The 5th Environment and Natural Resources International Conference (ENRIC 2024)

Theme: Net Zero World: Action for a Sustainable Future
14 - 15 November 2024, Bangkok, Thailand

Soil Cabon Sequstration Assessment in Major Cropping Patterns of the City of Batac, Philippines

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ABSTRACT

This study focused on assessing soil's capacity to sequester carbon under different rice-based cropping patterns that could result in formulation-specific soil and crop management for climate change mitigation in the agriculture sector. This study was conducted in the City of Batac with intensified and diversified cropping patterns centered around rice cultivation. A quantitative research design was employed to measure the different cropping patterns against the different soil characteristics. The hypotheses were tested focusing on the relationship among the variables through correlation and regression analysis. The cropping patterns observed in Batac City were dominantly rice followed by any of the following crops; corn, shallot, eggplant, rice, tomato, pepper, garlic, and tobacco. This cropping pattern is assumed to influence soil's pH, organic matter (OM), % carbon, phosphorus (P), potassium (K), bulk density, soil texture, moisture content, and soil carbon stock. Carbon stock was significantly influenced by soil organic matter content in various cropping patterns. Rice-tobacco exhibited the highest carbon stock (1.80%), while rice-garlic (0.63%) and rice-corn (0.60%) had the lowest carbon stocks. Due to their distinct organic matter compositions, different cropping patterns led to varying carbon stock levels. A regression model was constructed to predict the soil carbon stock variable using various predictors such as soil pH, soil texture, soil weight, phosphorus, potassium, Carbon, cropping pattern, and clay content. The regression model displayed a perfect fit with an R-squared value of 1.000, suggesting that the predictors collectively explain all the variability in the SC Stock variable. The model was statistically significant, as indicated by the low p-value and the significant F-test. Given the results, a further study should be done to have a thorough understanding of the physical, chemical, mineralogy, geology, and environmental conditions of a given area, which is necessary to fully interpret the significance of the above results. Importantly, this study can be used to design informed decision-making and advocacy for cropping patterns and management to be disseminated to farmers.

Keyword: Soil organic carbon/ Cropping pattern/ Climate change

1. INTRODUCTION

Soil carbon sequestration denotes transferring atmospheric CO_2 into the soil's carbon pool in the form of SOC, predominantly facilitated by plant photosynthesis [1]. The soil carbon pool dwarfs the atmospheric pool, approximately 3.1 times larger than the latter's 800 GT [2]. However, heightened temperatures can disrupt the carbon balance by limiting water availability and reducing photosynthesis rates [3]. Conversely, under conditions of water availability, elevated temperatures might bolster plant productivity and subsequently influence the carbon balance [4], accelerating SOM decomposition and yielding more CO_2, potentially engendering optimistic responses to climate change [5].

In cultivated lands, local influences on ecosystem processes, such as rainfall infiltration, soil erosion, sediment deposition, and varying soil temperatures due to landscape irregularities, can impact the carbon sequestration capacity of the soil. For instance, slope positioning affects soil moisture, nutrient levels, and plant root growth, all impacting soil carbon content [6]. The cumulative effects of carbon inputs and losses resulting from land use, management practices, and landscape dynamics lead to disparities in the capacity for carbon sequestration across landscapes. The critical threshold of soil organic carbon (SOC) in the root zone ranges from 1.5% to 2.0%, influenced by land use, soil

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management, and farming techniques. Over half of the total C pool at a 1-meter depth is concentrated between 0.3 and 1 meter [7]. Enhancing soil quality necessitates augmenting SOC concentration by implementing best management practices, such as conservation agriculture, which fosters a positive carbon budget [8].

The lowland areas of Ilocos Norte experience intensive cultivation, while upland and hilly areas remain less utilized. The province's agricultural production, centered in the City of Batac, is marked by rice-focused cropping patterns. Rice is typically cultivated during the wet season (June to October), and a diverse assortment of crops is grown during the dry season, including rice, corn, tobacco, garlic, eggplant, pepper, tomato, and onion. Given the escalating magnitude of typhoons and other natural calamities like drought impacting the province, it is imperative to evaluate the SOC content of the major rice-based cropping patterns in Batac City to estimate the extent of carbon sequestration by the soil.

The significance of this study lies in its potential to enhance soil fertility, structure, and crop yields, fostering favorable conditions for cultivation. Carbon is indispensable for sustaining life on Earth, underpinning biological activity, diversity, and ecosystem productivity. While humans and animals release CO_2, plants absorb it while emitting oxygen, ultimately returning carbon to the soil upon their demise. Moreover, crops exhibit greater resilience during droughts due to enhanced infiltration and water-holding capabilities. The proliferation of organic matter and associated soil biological populations stemming from diversified crop rotations augments soil health and vitality. It is, therefore, imperative to know the capacity of the soil to sequester carbon under different rice-based cropping patterns. Specifically, this study aimed to (1) identify the dominant rice-based cropping patterns in the city of Batac and select the major cropping patterns; (2) determine and compare the crop management practices; (3) determine and compare the soil characteristics under the major cropping patterns in the City of Batac; and (4) determine the relationship of physical properties, organic matter, and soil organic carbon under the major cropping patterns.

2. METHODOLOGY

2.1 Locale of the study

The City of Batac is situated in the province of Ilocos Norte's central-southwestern region, located approximately 17º17’ north and longitude 120º28’ east. It covers a total land area of 16,101 hectares; the terrain varies from gradually flat to rolling and hilly, with some areas being very steep. While the broader valleys are primarily located in the urban area, exhibiting a slope of 0-8%, the rural barangays, except those in the eastern section, have slopes ranging from 0-30%. The presence of different soil types with poor drainage characteristics is attributed to the heavy texture of the subsoil in most cases.

The City of Batac experiences a warm climate with two distinct seasons: the wet season spanning from the latter part of May to October, characterized by an annual average rainfall exceeding 2000 mm, and the dry season from November to April. It has a total cultivated land area of 2,063.65 ha, and the agricultural production system is characterized by intensified and diversified cropping patterns centered around rice cultivation. Figure 2 illustrates the sampling sites representing eight different cropping patterns.

2.2 Research design

The study utilized a quantitative research design due to the measurement of variables and testing hypotheses concerning the relationships among these variables through correlation and regression analyses. The sampling method employed was purposive random sampling, wherein barangays with the largest areas dedicated to major crops were chosen as the sampling sites.

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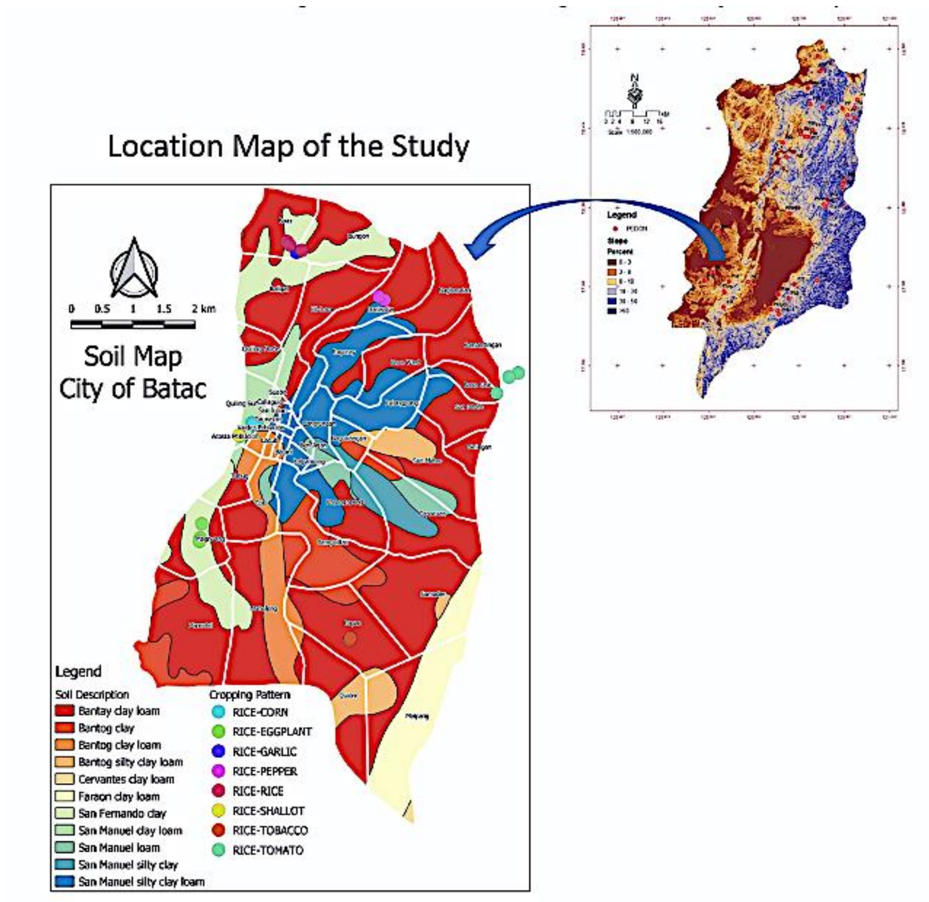

Figure 1. Sampling sites of the study area

The process of identifying the major crops planted and categorizing cropping patterns was executed by the City Agriculture Office, which provided classifications of major cropping patterns for each barangay. The top three crops with the most extensive planted areas were selected as the sampling sites among the barangays. A global positioning system (GPS) device was utilized to determine the geographical coordinates of these sampling sites.

Variables of the Study

INDEPENDENT VARIABLES

CROPPING PATTERNS

- Rice-Corn
- Rice-Shallot
- Rice-Eggplant
- Rice-Rice
- Rice-Tomato
- Rice-Pepper
- Rice-Garlic
- Rice-Tobacco

DEPENDENT VARIABLES

SOIL CHARACTERISTICS

- Soil pH
- Organic matter
- % Carbon
- Phosphorus (ppm)
- Potassium (ppm)
- Bulk density
- Soil texture
- Moisture content
- Soil carbon stock/ha

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2.3 Population and sample

The study's participants consisted of the landowners from whom soil samples were acquired. A total of ten respondents were involved in the study. The research design employed was qualitative. The sampling approach combined purposive random sampling and composite sampling methods, selected based on the characteristics present within the study as a whole.

The rationale for opting for a quantitative research design was to examine the relationships between various variables. Purposive random sampling was chosen to ensure the sample was closely aligned with the study's objectives. Additionally, the composite sampling method was applied to amalgamate individual samples into a unified composite sample, enhancing the reliability of both data collection and outcomes.

2.4 Research instrument

Information about the management practices implemented by farmers was collected using a survey questionnaire.

2.5 Data gathering procedure

To accurately assess the physical and chemical attributes of the area, a composite sampling technique was utilized. A total of one kilogram of soil was collected from the composite samples, securely packed in plastic containers, and kept in an icebox. The geographical coordinates of the sampling sites were established using a GPS device.

After collection, the soil samples were transported to the laboratory and subjected to air-drying. Following the drying process, the samples were ground and sifted through a mesh with a 2 mm diameter. The finely ground samples were then carefully stored in labeled plastic bags.

The following parameters were gathered with their corresponding procedure:

1. Bulk density

It serves as an indicator of soil compaction. Bulk density is usually denoted in g/cm3 and is determined by dividing the dry weight of soil by its volume, as illustrated below:

$$\text{Bulk Density} = \frac{\text{Weight of ovendry soil (g)}}{\text{Volume of the sampler}}$$

To calculate the volume, measurements of the core sampler's height and diameter were taken, and the volume was determined using the following formula:

$$V = \pi r^2 h$$

When collecting soil samples, a level soil surface was identified either horizontally or vertically at the intended depth within the field. The core sampler was cautiously inserted into the soil using a hammer to prevent compression. Subsequently, the samples were subjected to drying in an oven set at a temperature range of 105°C to 110°C for a duration of three to four days, or until a consistent dry weight was achieved.

2. Soil pH

Soil pH measurement involved utilizing a pH meter to assess the level of acidity or alkalinity in the soil specimens. Before taking measurements from the samples, the pH meter was calibrated using buffer solutions with known pH values. A 20 g soil sample was placed into a 100 ml beaker, and 20 ml of distilled water was added. The mixture was stirred at 20-minute intervals over an hour. Before the pH reading was obtained, the sample was thoroughly mixed.

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3. Soil Organic Matter Content

Two approaches exist for assessing soil organic matter (SOM) content: the colorimetric method and the Walkley-black method. The selection between these methods depended on the pH of the soil samples. The colorimetric method was employed when the soil samples exhibited a neutral to alkaline pH, whereas the Walkley-black method was utilized for acidic soil samples. The estimation of organic carbon was derived from the measurements of organic matter in the soil samples.

4. Determination of Organic Carbon per Hectare

The determination of soil sample bulk density readings was essential for computing the soil weight and quantifying soil organic carbon stocks in tons per hectare. This computation was carried out using the formula outlined by the Agriculture and Food Division of the Department of Primary Industries and Regional Development in Australia (https://www.agric.wa.gov.au/soil-carbon/measuring-and-reporting-soil-organic-carbon).

$$\text{Soil Weight per Ha} = 10{,}000\,\frac{\text{m}^2}{\text{ha}} \times \text{Soil Depth} \times \text{Bulk Density}$$

$$\text{Soil Carbon Stock per Ha} = \text{Soil Carbon} \times \text{Soil Depth} \times \text{Weight of Soil per hectare}$$

5. Soil texture

Soil texture significantly affects soil structure, water dynamics, microbial communities, and organic matter stabilization – all of which play vital roles in soil carbon sequestration. Understanding the interactions between soil texture and these processes is essential for developing effective strategies to enhance carbon sequestration

6. Soil potassium

The soil's overall potassium content is typically abundant, except in sandy soils. The quantified amount of potassium, measured in milliequivalents per 100g of soil, extracted through neutral 1N ammonium acetate, is commonly used to indicate potassium availability in soils. Available potassium comprises the combined presence of exchangeable and water-soluble potassium ions. Exchangeable potassium is the portion that can freely replace cations within salt solutions added to soils. However, since the extent of potassium exchange depends on the properties of the replacing solution, the term "exchangeable K" is more precisely defined as the portion extractable with neutral 1N NH4OAc, subtracting the water-soluble potassium.

7. Soil phosphorous

The analysis of soil phosphorus utilized the Modified Truog method, which entails the extraction of adsorbed phosphate from the soil using a specific solution. Within an acidic environment, soluble orthophosphates interact with molybdates, resulting in the formation of heteropoly molybdophosphoric acid. The intensity of color developed through this reaction is directly proportional to the quantity of phosphates in the soil.

8. X-ray fluorescence (XRF) analysis

X-ray fluorescence analysis is a method that uses characteristic X-rays (fluorescent X-rays) generated when X-rays irradiate a substance. X-ray fluorescence analysis can be considered spectrochemical analysis within an X-ray region. It has the same characteristics as atomic absorption and optical emission spectrometry, except that the sample does not need to be dissolved in a solution to be analyzed.

This method allows you to theoretically derive the intensity of the fluorescent X-rays if the type and properties of all elements that compose a sample are known. The fluorescent X-ray intensities of each element extrapolated the composition of the unknown sample.

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9. X-ray diffraction (XRD) analysis

The sample was analyzed using Olympus BTX (Laue method) with Cu kα metal target and 2 theta from 0 to 55 degrees. Phase identification was carried out using match! computer program and using the principle of the Hanawalt method.

10. Determination of organic carbon per hectare

Determining soil sample bulk density readings was essential for computing the soil weight and quantifying soil organic carbon stocks in tons per hectare. This computation used the formula outlined by the Agriculture and Food Division of the Department of Primary Industries and Regional Development in Australia (https://www.agric.wa.gov.au/soil-carbon/measuring-and-reporting-soil-organic-carbon).

$$\text{Soil Weight per Ha } = 10{,}000\frac{\text{m}^2}{\text{ha}} \times \text{ Soil Depth } \times \text{ Bulk Density}$$

$$\text{Soil Carbon Stock}\frac{\text{kg}}{\text{ha}} = \text{ Soil Carbon } \times \text{ Soil Depth } \times \text{ Weight of Soil per hectare}$$

2.6 Data analysis

The collected data was compiled and subjected to analysis of variance using STAR 2.0 v.1. Variations in means were assessed through the honest significant difference test at a significance level of 0.05 (HSD0.05). Additionally, correlation and regression analyses were conducted using SPSS to ascertain the connections and associations among the parameter.

3. RESULTS AND DISCUSSION

3.1 Major rice-based cropping patterns in the city of Batac

As per the records from the City Agriculture Office of Batac, approximately 2,053.65 hectares are utilized for rice cultivation during the wet season, while various vegetables and other high-value crops are grown in the dry season, involving a total of 5,193 farmers (as shown in Table 1). The city adheres to 13 distinct cropping patterns, among which the predominant ones include rice-corn (1,497.45 ha), rice-tobacco (374.74 ha), rice-rice (115.62 ha), rice-mungbean (53.91 ha), rice-garlic (41.10 ha), rice-eggplant (29.15 ha), and rice-shallot (14.68 ha). The rice-corn cropping pattern holds the largest area and engages the highest number of farmers, largely due to the support from the Department of Agriculture and the Cornick industry. Conversely, the study also encompasses the rice-tomato cropping pattern, which was once commonly cultivated until the closure of the National Foods Corporation (NFC), primarily known for tomato paste production.

3.2 Crop management practices

Table 2 assesses various crop management practices across different cropping patterns. The findings reveal that respondents following the rice-rice, rice-pepper, and rice-eggplant cropping patterns incorporated organic fertilizer before planting. Conversely, for rice-garlic and rice-tomato, they applied complete ammonium and sulfate. At the same time, respondents engaged in rice-corn, rice-tobacco, and rice-shallot patterns did not apply fertilizers before planting. Nearly all participants applied urea, complete, and sulfate fertilizers to their crops throughout the cropping period. Regarding pesticide usage, all the respondents applied insecticides and fungicides to control insect pests and diseases.

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Table 1. Cropping pattern and the number of farmers being engaged in 2020-2021.

CROPPING PATTERN	AREA PLANTED/HA	NUMBER OF GROWERS
Rice – Corn	1,497.45	3,637
Rice – Tobacco	274.74	593
Rice – Rice	115.62	316
Rice – Mungbean	53.91	288
Rice – Garlic	41.10	173
Rice – Eggplant	29.16	96
Rice – Shallot	14.68	62
Rice – Pepper	10.63	45
Rice – Squash	5.00	26
Rice – Stringbean	4.97	26
Rice – Ampalaya	3.63	23
Rice – Okra	1.24	5
Rice – Tomato	1.22	4
TOTAL	2,053.65	5,193

Source: City Agriculture Office, City of Batac

Table 2. Crop management practices of the different cropping patterns.

CROPPING PATTERNS	CROP MANAGEMENT PRACTICES				
	Code #	Rice-based	Fertilizer added before cropping	Fertilizer added during cropping	Pesticide used during cropping
Rice-Corn	1	/	None	Urea	Round up
	2	/	None	Urea	Round up
	3	/	None	Urea	Round up
Rice-Garlic	4	/	Complete, $NH_4^+$and SO4	None	Insecticide and Boulder
	5	/	Complete, $NH_4^+$and SO4	None	Insecticide and Boulder
	6	/	Complete, $NH_4^+$and SO4	None	Insecticide and Boulder
Rice-Rice	7	/	Organic Fertilizer	Urea and complete	Brodan and Magnum
	8	/	Organic Fertilizer	Urea and complete	Brodan and Magnum
	9	/	Organic Fertilizer	Urea and complete	Brodan and Magnum
Rice-Pepper	10	/	Organic Fertilizer	Urea, sulfate and complete	Brodan
	11	/	Organic Fertilizer	Urea, sulfate and complete	Brodan
	12	/	Organic Fertilizer	Urea, sulfate and complete	Brodan
Rice-Tobacco	13	/	None	Urea	Brodan
	14	/	None	Urea	Brodan
	15	/	None	Urea	Brodan
Rice-Tomato	16	/	Complete	Urea	Lanid
	17	/	Complete	Urea	Lanid
	18	/	Complete	Urea	Lanid
Rice-Eggplant	19	/	Organic Fertilizer	Complete	Magnum and Alika
	20	/	Organic Fertilizer	Urea and complete	Gold
	21	/	Organic Fertilizer	Urea and complete	Gold
Rice-Shallot	22	/	None	Urea and complete	Fungicide
	23	/	None	Urea and complete	Fungicide
	24	/	None	Urea and complete	Fungicide

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3.3 Soil characteristics of the cropping pattern

Soil physical properties are important in crop production due to their direct impact on root development, water accessibility, nutrient availability, and overall plant well-being. Furthermore, they shape nutrient cycling mechanisms within the soil, notably in the accumulation of organic matter. The physical attributes of soil also influence the availability, retention, and discharge of nutrients derived from organic matter. Soils that possess favorable structural characteristics contribute to effective nutrient cycling, ensuring that organic matter contributes to the nourishment essential for plant growth [9].

3.4 Soil physical properties under the different cropping patterns

Table 3 presents the soil physical properties of the selected cropping patterns investigated in this study. Soil texture was determined based on the relative proportions of three distinct soil particles: sand, silt, and clay. The analysis of variance results indicated significant variations (p=0.01) among the observed soil physical properties. The highest percentage of clay content was found in the rice-rice cropping pattern at 46.20%, followed by rice-garlic at 38.67%. Other cropping patterns showed similar clay contents ranging from 3.37% to 6.03%.

In terms of percent silt, the rice-eggplant cropping pattern exhibited the highest value at 32.53%, followed closely by rice-corn, rice-rice, and rice-garlic patterns with 29.07%, 28.60%, and 27.07% respectively. These values were comparable to the rice-pepper pattern at 23.33%. The rice-pepper pattern was similar to rice-shallot and rice-tobacco patterns, with silt contents of 20.40% and 20.27%, respectively.

Furthermore, the highest percentage of sand was found in the rice-tobacco and rice-shallot patterns at 74.77% and 74.24%, respectively, closely followed by the rice-tomato pattern at 72.47%. This value was also similar to the sand content in the rice-pepper pattern at 68.40%. Conversely, the rice-corn and rice-eggplant patterns exhibited the least sand content at 65.33% and 64.20%, respectively. Rice-garlic and rice-rice patterns had the lowest sand content, with 34.27% and 25.20% respectively.

According to [10], bulk density is influenced by various factors including clay content, land use, and management practices. Additionally, the impact of sand content on soil bulk density was found to be more significant than other soil properties [11]. Similar trends were observed in the bulk density values derived from different cropping patterns. Generally, cropping patterns with higher sand content exhibited greater soil bulk density. A study conducted also revealed a significant positive correlation between bulk density and sand content [12]. In the current study, the highest bulk density values were observed in cropping patterns such as rice-corn, rice-pepper, rice-tomato, rice-shallot, rice-eggplant, and rice-tobacco, all exhibiting comparable results. Conversely, the lowest bulk density values were found in the rice-garlic and rice-rice cropping patterns, characterized by clayey-textured soil, with 1.28 g cm^{-3} and 1.30 g cm^{-3}, respectively.

3.5 Soil chemical properties under the different cropping patterns

On the other hand, the impact of chemical soil properties can significantly influence the accumulation of organic matter in the soil. Sufficient nutrient availability is essential for the decomposition of organic matter. Microorganisms engaged in the breakdown of organic substances require vital nutrients like nitrogen (N), phosphorus (P), and potassium (K) to fuel their metabolic processes. The activity and efficiency of microbial decomposition and the subsequent accumulation of organic matter are influenced by soil pH [13].

Table 4 reveals notable disparities in the build-up of organic matter content among various cropping patterns. The rice-tobacco cropping pattern exhibited the highest organic matter content (3.11%), followed by rice-eggplant (2.46%). This can be attributed to the crops' characteristics, primarily broad leaves. Conversely, the rice-corn and rice-garlic cropping patterns displayed the lowest organic matter content, measuring 1.04% and 1.07%, respectively.

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Table 3. The soil's physical properties under the different cropping patterns.

CROPPING PATTERN	SOIL PHYSICAL PROPERTIES				
	% Clay	% Silt	% Sand	Soil Texture	Bulk Density
	**	**	**	**	**
Rice-Corn	5.60^{c}	29.07^{ab}	65.33^{c}	sandy loam	1.43^{a}
Rice-Garlic	38.67^{b}	27.07^{abc}	34.27^{d}	clay loam	1.30^{bc}
Rice-Rice	46.20^{a}	28.60^{abc}	25.20^{e}	clay	1.28^{c}
Rice-Pepper	6.03^{c}	25.57^{bcd}	68.40^{bc}	sandy loam	1.41^{a}
Rice-Tobacco	4.97^{c}	20.27^{d}	74.77^{a}	sandy loam	1.36^{ab}
Rice-Tomato	4.20^{c}	23.33 ^{cd}	72.47^{ab}	sandy loam	1.41^{a}
Rice-Eggplant	3.37^{c}	32.53^{a}	64.10^{c}	sandy loam	1.37^{ab}
Rice-Shallot	5.37^{c}	20.40^{d}	74.24^{a}	sandy loam	1.41^{a}
CV (%)	14.23	7.59	3.00		2.14

*** –- Significant at 1% level; CV – coefficient of variation; Means with the same letter are significantly different at a 1% level of significance using the HSD Test.*

Bulk density, on the other hand, reflects the soil's capacity to serve as structural support, facilitate water and solute movement, and promote soil aeration. Bulk densities exceeding specific thresholds indicate compromised functionality (Table 1). Additionally, bulk density is utilized to convert between the weight and volume of soil. It expresses soil physical, chemical, and biological measurements based on volume for assessing soil quality and comparing different management systems. By using bulk density, errors stemming from variations in soil density at the time of sampling are eliminated, thus enhancing the validity of comparisons [14].

Table 4. The soil chemical properties under the different cropping patterns.

CROPPING PATTERN	SOIL CHEMICAL PROPERTIES				
	% OM	% OC	P, ppm	*K, ppm*	pH
	**	**	**	ns	**
Rice-Corn	1.04^{e}	0.60^{e}	161.77^{b}	268.26	7.00^{a}
Rice-Garlic	1.07^{de}	0.63^{de}	61.50^{d}	210.79	7.00^{a}
Rice-Rice	1.33^{cde}	0.77^{cd}	54.16^{d}	223.47	7.00^{a}
Rice-Pepper	1.33^{cd}	0.77^{cd}	122.54^{c}	225.83	7.03^{a}
Rice-Tobacco	3.11^{a}	1.80^{a}	72.11^{d}	247.06	6.87^{a}
Rice-Tomato	1.57^{c}	0.91^{c}	46.56^{d}	257.62	6.80^{ab}
Rice-Eggplant	2.46^{b}	1.43^{b}	126.62^{bc}	222.95	6.57^{b}
Rice-Shallot	1.34^{cd}	0.78^{cd}	293.30^{a}	265.82	6.80^{ab}
CV (%)	5.96	5.90	11.11	8.68	1.25

*** – Significant at 1% level; ns – not significant; CV – coefficient of variation*
Means with the same letter are significantly different at a 1% level of significance using the HSD Test.

The organic carbon estimation was conducted based on the assumption that soil organic matter comprises 58% carbon, which applies to certain soils or specific components of soil organic matter [15]. The results demonstrate a direct proportionality between organic carbon (OC) and organic matter (OM). As a result, the rice-tobacco cropping pattern exhibited the highest OC content at 1.80%, followed by rice eggplant at 1.43%. Conversely, rice-corn displayed the lowest OC content, accompanied by rice-garlic at 0.60% and 0.63%, respectively. Significant variation was observed in the phosphorus content among the different cropping patterns. The rice-shallot pattern exhibited the highest phosphorus content at 293.30 ppm, trailed by rice-corn (161.77 ppm) and rice-eggplant (126.62 ppm). However, the potassium content of soils across the various cropping systems did not exhibit significant differences.

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The soil pH of the distinct cropping patterns also displayed significant divergence. The results indicated that rice-corn, rice-garlic, rice-rice, and rice-pepper patterns possessed a neutral pH, while the remaining cropping patterns featured slightly acidic soils. It is worth noting that soil pH has a bearing on microbial activity and the composition of microbial communities. Different microbial groups exhibit preferences for specific pH levels. Soil chemical attributes influencing pH levels can impact the abundance and activity of microorganisms in decomposing organic matter. An optimal pH range, particularly a neutral pH, can stimulate microbial activity and enhance the breakdown of organic matter. Research has underscored that soil organic matter (SOM) associated with the sand-size fraction is more susceptible to decomposition, leading to higher turnover compared to the silt- or clay-size fractions [16].

3.5 X-ray fluorescence (XRF) analysis

As can be observed from the X-ray flourescence data (Figure 2), soil samples are Si-rich with significant amount of iron and aluminum with at least 60% light elements. Other inorganic ions such as magnesium, calcium, titanium and manganese were observed. It can be noted that the soil samples for Rice-Onion cropping pattern have trace amounts of phosphorous.

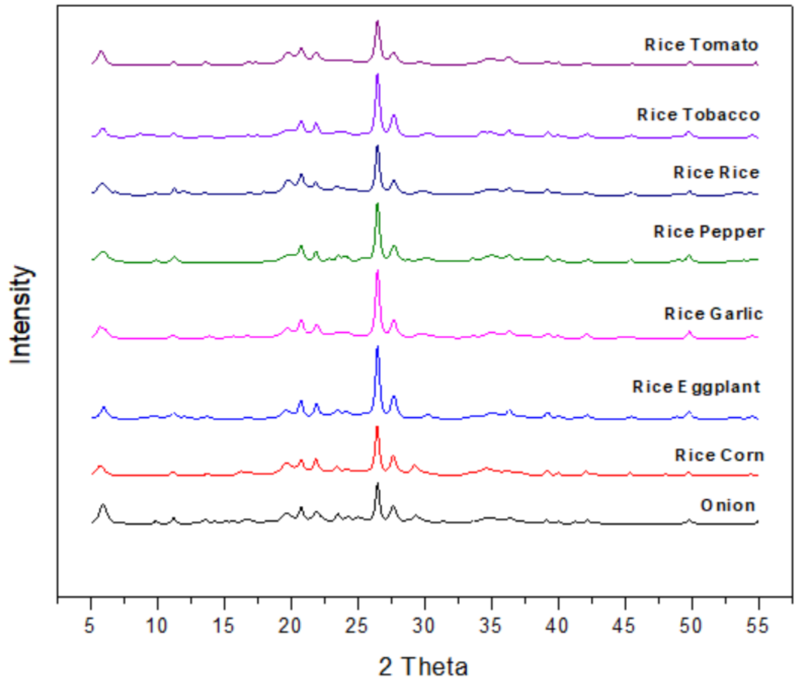

Figure 2. X-ray Fluorescence Analysis of soils under different cropping patterns in the City of Batac

It is also very evident that the ratio of silicon to aluminum is consistent for all the samples and is about 3.0 (Table 9). For environmental considerations, a high Si/Al ratio in soil or minerals can affect environmental factors like soil erosion and water retention. Minerals with higher Si/Al ratios may contribute to better soil stability and water-holding capacity. Similarly, a consistent ratio of iron to aluminum can also be observed and is equal to 1.0. This suggests that soils with a 1:1 Fe to Al ratio may contain significant amounts of these Fe-Al smectite minerals. Smectite minerals have a high cation exchange capacity (CEC), meaning they can hold onto and exchange various cations (positively charged ions) like calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na). This can affect nutrient availability in the soil. Smectite-rich soils have good water retention capabilities due to their expandable lattice structure, which can swell and hold water. This can be beneficial for plants in retaining moisture during dry periods [17].

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Table 5. The Chemical Composition of Soil based on the ratio of its components

CROPPING PATTERN	Si/Al Ratio, ppm	Fe/Al Ratio, ppm
Rice – Shallot	3.45	1.14
Rice – Eggplant	3.21	1.22
Rice – Tomato	3.12	1.13
Rice – Tobacco	3.28	1.09
Rice – Sweet Pepper/Chili	3.13	1.07
Rice – Rice	2.95	1.0
Rice – Corn	3.27	1.09
Rice – Garlic	3.24	0.99

3.6 Soil weight and soil carbon stock of the different cropping patterns

Soil weight was assessed at a depth of 30 cm, and the determination of carbon stock in the soil for each cropping pattern was based on bulk density. Findings indicated that soils characterized by higher bulk density tended to exhibit greater weight, ranging from 4,090 kg ha^{-1} (rice-tobacco) to 4,280 kg ha^{-1} (rice-corn), as detailed in Table 9. These soil types were identified as sandy loam and loamy sand.

In contrast, soils with a clay composition demonstrated notably lower weight, registering at 3,830 kg ha^{-1} (rice-rice) and 3,900 kg ha^{-1} (rice-garlic). The carbon cycle encompasses alterations in carbon stocks due to both ongoing processes and distinct occurrences. Continuous processes exert an impact on carbon stocks across all areas annually, while discrete events result in emissions and the redistribution of ecosystem carbon. The data underscores that carbon stock is significantly influenced by the presence of soil organic matter within various cropping patterns. The rice-tobacco pattern exhibited the highest carbon stock at 2,215.32 kg ha^{-1}, which was statistically distinct from the rice-eggplant pattern (1,757.16 kg ha-1) and rice-tomato pattern (1,155.10 kg ha^{-1}). Conversely, the lowest carbon stocks were observed in the rice-garlic (725.27 kg ha^{-1}), rice-corn (776.33 kg ha^{-1}), and rice-rice (883.19 kg ha^{-1}) patterns.

Table 6. Soil weight and soil carbon stock of the different cropping patterns.

CROPPING PATTERN	CARBON WEIGHT, kg/ha	CARBON STOCK, kg/ha
Rice – Shallot	4,220^{a}	980.40^{cd}
Rice – Eggplant	4,100^{ab}	1,757.16^{b}
Rice – Tomato	4,230^{a}	1,155.10^{c}
Rice – Tobacco	4,090^{ab}	2,215.32^{a}
Rice – Sweet Pepper	4,220^{a}	978.65^{cd}
Rice – Rice	3,830^{c}	883.19^{d}
Rice – Corn	4,160^{a}	779.25^{e}
Rice – Garlic	3,780^{d}	751.36^{e}

*** –- Significant at 1% level; CV – coefficient of variation*
Means with the same letter are significantly different at a 1% level of significance using the HSD Test.

3.7 Relationship of physical properties, organic matter, and organic carbon of the soil under the major cropping patterns

In Table 6, the clay content (Clay) displays a robust negative correlation with organic matter (OM) and sand content (Sand). At the same time, it exhibits a positive correlation with carbon (Carbon) and silt content (Silt). Sand content demonstrates a pronounced negative correlation with clay and a positive correlation with organic matter and silt content. Organic matter exhibits positive correlations with clay, sand, and silt content, indicating its association with higher proportions of these soil

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components. Bulk density (BD) exhibits a marked negative correlation with clay and silt content, implying that increased clay and silt content leads to reduced bulk density. Phosphorus (P) demonstrates positive correlations with clay, sand, and silt content, indicating its affiliation with higher proportions of these components. pH shows a robust negative correlation with clay, organic matter, and carbon content, suggesting that greater proportions of these components lead to lower soil pH. These correlations provide valuable insights into the interrelationships among various soil properties, enhancing our comprehension of soil composition and fertility.

Soil organic carbon constitutes a vital fraction of soil organic matter. Notably, organic matter consists primarily of carbon, constituting 58% [18]. As a result, the content of organic carbon is directly proportional to that of organic matter. Consequently, the rice-tobacco cropping pattern boasts the highest organic carbon content at 1.80%, followed by rice-eggplant at 1.43%. Conversely, rice-corn exhibits the lowest organic carbon content, accompanied by rice-garlic at 0.60% and 0.63%, respectively.

3.8 Regression

Table 7 offers a concise overview of the performance of a regression model in predicting the dependent variable "SC Stock" through the utilization of various predictors. The table presents measures of the model's fitness and its statistical significance.

The regression model demonstrates an impeccable match with an R-squared value of 1.000, implying that the collective effect of all predictors elucidates 100% of the variance in the SC Stock variable. The adjusted R-squared value of 1.000 further corroborates the robustness of the fit, underscoring that the model comprehensively encapsulates all available information. The standard error of the estimate is 8.55625, representing the average discrepancy between projected and actual values of the SC Stock variable. A smaller value suggests enhanced predictive precision.

The "Change Statistics" segment delineates the influence of adding predictors to the model. The R-squared change stands at 1.000, signifying that the incorporation of predictors accounts for the entire augmentation in the explained variance. The F-change statistic, computed at 8,951.352 with 9 degrees of freedom in the numerator and 14 degrees of freedom in the denominator, assesses the overall significance of the model. The exceedingly low p-value (<.001) indicates the statistical significance of the model, affirming its reliability in forecasting the SC Stock variable.

The predictors encompassed by the model encompass pH, REP, Silt, WS, P, K, Carbon, CP, and Clay. Additionally, the model incorporates a constant term as a predictor. These predictors hold substantial relevance in forecasting the SC Stock variable.

The regression model appears remarkably efficacious in predicting the SC Stock variable, evidenced by the impeccable fit, significant F-test, and inclusion of pertinent predictors. The ANOVA table elucidates the sources of variance within the regression model and appraises the significance of the overall model fit. Within the "Regression" segment, the sum of squares stands at 5,897,912.039, signifying the total variability elucidated by the regression model. The degrees of freedom (df) for the regression model amount to 9, corresponding to the number of predictors utilized. The mean square, calculated as 655,323.560 by dividing the sum of squares by the degrees of freedom, represents the average sum of squares. The computed F-statistic is 8,951.352, which is determined by dividing the regression mean square by the residual mean square (stated in the "Residual" section). The F-statistic evaluates the overall significance of the regression model. The exceedingly low p-value (<.001) attests to the model's statistical significance, substantiating that the predictors collectively substantially influence the dependent variable, SC Stock.

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Table 7. Sources of variation in the regression model and evaluates the significance of the model's overall fit.

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	5897912.039	9	655323.560	8951.352	<.001[b]
	Residual	1024.932	14	73.209		
	Total	5898936.972	23			

a=Dependent Variable SC Stock; b=Predictors: (Constant), pH, REP, Silt, WS, P, K, Carbon, CP, Clay

Consequently, the ANOVA table (Table 8) reaffirms the high significance of the regression model, underscored by the substantial F-statistic and the remarkably low p-value. The model expounds on a substantial portion of the variability within the SC Stock variable, leaving only a relatively minor unexplained variability (Table 9).

Table 8. Coefficients of Regression

COEFFICIENTS[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-804.079	186.153		-4.319	<.001
	CP	1.710	1.488	.008	1.150	.270
	Clay	-.190	.323	-.006	-.590	.564
	Silt	-.136	.552	-.001	-.247	.809
	Carbon	1217.354	7.749	.991	157.091	<.001
	WS	.200	.028	.068	7.161	<.001
	P	-.050	.032	-.008	-1.562	.141
	K	.031	.090	.002	.346	.735
	pH	-.545	19.400	.000	-.028	.978

a=Dependent Variable SC Stock

Table 9. Excluded Variables of Regression

EXCLUDED VARIABLES[a]						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	Sand	-9.619[b]	-.231	.821	-.064	7.653E-9
	OM	.[b]	.	.	.	.000
	BD	.[b]	.	.	.	.000

a=Dependent Variable SC Stock; b=Predictors in the Model: (Constant), pH, REP, Silt, WS, P, K, Carbon, CP, Clay

Table 10. Residual Statistics of Regression.

RESIDUALS STATISTICS[A]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	637.044	2246.402	1183.926	506.390	24
Residual	-14.659	15.750	0.000	6.675	24
Std. Predicted Value	-1.080	2.098	0.000	1.000	24
Std. Residual	-1.713	1.841	0.000	0.780	24

Dependent Variable: SCStock

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The regression model demonstrates an impeccable alignment, evidenced by an R-squared value of 1.000, signifying that the collective impact of all predictors fully accounts for 100% of the variability in the SC Stock variable. Additionally, the adjusted R-squared value of 1.000 underscores the model's exceptional fit, indicating that the model effectively accommodates all accessible data.

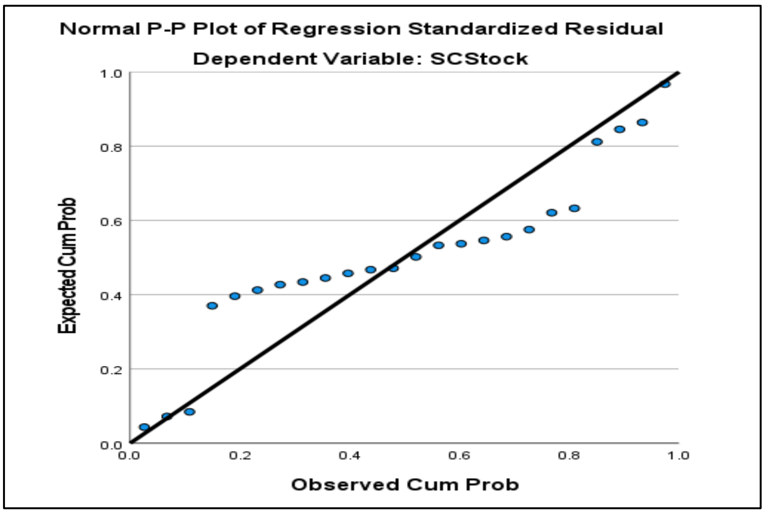

Figure 3. Regression Fit

4. CONCLUSIONS

Based on the comprehensive analysis of the study's findings, several noteworthy conclusions can be drawn, shedding light on the intricate relationships between soil properties, cropping patterns, and carbon sequestration:

1. Rice-corn cropping pattern is the most dominant followed by Rice-Tobacco in the City of Batac of which the latter obtained the higher Carbon stock
2. The traditional cropping management of the farmers includes the use and application of fertilizer and pesticides in their crops.
3. Cropping patterns significantly influence the clay, silt, and sand particles of the soil. Cropping patterns with higher proportions of clay tended to exhibit lower bulk density and soil weight. Conversely, those dominated by sand showed higher bulk density and soil weight.
4. Phosphorus content of the soil was significantly different among cropping patterns while potassium did not differ significantly. The soil organic content of the soil was highest in rice-tobacco cropping pattern as attributed to the biomass (broadleaves) of the crop. The rice-tobacco pattern demonstrated the potential to foster greater organic carbon accumulation in the soil.
5. The highest carbon stock was associated with the rice-tobacco pattern, while other patterns displayed varying levels. These findings highlight the potential for strategic cropping choices to enhance carbon sequestration, thus contributing to climate change mitigation efforts.
6. The model's high goodness of fit and significant predictors suggest that factors such as pH, soil texture, WS, P, K, Carbon, CP, and Clay can effectively predict carbon storage potential. This model can serve as a valuable tool for informed decision-making in land management.

Acknowledgement

This paper is supported by Mariano Marcos State University through its GAA-Funded Research Projects.

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Appendix 1

Questionnaire for Farmers

“ASSESSMENT OF SOIL CARBON SEQUESTRATION CAPACITY IN MAJOR CROPPING PATTERNS IN SELECTED BARANGAYSOF THE CITY OF BATAC, ILOCOS NORTE”

Name (Optional): ……………………………………………………Contact Number: ………………………..
Address: ……………………………………………………………………………………………………….

1. Crop Management Practices

1. Is the soil or land where you are planting rice-based? …………………………………………………….
2. Is there anything you add to the soil before you plant a certain crop? …………………………………….
   If there’s any, what is it or what are those?
   ……
3. What fertilizer are you adding and how many kilograms of fertilizer you are adding in every cropping?
   ……
4. Do you use pesticides in your crops?
   ……
   If yes, what kind of pesticides are you using?
   ……

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