Soil Fertility Evaluation For Rice Production In Catanduanes Province, Philippines

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Abstract: The study evaluates soil fertility status of rice fields in the eleven (11) municipalities of Catanduanes, Philippines. A stratified random sampling was used to cluster sampling sites into strata and come up a random proportional population size. Soil samples from each sampling site were gathered and analyzed for organic matter (OM) content, soil pH, available phosphorus and potassium following the BSWM (Bureau of Soils and Water Management) procedures with the aid of Soil Spectrophotometer and Flamephotometer (SPF-3).Soil texture and soil color of the samples were also determined using feel method and visual comparison, respectively. Results were implicated into individual fertilizer recommendation peculiar to sampling site within respective municipality. Moreover, a soil fertility map was delineated thru DIVA-GIS software by plotting local coordinates in Google Map. With reference to ideal pH for rice, six (6) towns exhibited favorable pH (5.5-7.0) range while five (5) towns were observed with strongly acidic (pH<5.0) condition. Suggested pH amendments include calcium carbonate (CaCO3) applications and or field submergence of rice fields having pH below 5.5. For Organic Matter (OM), (following the soil fertility rating of >3% - favorable; <3% - unfavorable to plant rice) six (6) towns showed favorable results for planting rice while five (5) towns registered low OM content. Ten (10) municipalities exhibited high available phosphorus>10ppm (Olsen P method) while six (6) municipalities categorically indicate high K content equivalent to≥82ppm. The overall mean results for soil pH level, OM, P and K content of majority of the rice fields in Catanduanes, Philippines werefavorable for lowland rice production, however, the ideal pH and NPK levels may be constantly checked following the recommendations given to maintain optimum possible harvests of rice.

Index Terms: Soil fertility, stratified random sampling,soil pH, spectrophotometer, flamephotometer.

1 INTRODUCTION

Rice (*Oryza sativa*) is the staple food and the most important crop in the Philippines [1]. Philippines contributed 2.8% of the global rice production and ranked 8th among the largest rice producers in the world [2]. About 15.7 million MT of palay was produced in 2010:accounting to 21.86% and 2.37% of the GVA in agriculture and GNP respectively [3, 4]. InCatanduanes, rice is grown in about 12,993 hectares out of 53,709 hectares agricultural lands of the province [5]. Although the average production of rice per hectare in Catanduanes increased by 5% in year 2010, the total production declined by 474 MT [6]. Soil fertility assessment thru soil testing is effective in increasing productivity [7] hence considered as the first step to managing soil fertility [8]. It is a process by which elements present in soil are measured for their "plant available" content within the sample. The quantity of available nutrients in the sample determines recommended fertilizer application for the optimum crop growth and production [9]. Soil testing is essential in order to determine the soil's nutrient content and determine deficiencies that need to be remedied, so that growth and yield may be maximized [9]. Applying fertilizer without fertilizer recommendation may give harmful effects as the nutrients present in the soil may exceed than the nutrients required. This will actually lead to depletion of soil fertility that is one of the major problems in less-favored areas [10], alongside with high plausibility of nutrient leaching. To attain passable crop growth and sufficient crop yield, ensuring crops a proper nutrition is necessary. In Pakistan, farmers tend to apply heavy doses of fertilizers without soil testing [11] while Filipino farmers N-application usually exceed the recommended amounts [12]. Majority of the rice farmers in Catanduanes applied complete fertilizer or urea to restore nutrients to their soil. Farmers need to conduct soil test prior to fertilizer application to ensure the kind and adequate amount of fertilizer to be applied for a profitable yield [9,11]. Since there was no comprehensive information on the soil fertility status of rice fields in the province, the current study sought to determine fertility status of lowland rice fields in Catanduanes province. Specifically, the objectives of the study include: 1) assessment of soil organic matter (OM) content, pH, available phosphorus and potassium. Conversely, soil color and texture were also determined; 2) delineate a fertility map for rice fields in Catanduanes; and 3) provision of a locality-specific fertilizer recommendation based on soil fertility aspects and rice nutrient-need requirements.

2. MATERIALS AND METHODS

2.1 Soil sampling

Soil samples were gathered in all the municipalities of Catanduanes using Stratified Random Soil Sampling by proportionate allocation. This uses a fraction in each of the strata that is proportional to that of the total population[32]. This involves taking soil samples in a random pattern across a field, generally avoiding unusual or problem soil areas within a field. It is the traditional approach that works for uniform fields with little variation.

2.2 Soil fertility, pH, color and textural Assessment

Soil testing has followed BSWM procedure and used Soil Spectrophotometer and Flamephotometer (SFP-3) acquired thru the Japan International Cooperation Agency (JICA). Soil pH was measured using Oakton pH meter. CSU soil testing laboratory uses a 1:1 soil:water ratio. Feel method was used for estimating the Soil Texture. A bit of soil sample was moistened and rubbed between thumb and forefinger. Sandy soil feels gritty and rough, Silt soils feel smooth and particles slide easily between the fingers, while Clay soil particles tend to stick together when wet and feel sticky. To further test the soil, a ball of moist soil was squeezed in the palm of the hands. Sandy soils break easily, whereas clay soils did not. Loam soils stick hold together but were also malleable.Visual color comparison of the dried soil was used to determine soil color. The general guideline for soil fertility rating of rice from BSWM Manual with categorical rating of low, medium or high for NPK level was also used. Likewise, Nutrient requirement also from BSWM manual served as the basis for fertilizer recommendation plotted in Microsoft Excel.

2.3 GIS mapping

DIVA-GIS was used for mapping by finding the coordinates of localities using Google map, and by checking existing

coordinates using overlays of the collection sites and administrative boundary databases.

3. Results and discussion

3.1 pH and NPK soil test results for rice lands

3.1a) pH 1:1H_20

Based on the ideal pH for rice which is 5.5 to 7.0 [23], the following six (6) municipalities have favorable pH: Bagamanoc, Bato, Gigmoto, Pandan, San Andres, and Virac. Other municipalities obtained values lower than 5.5, although exhibited moderately acidic soil reaction, include Caramoran and San Miguel. Municipalities of Baras, Panganiban and Viga were strongly acidic. Acidic rice fields observed in these areas may need no liming in correcting soil acidity hence simple flooding or field submergence may be employed [13].

3.1b) %Organic Matter (OM) Colorimetric Method

From the general guidelines for soil fertility ratings for rice, the adequate Organic Matter (OM) percentage for lowland rice (irrigated) is greater than 3 [24]. Results less than 3% are deficient or unfavorable. Table 1 shows that the following towns have obtained favorable amount of OM: Pandan, Caramoran, Baras, Bato, Viga, and Virac. Deficient towns includes: Bagamanoc, Gigmoto, Panganiban, San Andres and San Miguel. In reference to the BSWM Manual, the following towns were low in OM: Bagamanoc, Gigmoto, Panganiban, San Andres and San Miguel. Baras, Bato, Viga and Virac are medium while Caramoran and Pandan are high. Organic Matter is essential part of a productive soil especially as chief source for Nitrogen [25] which is primarily essential for rice growth and grain production [14, 15, 16].

3.1c) Available Phosphorus (ppm) Olsen P

Categorical level of available P (Olsen P method) for rice ranges with values <5ppm, 5-10ppm, and >10ppm inclusive for low, medium and high available phosphorus, respectively. The recommended P application with such categorical values was inversely proportional with the amount of P-containing fertilizer [30]. Soil phosphorus level increases under flooded condition and decreases when the soil is drained and aerated [17]. Ten Municipalities (i.e. Bagamanoc, Baras, Caramoran, Gigmoto, Pandan, Panganiban, San Andres, San Miguel, Viga and Virac) has high available phosphorus which is greater than 10 ppm. The Municipality of Bato fall within the range of 5-10ppm this indicates medium level of available phosphorus. Phosphorous is essential for energy transfer system. It is a component of RNA and DNA [26], regulating genetic information. It is also essential for phytin, an important component of seeds [27].

3.1d) Exchangeable Potassium K (ppm) Cold H_2SO_4 Method

Optimum Potassium requirement of rice were 1.8-2.6%, 1.4-2.0% and 1.5-2.0% in the tillering to panicle initiation stage, flowering stage and maturity stage respectively [29]. Available K (ppm) for rice ranges with values 20-80ppm and 82-246ppm representing low and high available potassium, respectively [31]. The Municipality of Bagamanoc, Caramoran, Pandan, Panganiban, San Andres and Viga fall within the range of 82-246ppm and possess a high level of available potassium while the rest of the municipalities have low level of available potassium. Potassium is essential for carbohydrate synthesis and transfer of sugars [28]. It helps maintain proper balance of other ions, regulates water status, disease resistance and overall rice plant nutrition throughout the growth cycle [17]. Table 1 shows the summary of the result (in median) for soil testing in all the municipalities of Catanduanes*(Complete data is available at the Soil Testing Laboratory of Catanduanes State University, Virac, Catanduanes Philippines).*

Table 1. Summary of pH and NPK soil test results for rice fields in the province of Catanduanes, Philippines.

Municipality	No. of soil samples	pH	% OM	Ave P (ppm)	Ave K (ppm)
Bagamanoc	14	5.60	2.66	10.18	104.72
Baras	10	4.96	4.20	23.83	67.41
Bato	3	5.63	3.18	8.53	68.20
Caramoran	12	5.38	4.61	31.37	88.10
Gigmoto	4	5.80	2.76	19.56	67.10
Pandan	9	6.28	5.42	26.43	110.18
Panganiban	8	4.78	2.66	16.96	85.26
San Andres	5	6.06	2.80	14.40	162.30
San Miguel	6	5.03	2.48	11.10	79.66
Viga	16	4.98	3.29	10.65	129.76
Virac	11	6.99	4.42	29.87	50.85
TOTAL	125	5.59	3.49	18.44	92.14
MEAN					

3.2 Soil Color and Texture

Soil texture relates most specifically to the overall porosity of the soil including its macro and micropores, long term drain ability and compressibility [18]. Although, superiority of clay textured soil in rice paddies were observed, there were no mutual findings on the ideal soil composition for rice growing soils [19, 20, 21]. It shows that the dominant soil texture of the province planted with rice is loam with 30 soil samples out of 98 soil samples. Silty clay and clay loam with twelve (12) soil samples, sandy loam and sandy clay loam of both 10 soil samples, light clay is 9, loamy sand is 5, clay is 4, silt and sandy clay are both 2 and silty clay loam and sand is one. Soil color reflects on the transformation and translocation occurred in the soil due to chemical, biological and physical attributes [18]. The dominant soil color, for the province is light brown and yellow brown with 16 soil samples each followed by red yellow brown – 15, light yellow brown is 14 and light gray brown is 11. A Bright-light color of soil is related to elluvial (E) horizon which is classified as the zone of leaching of clay, carbonates and sesquioxides [18]. Yellow/ Red colored soils indicates the presence of iron in an aerated soil condition while gray and bluish colored soils indicate reduction of iron in anaerobic soil condition [18]. *(Complete data is available at the Soil Testing Laboratory of Catanduanes State University, Virac, Catanduanes Philippines).*

Table 2. Summary of soil color and texture

Soil color	No. of soil samples	Soil texture	No. of soil samples
Light brown	16	Loam	30
Yellow brown	16	Silty clay	12
Red yellow brown	15	Clay loam	12
Light yellow brown	14	Sandy loam	10
Brown	11	Sandy clay loam	10
Brown yellow	5	Light clay	9
Dark brown	5	Loamy sand	5
Gray brown	4	Clay	4
Light yellow gray	3	Silt	2
Red brown	2	Sandy clay	2
Dark brown gray	2	Silty clay loam	1
Light black	1	Sand	1
Light gray	1	Total	98
Yellow gray	1		
Yellow gray brown	1		
Total	98		

3.3 Fertilizer Recommendation for rice

The amount of fertilizers needed by the plant depends on the inherent fertility of the soil. Table 3 shows the fertilizer recommendation for rice following the reference from BSWM [22]. The table gives the user the idea on the amount of fertilizer to apply. The left portion of the table shows the amount of inorganic fertilizer and on the right side is the amount of mixture of organic and inorganic. The lower the nutrient content, the higher the amount of the needed fertilizer. Parts of the table without numerical value indicate no fertilizer is required. *(Note: Complete data is available at the Soil Testing Laboratory of the Catanduanes State University)*

Table 3. Fertilizer recommendation for rice

No.	Barangay	Fertilizer recommendation using inorganic fertilizer (bags/ha)					Fertilizer recommendation using inorganic and organic fertilizer (bags/ha)				
		14-14-14	18-46-0	46-0-0	21-0-0	0-0-60	14-14-14	manure	46-0-0	21-0-0	0-0-60
	Bagamanoc										
48	Bacak	1	2.6	1.3			1.0	24	1.6		
49	San Rafael	1	1.7	2.1			1.0	16	2.3		
106	San Vicente	1	2.6	2.2			1.0	24	2.4		
107	Bagatabao		2.2	2.6		2.0	1.0	20	2.6		1.7
108	Bagatabao		2.6	2.5		0.7	1.0	24	2.4		0.3
109	Bagatabao	1	2.6	2.2			1.0	24	2.4		
110	Sta Teresa		2.6	2.5		1.0	1.0	24	2.4		0.6
111	Bugao	1	2.2		2.2		1.0	20		2.9	
112	Magsaysay	1	2.2	1.5			1.0	20	1.7		
113	San Rafael	1	2.6	2.2			1.0	24	2.4		
136	San Rafael	1	2.6		1.9		1.0	24		2.5	
137	San Rafael	1	1.7	1.2			1.0	16	1.5		
138	San Rafael	1	2.2	1.0			1.0	20	1.3		
139	San Rafael	1	2.2	1.0			1.0	20	1.3		
	Baras										
8	Puraran		1.3	2.1		2.0	1.0	12	2.1		1.8
13	Paniguihan	1	2.6		2.8		1.0	24		3.4	
31	BagongSirang	1	2.2	1.5			1.0	20	1.7		
57	Agban west		2.2	1.8		2.0	1.0	20	1.7		1.7
58	MoningTilod	1	0.9	2.0			1.0	8	2.3		
59	Moning	1	1.3	2.2			1.0	12	2.5		
278	Moning		1.3	1.7		0.7	1.0	12	1.7		0.5
279	Moning	1	2.2	1.0			1.0	20	1.3		
280	Moning		2.6	1.2		1.0	1.0	24	1.1		0.6
284	Moning		1.3	1.0		3.3	1.0	12	1.7		3.1
	Bato										
14	Sibacungan		2.6	2.5		1.0	1.0	24	2.4		0.6
25	Tamburan	1	2.6	1.3			1.0	24	1.6		
36	LibodPoblacion		0.0	2.6		2.0	1.0	0	2.6		2.0
	Caramoran										
26	Toytoy		2.6	2.0		0.7	1.0	24	2.		0.3
27	Datag East	1	0.9	2.8			1.0	8	3.1		
61	Hitoma	1	1.3	2.2			1.0	12	2.5		
62	Salvacion	1	1.3	2.7			1.0	12	3.0		

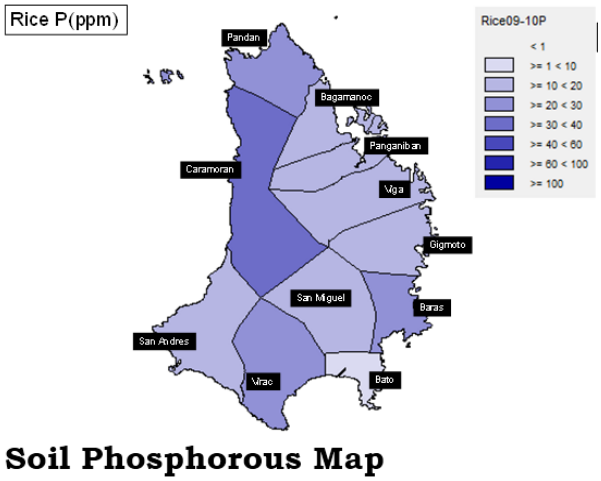
64	Datag East	1	0.4	1.7			1.0	4	2.0		
65	Datag West	1	1.7	1.6			1.0	16	1.9		
223	Camburo	1	0.9	1.5			1.0	8	1.8		
266	Paniqui	1	1.7	1.2			1.0	16	1.5		
267	Paniqui	1	1.3	1.4			1.0	12	1.7		
268	Paniqui		2.2	1.3		0.7	1.0	20	1.3		0.3
269	Paniqui	1	1.7	1.2			1.0	16	1.5		
270	Paniqui		1.7	1.5		3.3	1.0	16	1.5		3.1
	Gigmoto										
22	Dororian	1	0.4	2.1			1.0	4	2.4		
55	San Pedro	1	1.7	2.1			1.0	16	2.3		
56	Biong		2.2	1.8		1.0	1.0	20	1.7		0.7
60	Poblacion District II		2.6	2.5		1.0	1.0	24	2.4		0.6
	Pandan										
66	Cobo	1	0.0	2.3		2.0	1.0	0	2.6		1.7
67	San Rafael (Bogtong)	1	1.7	2.5			1.0	16	2.8		
222	Cobo		2.2	1.3			1.0	20	1.3		
224	Cobo	1	0.4	1.7			1.0	4	2.0		
225	Cobo	1	0.9	1.5			1.0	8	1.8		
226	Cobo	1	1.7	1.2			1.0	16	1.5		
227	Cobo	1	2.2	1.0			1.0	20	1.3		
228	Cobo	1	2.2	1.0			1.0	20	1.3		
229	Cobo	1	0.9	1.5			1.0	8	1.8		
	Panganiban										
51	Santa Ana	1	1.7	2.1			1.0	16	2.3		
52	Santa Ana	1	2.2	1.5			1.0	20	1.7		
53	Santa Ana	1	0.4	2.6			1.0	4	2.9		
54	Santa Ana		2.2	1.8		1.0	1.0	20	1.7		0.7
114	Santa Ana		2.2	1.8		1.0	1.0	20	1.7		0.7
115	Santa Ana		2.6	2.0		1.0	1.0	24	2.0		0.6
116	Santa Ana	1	0.9	2.8			1.0	8	3.1		
117	Santa Ana	1	2.2	2.3			1.0	20	2.6		
	San Andres										
12	Putting Baybay	1	2.2	1.9			1.0	20	2.2		
15	Yocti	1	2.2	1.5			1.0	20	1.7		
18	BatongPalowa y	1	2.2	1.9			1.0	20	2.2		
45	Bislig		2.6	2.5		2.0	1.0	24	2.4		1.6
47	Codon		1.7		4.2	2.0	1.0	16		4.2	1.7
	San Miguel										
11	Paraiso		2.6	2.0		2.0	1.0	24	2.0		1.6
28	Progreso	1	2.2		5.1		1.0	20		5.7	
34	Buhi	1	2.6	1.7			1.0	24	2.0		
73	J.M. Alberto		2.6	1.6		0.7	1.0	24	1.6		0.3
74	Kilikilihan		2.2	1.8		2.0	1.0	20	1.7		1.7
75	Mabato	1	2.2	2.3			1.0	20	2.6		
	Viga										
10	San Jose Oco	1	2.2	2.3			1.0	20	2.6		
70	Del Pilar	1	2.6	1.7			1.0	24	2.0		
71	Penafrancia	1	2.6	1.7			1.0	24	2.0		
72	Rizal	1	2.2	1.0			1.0	20	1.3		
103	Penafrancia	1	2.6	2.2			1.0	24	2.4		
104	Penafrancia		2.6	2.0		1.0	1.0	24	2.0		0.6
105	Penafrancia	1	2.2	2.3			1.0	20	2.6		
118	Penafrancia	1	2.6	1.3			1.0	24	1.6		
119	Penafrancia	1	1.7	1.6			1.0	16	1.9		
120	Penafrancia	1	2.2	1.5			1.0	20	1.7		
121	Penafrancia	1	2.6	1.3			1.0	24	1.6		

122	Penafrancia	1	2.2	1.5			1.0	20	1.7		
123	Penafrancia	1	2.6	0.8			1.0	24	1.1		
124	Penafrancia	1	2.2	1.0			1.0	20	1.3		
126	Sagrada	1	2.6	0.8			1.0	24	1.1		
128	Sagrada		2.6	1.2			1.0	24	1.1		
	Virac										
2	Calatagan		2.2	1.8			1.0	20	1.7		0.7
35	Magnesia Del Sur		2.6	1.6			1.0	24	1.6		2.9
46	Simamla	1	2.6	2.2			1.0	24	2.4		
68	Pajo San Isidro		2.2	2.6		0.7	1.0	20	2.6		0.3
76	Calatagan		0.9	2.3		2.0	1.0	8	2.3		1.9
89	Calatagan		0.9	1.8		1.0	1.0	8	1.8		0.9
90	Calatagan		0.9		4.0	2.0	1.0	8		4.0	1.9
91	Calatagan		1.3		3.6	3.3	1.0	12		3.6	3.1
92	Calatagan		1.3		4.6	2.0	1.0	12		4.6	1.8
93	Calatagan		1.7		3.3	3.3	1.0	16		3.2	3.1
94	Calatagan		2.2		2.9	3.0	1.0	20		2.9	2.7

3.4 Soil Fertility Map of the Province

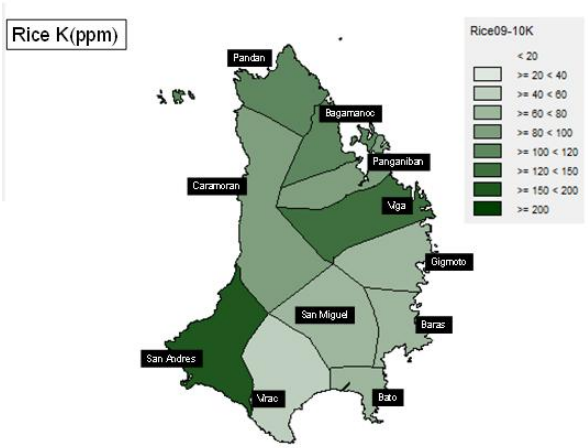
Based on the ideal pH for Rice (5.5 to 7.0), results showed that Baras, Panganiban and Viga towns were moderately acidic characterized by a red color in the map (Figure 1). The rest of the towns are favorable for rice. The townsof Baras, Bato, Pandan, Caramoran, Viga and Virachave high Organic Matter content. As shown in the map, (Figure 1) with brown chromacolor. The highest soil test result for Phosphorous is the municipality of Caramoran which has the darkest blue color followed by Virac, Pandan, Baras, Gigmoto, Panganiban, San Andres, San Miguel, Viga and Bagamanoc.

Figure 1: Soil Map of the Province (pH, %OM, P, K levels)

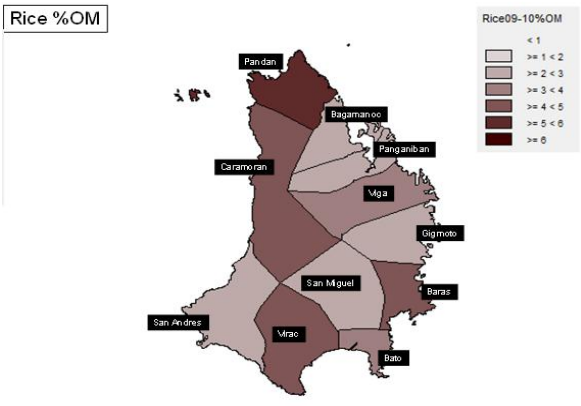


Soil Phosphorous Map

Only the Municipality of Bato has a medium available P content. It also showed that the province is rich in potassium except Baras, bato, Gigmoto, San Miguel and Virac. The rest has low results in available potassium. Lastly, predominant soil textural category of rice fields in Catanduanes ranges from loam to clay loam while the indicative color is light brown and yellow brown (Figure 2).

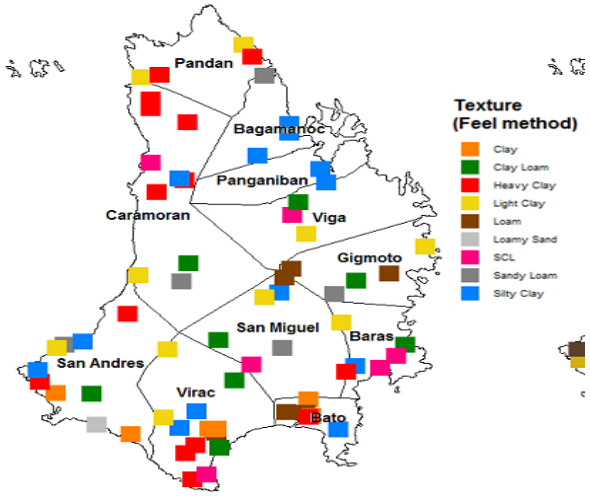


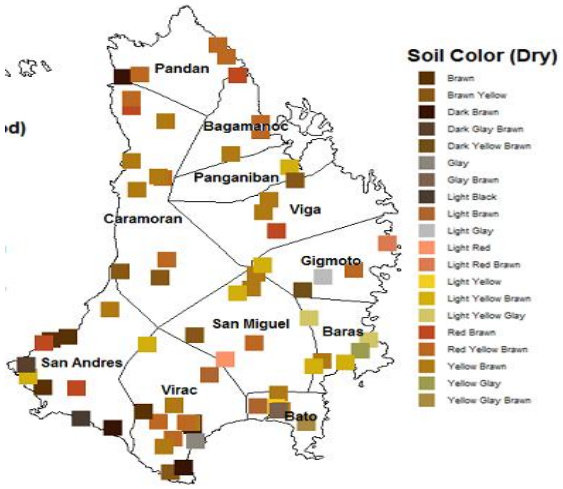
Soil Potassium Map



Soil Organic Matter (OM) Map

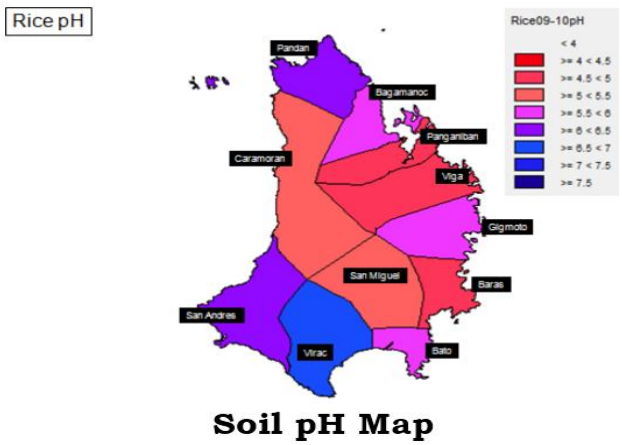
***Figure 2**: Rice Soil Color and Texture Map of the Province*





4. Conclusion

The overall mean results conformed to the optimum requirement of lowland rice on soil pH level (i.e. 5.5-7.0) [23], Organic Matter percentage (i.e. >3) [24], the Available Phosphorus (ppm) in Olsen P (i.e. >10) [30], and the Available Potassium (ppm) [31]. Municipality of Bagamancoc, Bato, Gigmoto, Pandan, San Andres and Virac have favorable soil pH level, another six municipalities (i.e. Baras, bato, Caramoran, Pandan, Viga, Virac) contain adequate organic matter percentage for lowland rice. Phosphorus rich soils recorded were Bagamanoc, Baras, Caramoran, Gigmoto, Pandan, Panganiban, San Andres, San Miguel, Viga and Virac. Potassium Rich rice fields dominated the Municipalities of Bagamanoc, Caramoran, pandan, San Andres and Viga.The dominant soil texture is loam while majority of the rice fields has light brown and yellow brown soil color which is related to elluvial horizon or zone of leaching.Since majority of rice fields in the province projected adequate content of OM, available phosphorus, available potassium and has an optimum soil pH level, fertilizer recommendation of NPK is in minimum amount however, relatively higher rates of organic and inorganic fertilizers are recommended for the municipalities recorded with low Organic Matter and NPK content.



5. Recommendations

Based from the findings and conclusions of this study the following recommendations are given:applications of Calcium carbonate, $CaCO_3$ (agricultural lime) for soils with pH below 5.5. Also, flooding for 3-4 weeks to soak the field may be done by farmers as a simple and relatively economical way to amend soil pH. Regular soil testing should be conducted to monitor the soil fertility level of rice plantation primarily for nitrogen, phosphorus and potassium levels. Fertilizer should be applied following the locality-specific recommendations specific for rice for optimum yield.

Acknowledgement

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