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ORIGINAL ARTICLE

Soil and Crop Suitability Analysis for Sustainable Agricultural Practice in Sitio Pulot/Bae, Barangay San Antonio, Kalayaan, Laguna, Philippines

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***Abstract*:** Sitio Pulot/Bae is a part of Barangay San Antonio in the town of Kalayaan, province of Laguna in the Philippines. It is bounded by the Caliraya man-made lake and is reached by riding a boat from either Cavinti, Laguna or sitio Magalolon in Barangay San Antonio. It is isolated from the rest of the barangay without any source of electricity and safe drinking water for the households. Water used for drinking and other purposes is gathered from a small spring and the lake. Residents are financially poor and looking for sustainable sources of livelihood. Agriculture is one of the main sources of food and income in the sitio. Thus, the study aimed to identify crop suitability by analyzing the soil condition in the site. Soil samples were gathered from five sites in the sitio (residential, school garden, charcoal area, mangium plantation, and dried streambed). They were subjected for qualitative analysis of pH, nitrogen, phosphorus, and potassium. Results show that most of the sites contain medium amount of nitrogen except the charcoal area with low to medium nitrogen content. Most of the sites were found to be deficient in phosphorus, except for the streambed area with sufficient phosphorus content. All sites were found to contain low to medium potassium. Lastly, the five sites in the sitio all have average pH content of 6 which was within the normal requirement for the plants. Based on these results, it is recommended that fertilizers and nutrient fixing plants should be used to improve the soil quality in the area. Furthermore, crops such as rice, maize, potato, cassava, beans, cucumbers, onions, sugar cane, and banana were suitable given the soil condition of the site. Lastly, conservation agriculture was also recommended as a means to improve the agricultural as well as environmental conditions in the sitio.

Keywords: Soil Analysis, Soil Quality, Suitable Crops, Sustainable Agricultural Practice

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1. Introduction

1.1. Background of the study

Sitio Pulot/Bae is a part of Barangay San Antonio in the town of Kalayaan, province of Laguna in the Philippines (located approximately at 14º20’ to 14º22’ latitude and 121º28’ to 121º38’ longitude). It is bounded by the Caliraya man-made lake and is reached by riding a boat from either Cavinti, Laguna or sitio Magalolon in Barangay San Antonio. It is isolated from the rest of the barangay without any source of electricity and safe drinking water for the households. Water used for drinking and other purposes is gathered from a small spring and the lake. Residents are financially poor and looking for sustainable sources of livelihood. Agriculture is one of the main sources of food and income in the sitio.

1.2. Study Area

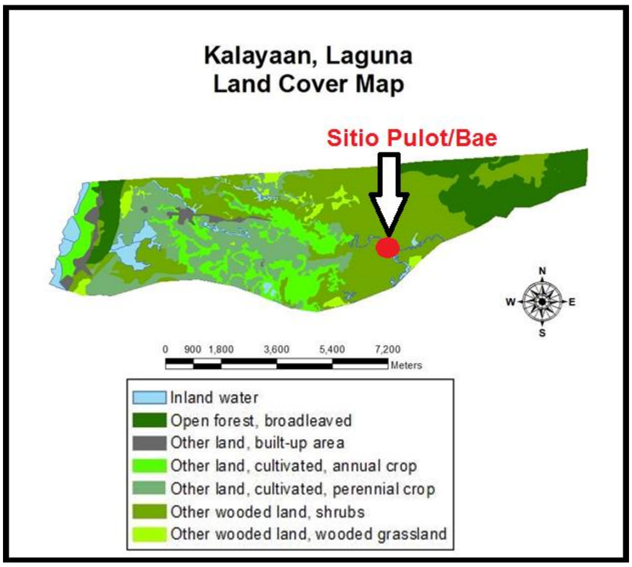

Figure 1. Municipality of Kalayaan, Laguna Land Cover Map

Sitio Pulot/Bae, though bounded by a man-made lake, is a mountainous area. It constitutes a relatively small portion of the entire municipality of Kalayaan Laguna. Generally, it has undifferentiated mountain soil and is a forested area. There are patches of land used as residential and agricultural areas. According to the Comprehensive Land Use Plan (CLUP) of Kalayaan municipality, its exact land area is currently undetermined but may range from 4,660 hectares to 5,545.8 hectares.

At the time that the authors visited the study area, it was estimated that there were about ninety (90) households in the sitio. These households are widely scattered in the entire study area. Most, if not all, of their houses are made mainly of wood and other light materials making them vulnerable to calamities such as typhoons.

The average monthly rainfall that the municipality experience from 1977 to 2013 ranges from approximately 1,800 mm/month up to about 11,500 mm/month. The lowest amount of rainfall can be experienced during months of January to April and peaks from June to October. During the initial interviews conducted in the sitio, the residents stated that they usually experience heavy rains but due to lack of news sources, they are unaware of when and how strong the rain is and whether a typhoon is coming.

There are two ways in which the sitio is accessed. The first is through boating which could be quite expensive for the poor residents of the sitio if they use this are a regular means in reaching the town proper. The second is through hours of traversing through the forested mountains. This difficulty of accessing the sitio can explain why electricity and the water utilities installment is met with much struggle. It also limits the access of the residents to other necessary utilities such as markets, hospitals, and secondary to tertiary education. The public school in the area is for grades 1 to 5 currently with about 4 teachers employed. The poverty incidence in sitio Pulot/Bae can be rooted in the problem of accessibility as both the residents and the local government as well as other agencies find it laborious to travel goods and services to and from the area, which is the main problem for other isolated communities in the highlands as well.

1.3. Research Problem

This study was conducted in response to the need for assessing the current soil condition of different areas in the sitio. Furthermore, it also used the acquired data to identify specific crops and agricultural practice that are suitable for the kind of soil in the area.

1.4. Objectives

The objectives of the study were:

1.4.1 To identify the soil conditions in different areas of sitio Pulot/Bae

1.4.2. To categorize crops that are suitable for the current soil condition of the area

1.4.3. To recommend agricultural practices that are easily adaptable for the residents in the sitio

1.5. Significance

Soil condition is an important factor in the identification of appropriate crops and practices for an agricultural area. By knowing the soil type of an agricultural land, experts and farmers can evaluate the current state of the agricultural practice in the site as well as derive ways on how to improve the yield of agricultural products. This can lead to efficient use of land and other agricultural resources and minimize losses in the side of the farmers. Also, the area of sitio Pulot/Bae is relying heavily on agriculture both for food source and for livelihood. Thus, this kind of study will be of significant benefit to the local community in terms of improving its current economic condition. Furthermore, this study can augment the aim of climate-proofing the community by improving its soil quality. In the study conducted by Barrett & Bevis (2015), they concluded that soils may also be essential for the community's reduction in vulnerability to climate-related calamities like drought. This can connect the importance of soil quality to climate adaptation measures for poor communities.

1.6. Scope and Limitations

In this study, the specific sites in the sitio Pulot/Bae which were subjected to soil analysis were the residential, school garden, charcoal area, Mangium plantation, and dried streambed areas. The recommended crops were based on the compatibility to the kind of soil that the site has. Other factors such as climate variability and the seasonality of the recommended crops were not emphasized in the study.

2. Review of Literature

Understanding the different components of a particular soil area is an important part of establishing a productive agricultural practice and efficiency of land use. Nutrients such as phosphorus, magnesium, and potassium should be in an optimum level for the soil to be able to support the growth of crops planted on it. In addition to this, efficiency of land cultivation is also crucial. Thus, maintaining the right level of nutrients using different farming methods should be both biologically and economically efficient. It can be done through analyzing the soil type and its current nutrient requirement and looking into land fertilizing methods that can lead to higher crop production and minimize capital costs (Johnston, J., & Fellow, L. T. S., 2005).

Soil analysis and other forms of research in soil is essential for the development of better agricultural practice especially in the Philippines. According to Navarrete, I. A., & Asio, V. B. (2014), an increasing trend in the field of soil science research has been observed from the 1970's up to year 2000 and is still continuing to increase up to the present. However, it was also found out that this increasing trend mostly comes from rice-related researches. It therefore gives rise to the call for soil science researches that are related to other crops as well as connecting it to environmental science researches. This will not only target sustainable agricultural practice that is helpful to the environment will also aid in proper allocation of funds for such researches and in its application and implementation especially to those areas which highly needs it.

Since poverty and food scarcity are the most pressing issues for developing countries, they also become the greatest hindrance for these countries to obtain continuous development that is sustainable. This is because of the overwhelming threat in the agricultural industry that is worsened by both biological and anthropogenic causes like climate change, soil degradation, and rapid population growth that leads to unmet needs of the people (El-Lakany, H., 2004).

The biological equilibrium theory is the basis for sustainable agriculture as it displays the general idea of ecological succession but is contained in a managed environment. This is a response to the threats of modern agricultural practices that utilizes large amount of inputs and poses long term ecological imbalance (Harmsen, R., 1990).

In pushing for a sustainable agricultural practice, it is important to look into the natural state of the environment and how it can be improved with minimal inputs. Climatic conditions, nutrient cycling, and soil quality are some of the important components that must be observed so as to analyze the proper inputs to be used for maximizing crop production. Sustainability is also a necessary factor in agriculture because some of the inputs that are currently used have long-run disadvantages such as permanent damage to soil quality when improper fertilizer application is used. Furthermore, sustainability is also of much importance when the people involved in the process come from a community that rely heavily in land cultivation for their basic needs. Equipping these people with the proper knowledge and skills for sustainable agricultural practices will help them to be more productive in both economic and social aspects. It will also help them in sustaining their basic needs without sacrificing the quality of their environment in the long run especially for the generations to come (Pretty, J. N., & Hine, R., 2001).

The benefits of sustainable agricultural practice also extends to the maintenance of the natural environment like trees which are both ecologically and historically important. These trees can be used for the prevention of soil erosion, maintaining ecological balance, and for the sentimental value that it has for the local people (Stoate C. & Jarju A.K., 2008).

Farming strategies like the application of agroforestry in a specific community is needed for the achievement of sustainability in the local agricultural practices. Applying this will not only increase food production but will also help in sustaining other needs for shelter and fuel. And the large scale applications of such practices will also have a positive impact in the reduction of damages due to climate change (Tiwari, P, et al., 2017).

Aside from agriculture, soil analysis can also function as a means to gather data on the soil quality relating to erosion, floods, compaction, endangerment of soil water recharge and quality (Beste, A., 1998).

3. Methodology

3.1. Site Identification

The sitio a described, is a type of an isolated community

Soil samples were gathered from five sites in the sitio:

Site 1 – Residential, where there are inhabitants of the sitio and their houses are clustered compared to other residential houses which were located far from the group of other houses.

Site 2 – School garden which was located behind the school in the sitio. During the time of sampling, crops such as eggplant and tomatoes were planted in the site.

Site 3 – Charcoal area which was located along the shore in the sitio. It was identified by the citizens as a charcoal-making area which was confirmed when the soil sampling was done. The soil was mostly black.

Site 4 – Mangium plantation which was reached through a 10 to 15 minute walk from the chapel in the sitio.

Site 5 – Dried streambed which was the farthest location for the soil sampling in the sitio. This site is also a charcoal-making area.

Table 1. Soil Sample Coordinates

Soil Sample	Coordinates	
	Longitude	**Latitude**
1A	121.57367	14.324
1B	121.57378	14.324
1C	121.5736	14.324
2A	121.56978	14.32635
2B	121.56968	14.32648
2C	121.56992	14.32635
3A	121.56993	14.32583
3B	121.57002	14.32578
3C	121.5701	14.32583
4A	121.57055	14.32808
4B	121.5706	14.32803
4C	121.57058	14.328
5A	121.57063	14.32898
5B	121.57093	14.32905
5C	121.57083	14.32887

Global positioning system (GPS) reading was used to identify the coordinates - longitude and latitude - of each sampling site.

3.2. Soil Sampling

Three soil samples were gathered in each identified site by digging down to 30 cm deep into the ground. The soil samples were then placed in plastic bags labeled according to their site and sample numbers: Soil samples 1A, 1B, 1C from the first site, 2A, 2B, 2C from the second site, 3A, 3B, 3C for the third, 4A, 4B, 4C for the fourth and lastly, 5A, 5B, and 5C for the fifth site. A total of fifteen (15) samples (5 soil sampling sites with 3 sampling replicates each) were then collected from the sitio and was subjected to a qualitative soil analysis (see Table 1).

3.3. Soil Analysis

The qualitative soil analysis which was conducted for this study was based on the Soil Test Kit of the Agricultural Systems Cluster. (n.d) University of the Philippines Los Baños, College of Agriculture, in Laguna, Philippines. The Soil Test Kit which was used in this study "uses simple colorimetric chemical analyses in which chemical reagents are made to react with soil sample in a test tube to give a characteristic color depending on the amount of available nutrients in the soil".

Figure 2. Soil Samples (in plastic bags) and Contents of the Soil Test Kit

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The kit specifically subjects soil samples to Nitrogen (N), Phosphorus (P), Potassium (K), and pH tests. The kit includes the usage manual, test tubes, and different solutions (see Figure 2).

Figure 3. Adding of Solution to Test Tubes with Soil Samples

This method was chosen for the conduct of this study due to its cost-effectivity and ease of use. In this method, test tubes are filled with soil samples up to the scratch mark. Different solutions with specified amounts are added to each soil sample (see Figure 3). The solution reacts with the type of soil in the test tube through the change in its color (see Figure 4).

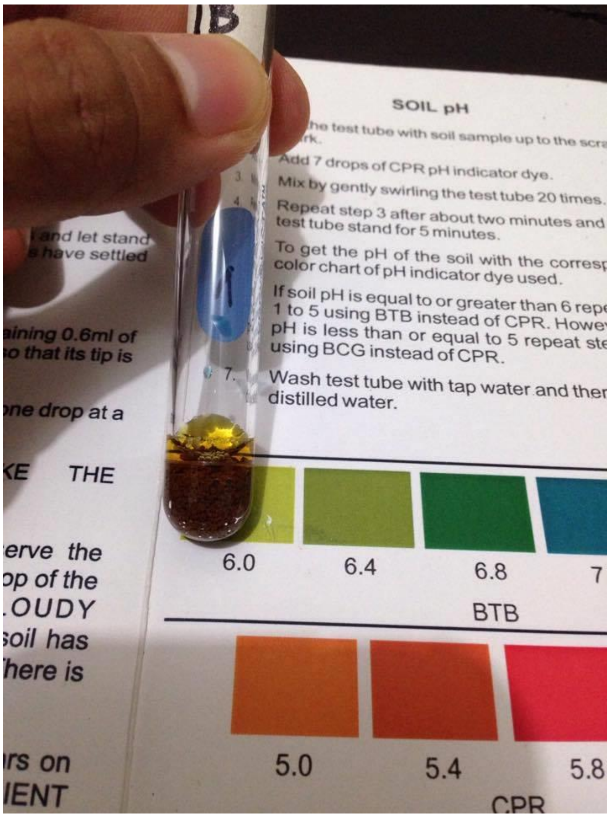

Figure 4. Comparing the Color Reaction of the Solution with its Equivalent Value

For the Nitrogen (N) test, the color of the solution may vary from orange (low N content), yellow green (medium N content), and green (high N content). Nitrogen is an essential nutrient for plants included among amino acids, vitamins, and other energy sources. It is a nutrient that is needed for plant photosynthesis, production of chlorophyll, and protein build up.

Phosphorus (P) content is based on the colors sky blue, lavender, and blue, showing low, medium, and high results respectively. P is an important part of the energy unit of plants which is the adenosine triphosphate (ATP) which is needed for plant growth from seedling stage up to its full maturity.

This includes factors such as growth in roots, stalk, stem, flowers, seeds production, and nitrogen fixation, as well as improvement in health and resistance against plant diseases.

The Potassium (K) content is classified as either sufficient when there is a distinct cloudy yellowish layer on top of the solution, or deficient when there is an absence of the cloudy yellowish layer. Like P, K is also needed in the regulation and sustenance of plant growth and development as well as reproduction and other plant processes (Detera, N. S, et al., 2014).

The soil pH is also identified using different solutions namely, CPR, BTB, and BCG, with the colors indicating the pH amount ranging from 4.0 (acidic) up to 7.6 (alkaline). The neutral pH level is between 6.0 and 7.0. The pH tests begin with the use of the CPR solution. If pH is equal or greater than 6.0, the BTB solution is used for the analysis, while BCG is used when pH is less than or equal to 5.0. Furthermore, fertilizer recommendations for different crops based on the nutrient content analysis are also included in the kit. Soil pH lower than 5.0 would entail nutritional disorders such as deficiencies in phosphorus, calcium, magnesium, potassium, and molybdenum. It may also indicate toxicities of aluminum, iron, and manganese. Higher than 7.5 pH levels would indicate deficiencies of phosphorus, potassium, iron, and zinc, and it may also include toxicity of boron.

A mapping software was used to plot the area that has the identified amount of nutrients in the entire study site.

3.4. Crop Suitability and Agricultural Practice Analysis

The results of the soil analysis became the basis for the recommendation of suitable crops and the amount of fertilizer needed in the area of sitio Pulot/Bae. Aside from the amount of fertilizer needed for the site as part of the recommended agricultural practice, other feasible agricultural practices were also identified by looking into similar sites which were developed for the purpose of sustainable agricultural production.

4. Results and Discussion

The result of the soil analysis show that the soil in all five (5) sites have medium Nitrogen (N) content except Site 3 or the charcoal area which has a low-medium N content (see table 2.a.).

In addition to this, sites 1 to 4 all have low Phosphorus (P) content except site 5 (Dried Streambed) which has medium P content.

Table 2.a. Soil Nutrient Content based on the qualitative analysis

Site	Nitrogen	Phosphorus
Site 1 (Residential)	Medium	Low
Site 2 (School Garden)	Medium	Low
Site 3 (Charcoal Area)	Low-Medium	Low
Site 4 (Mangium Plantation)	Medium	Low
Site 5 (Dried Streambed)	Medium	Medium

The result of the mapping analysis show the areas in the study site which probably has low, medium, and high N contents. Figure 5 shows that the greater area of the sitio has medium N content while small patches have either low or high N content. Nitrogen-fixing plants such as Mani-mani (*Arachis pintoi*), Mani (*Arachis hypogaea*), Ipil-ipil (*Leucaena leucophala*), and the Stylo grass (*Stylosanthes guinensis*) were recommended to be planted to improve the N content in the site.

As shown in Figure 6, majority of the sitio’s area have low P content. Only the fifth site, the dried streambed show medium and high P content. However, only one sampling point in Site 5 exhibited this high P content and the other two sampling points in the same site showing medium P content.

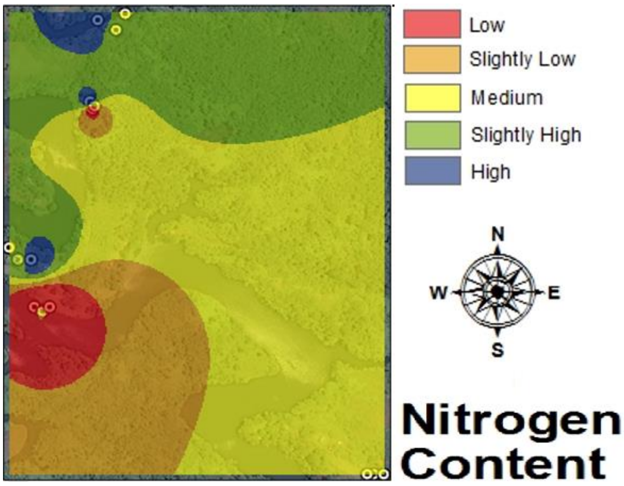

Figure 5. Nitrogen Content

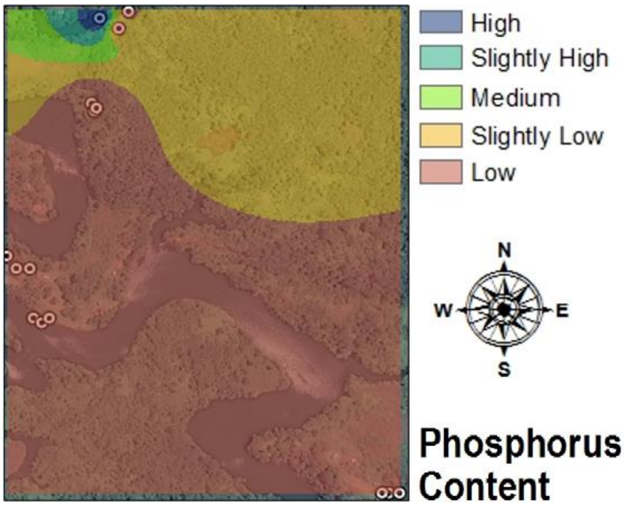

Figure 6. Phosphorus Content

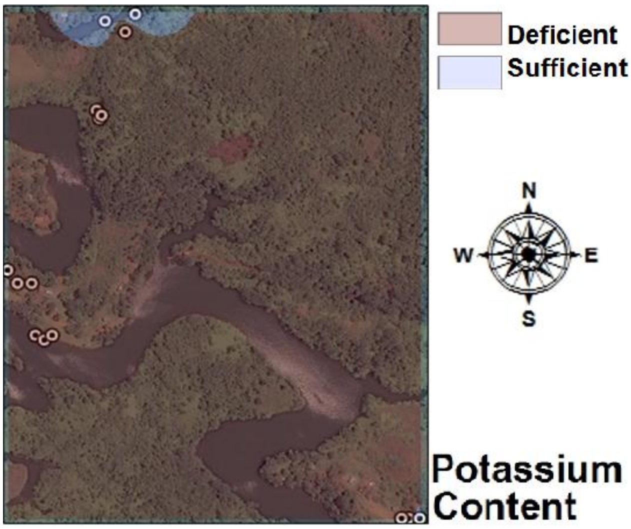

Figure 7. Potassium Content

Table 2.b. shows the Potassium (K) content and the pH levels in each sampling site. According to the soil analysis, Sites 1, 2, 3, and 4 all have deficient K content leaving only Site 5 with sufficient K content. The pH levels in each site range from 5.8 to 6.8 showing that each of the five sampling sites have slightly acidic to neutral soil types.

Table 2.b. Soil Nutrient Content based on the qualitative analysis

Site	Potassium	pH
Site 1 (Residential)	Deficient	6 – 6.8
Site 2 (School Garden)	Deficient	6 – 6.4
Site 3 (Charcoal Area)	Deficient	6.4 – 6.8
Site 4 (Mangium Plantation)	Deficient	6
Site 5 (Dried Streambed)	Sufficient	5.8 – 6

Using the results of the soil analysis and integrating it into a mapping analysis as shown in Figure 7, it can be observed that a large portion of the entire area of the sitio is deficient in K while only a very small part of the sitio, mostly in Site 5, are sufficient with K.

Figure 8 projects the probable areas with the same pH levels as with each of the five (5) sampling sites. However, their difference may be insignificant since the range of their levels are almost same.

With the soil sampling and analysis, and observing local crop species in the area, suitable crops were suggested (see Table 3). Rice (*Oryza sativa*), Maize (*Zea mays*), Potato (*Solanum tuberosum*), Cassava (*Manihot esculenta*), beans (*Fabaceae*), Cucumbers (*Cucumis sativus*), Onions (*Allium cepa*), Sugar Cane (*Saccharum officinarum*), and Banana (*Musa*) were top choices for the recommended crops to be planted in the area.

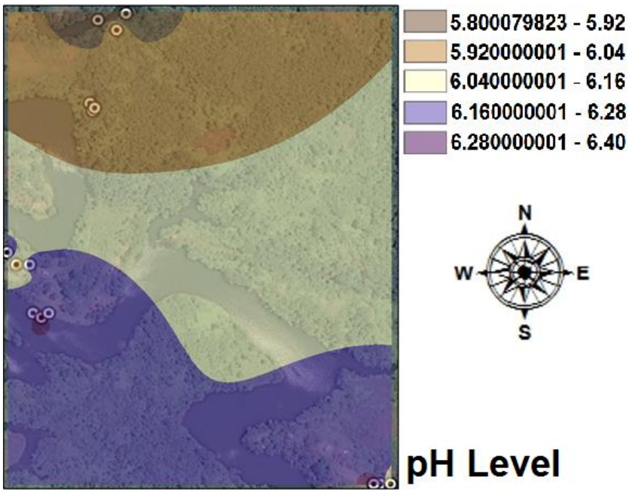

Figure 8. pH Level in the Soils of Sitio Pulot/Bae

Also, The required nutrients in each site for the specific crop species was also identified so as to come up with the recommended agricultural practice to be adapted, specifically the fertilizer usage to improve the quality of the land. Table 2 shows that among the chosen crop species, Cassava (*Manihot esculenta*), and beans (*Fabaceae*) are the top two (2) choices for crop production in the area since they are the crops that needed the least soil quality improvement implying to lower amounts of fertilizer usage leading to the least costs for the farmers. Furthermore, extensive use of fertilizers can also lead to soil degradation in the long run - a valid reason to choose crops that have minimal fertilizer use requirements.

In addition to this, Cassava and Beans also have a wider growing capacity in the sitio since it can grow in four (4) out of five (5) sites, suggesting that the residents can plant them almost anywhere within their sitio. However, this does not limit the residents to plant only those two identified top crop species. The other recommended crops can also be planted to diversify the products that they can harvest and utilize.

Crop rotation and backyard farming is also suggested for the locality since the households in the sitio have wide backyards.

Table 3. Recommended Crops, Site, and Nutrient Requirement

Crop	Nutrient Requirement (kg/ha)			Site
	N	P_2O_5	K_2O	
Rice	80 – 100	30 – 50	30	1,2,4,5
Maize	120 – 180	45 – 60	30 -60	1,2,4
Potato	85	175	40	1,2,4,5
*Cassava	90	25	95	1,2,4,5
*Beans	36	72	57	1,2,4,5
Cucumbers	130	90	200	1,2,4
Onions	75	70	180	1,2,4,5
Sugar Cane	100 – 250	60	80	1,2,3,4
Banana	300 - 500	30 -100	600 - 1200	1,2,4

*highly recommended

Furthermore, a type of practice called Conservation Agriculture can also be applied in the sitio since it is a practice which involves the planting of different crop species which are already being planted in the site. In the application of Conservation Agriculture, Nitrogen fixing plants such as *Arachis hypogaea* and the likes are planted along with other crops like Maize and Rice and it also requires minimal fertilizer use which is both economically and environmentally beneficial. It is also similar to Agro-forestry since it also incorporates the maintenance of trees. It is found suitable for the area since the practice was mostly applied in middle to high altitudes and uneven terrains.

5. Conclusion and Recommendation

The soils of sitio Pulot/Bae is most suitable for crops such as Cassava and Beans. With the improvement in the agricultural practice and application of strategies such as the Conservation Agriculture it is expected that there will be improvement in the overall condition of the economic, social, and environmental status of the isolated community of sitio Pulot/Bae. Other crops like Rice, Corn, and Sugarcane can also be cultivated in the area as long as the soil quality is improved through the use of fertilizers. However, this practice should be kept in moderation so as to avoid long term damages and soil degradation. Furthermore, the sampling sites chosen might not reflect the overall soil condition of the area. Thus, there is a need for further analysis in the actual soil condition of the other areas in the sitio. Increasing the number of sampling sites will improve the overall view of the actual state of the soil in the area. Also, looking into the current state of vegetation in the area might give further details on the suitability of the soil for the sitio.

Trainings on fertilizer use and sustainable agriculture practices can be of great help to the community since the residents will be the ones to manage the agricultural land in their own sitio. Coordination with the locality of Kalayaan, with public and government agencies should be established to create a detailed plan or policy for the land use in the sitio. These entails securing economic, social, and environmental benefits for all involved stakeholders especially the local community of the study site. Soil is an essential part of agriculture, and agriculture is an essential part in the sustenance of the people in sitio Pulot/Bae. Thus, any improvement in the soil quality can also lead to the improvement of the quality of life of the residents of sitio Pulo/Bae. By equipping them with proper knowledge and skills in managing their land, the people of the sitio can become more resilient and adaptable to whatever challenges their environment may bring especially those adverse effects of climate change and other climatic disasters. Lastly, continuous monitoring of the agricultural developments in the area will help both the local community and the local government in establishing projects and policies that can further improve the quality of living in the sitio. Thus, it is also encouraged to make similar researches such as this in other isolated communities for other them to adapt or improve the methods that may be applied in the analysis of soil and agricultural practices in areas of similar case.

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