqui, H. (2017). Biochar and soil physical properties. Soil Science Society of America Journal, 81(4), 687-711.

[5] Chhay T. , Vor S., Borin, K. & Preston, T. R. (2013). Effect of different levels of biochar on the yield and nutritive value of Celery cabbage (*Brassica chinensis var*), Chinese cabbage (*Brassica pekinensis*), Mustard green (*Brassica juncea*) and Water spinach (*Ipomoea aquatica*). *Livestock Research for Rural Development. Volume 25, Article #8*. Retrieved May 14, 2025, from http://www.lrrd.org/lrrd25/1/chha25008.htm

[6] Enders, A., & Lehmann, J. (2017). Proximate analyses for characterising biochars. Biochar: a guide to analytical methods, 9-22.

[7] Ephraim, W., Paul, N. N., & Rebbeca, Y. (2024). Rice husk biochar for carbon sequestration, soil fertility and plant health improvement: A review. African Phytosanitary Journal, 4(2), 54-84.

[8] Hassan,E.A.H.(2002).Effect of chicken manure and season on the performance and HCN Content of two Forage sorghum cultivar, Ph.D. Thesis, Faculty of Agriculture, University of Khartoum, Sudan

[9] Hossain, M. F. (2019). Effect of biochar and fertilizer application on the growth and nutrient accumulation of rice and vegetable in two contrast soils. Acta Scientific Agriculture, 3, 74-83.

[10] Hu, J., Wu, F., Wu, S., Lam, C. L., Lin, X., & Wong, M. H. (2014). Biochar and Glomus caledonium Influence Cd Accumulation of Upland Kangkong (Ipomoea aquatica Forsk.) Intercropped with Alfred Stonecrop (Sedum alfredii Hance). *Scientific Reports*, *4*(1). https://doi.org/10.1038/srep04671

[11] Islam, S. J. M., Mannan, M. A., Khaliq, Q. A., & Rahman, M. M. (2018). Growth and yield response of maize to rice husk biochar. Australian Journal of Crop Science, 12(12), 1813.

[12] Ismaeil, F. M., Abusuwar, A. O., & El Naim, A. M. (2012). Influence of chicken manure on growth and yield of forage sorghum (Sorghum bicolor L. Moench). International Journal of Agriculture and Forestry, 2(2), 56-60.

[13] Jiang, S., Liu, Y., & Shu, Y. (2021). Biochar and exogenous calcium assisted alleviation of Pb phytotoxicity in water spinach (Ipomoea aquatica Forsk) cultivated in Pb-spiked soil. *Environmental Geochemistry and Health*, *44*(1), 207–219. https://doi.org/10.1007/s10653-021-00977-0

[14] Joshi, R., & Vig, A. P. (2010). Effect of vermicompost on growth, yield and quality of tomato (Lycopersicumesculentum L). African Journal of Basic & Applied Sciences, 2(3-4), 117-123.

[15] Kämpf, A. N., & Jung, M. (1991). The use of carbonized rice husks as a horticultural substrate. Acta Horticulturae, 294, 271–284. https://doi.org/10.17660/ActaHortic.1991.294.29

[16] Khoi, N. T. (2024). Improving yield and quality of water spinach (Ipomoea aquatica) through optimization of biochar and organic fertilizer application rates. *International Journal of Agriculture Extension and Social Development*, *7*(8), 265–269. https://doi.org/10.33545/26180723.2024.v7.i8d.923

[17] Lehmann, J., & Joseph, S. (Eds.). (2015). Biochar for environmental management: science, technology and implementation. Routledge.

[18] Lehmann, J., & Rondon, M. (2006). Bio-char soil management on highly weathered soils in the humid tropics. Biological approaches to sustainable soil systems, 113(517), e530.

[19] Lyons, G., Dean, G., Goebel, R., Taylor, M., & Kiata, R. (n.d.). Improving soil health, agricultural productivity and food security on atolls: SMCN2014/089 [Fact sheet No. 6]. Australian Centre for International

Agricultural Research (ACIAR). (Originally produced during project ACIAR PC/2010/063).

[20] Nagal, C., Travero, A., & Nagal M. (2024). Socio-Demographic Profile and Resistance to Change Among University Employees in the Post-Covid Era. Science International (Lahore) 36(2),149-152,2024. https://shorturl.at/DENeY

[21] Nur Hanis Syuhada, M. R. (2019). Antioxidant and anticholinesterase activities of Ipomoea aquatica Forssk. and Ipomoea reptans Poir/Nur Hanis Syuhada Mohd Rosli (Doctoral dissertation, University of Malaya).

[22] Philippine Rice Research Institute. (2005). Carbonized rice hull (Revised ed., Rice Technology Bulletin No. 47). Department of Agriculture.

[23] Rajkovich, S., Enders, A., Hanley, K., Hyland, C., Zimmerman, A. R., & Lehmann, J. (2012). Corn growth and nitrogen nutrition after additions of biochars with varying properties to a temperate soil. Biology and Fertility of Soils, 48(3), 271-284.

[24] Sarong, M. & Orge, R. F. (2015). Effect of Rice Hull Biochar on the Fertility and Nutrient Holding Capacity of Sandy Soils. OIDA International Journal of Sustainable Development, Vol. 08, No. 12, pp. 33-44, 2015, Available at SSRN: https://ssrn.com/abstract=2730687

[25] Southavong, S., Preston, T. R. & Man, N. V.(2012). Effect of soil amender (biochar or charcoal) and biodigester effluent on growth of water spinach (*Ipomoea aquatica*). *Livestock Research for Rural Development. Volume 24, Article #26*. Retrieved May 14, 2025, from http://www.lrrd.org/lrrd24/2/siso24026.htm

[26] Southavong, S., Preston, T. R., & Man N V. (2012). Effect of biochar and biodigester effluent on growth of water spinach (Ipomoea aquatic) and soil fertility. Livestock Research for Rural Development. Volume 24, Article #34. Retrieved May 14, 2025, from http://www.lrrd.org/lrrd24/2/siso24034.htm

[27] Sun, H., Chen, Y., & Yi, Z. (2022). After-Effects of Hydrochar Amendment on Water Spinach Production, N Leaching, and N2O Emission from a Vegetable Soil under Varying N-Inputs. *Plants*, *11*(24), 3444. https://doi.org/10.3390/plants11243444

[28] Travero, A., Nagal, C. J., & Herda, R. K. (2025). Study habits, mathematics performance and gender differences of agriculture students amidst the new normal. Jurnal Wahana Pendidikan, 12(1), 15. https://doi.org/10.25157/jwp.v12i1.16856

[29] Tridge. (n.d.). Latest global Kangkong insight news and analysis report | Tridge. Tridge. https://www.tridge.com/intelligences/kangkong/market-insights?

[30] Ty, C., Vor, S., Borin, K., & Preston, T. R. (2013). Effect of different levels of biochar on the yield and nutritive value of Celery cabbage (Brassica chinensisvar), Chinese cabbage (Brassica pekinensis), Mustard green (Brassica juncea) and Water spinach (Ipomoea aquatica). Livestock Research for Rural Development. Volume 25, Article, 8. Retrieved at Effect-of-different-levels-of-biochar-on-the-yield-and-nutritive-value-of-celery-cabbage-brassica-chinensis-var-Chinese-cabbage-brassica-pekinensis-Mustard-green-brassica-juncea-and-water-spinach-ip.pdf (researchgate.net)

[31] Varela Milla, O., Rivera, E. B., Huang, W. J., Chien, C., & Wang, Y. M. (2013). Agronomic properties and characterization of rice husk and wood biochars and their effect on the growth of water spinach in a field test. Journal of soil science and plant nutrition, 13(2), 251-266.

[32] Wang, X., Zhao, Y., Yao, G., Lin, Z., Xu, L., Jiang, Y., Jin, Z., Shan, S., & Ping, L. (2023). Responses of aquatic vegetables to biochar amended soil and water environments: a critical review. *RSC Advances*, *13*(7), 4407–4421. https://doi.org/10.1039/d2ra04847g

[33] Wangdi, K., & Intanon, S. (2021). Effect of different particle sizes of rice husk biochar on soil properties, nutrient leaching, and Brassica alboglabra productivity in sandy loam soil (Doctoral dissertation, Naresuan University).

[34] Warman, P. R. (1986). The effect of fertilizer, chicken manure and dairy manure on Timothy yield, tissue composition and soil fertility. Agricultural Wastes, 18(4), 289-298.

[35] Win, K. T., Okazaki, K., Ookawa, T., Yokoyama, T., &Ohwaki, Y. (2019). Influence of rice-husk biochar and Bacillus pumilus strain TUAT-1 on yield, biomass production, and nutrient uptake in two forage rice genotypes. PloS one, 14(7), e0220236.