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Fertility status of soils derived from mudstones in Samar, Philippines

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Abstract

Soils derived from sedimentary rocks such as mudstone, in particular, have low nutrient status. Samar is considered as a sedimentary island and there is very little information about the fertility and nutrient status of these soils. This study was conducted to evaluate the fertility status of soils derived from mudstones in Samar. Results reveal that the examined soils have low nutrient status which is inherited from the mudstone parent material. Moreover, all soils possess major fertility constraints for crop production. In order to provide efficient and effective measures that would be useful for sustainable crop production and environmental conservation of the study sites, a more comprehensive study is needed in assessing and monitoring of sedimentary soils in Samar. For the meantime, farmers are encourage to plant acid-tolerant crops and native tree species to alleviate soil structure, as well as to employ intercropping management system, application of P fertilization through organic fertilization.

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Introduction

Soil Fertility is the capacity of a soil to provide nutrients required by plants for growth. It is also the amount of organic matter or humus present in the soil. Soil fertility is always equated to organic matter. Since even before in the ancient time the use of applying organic matter in the soil such as manure is widely done to increase soil fertility for a good crop production. Most characteristics that contribute to the fertility of soil, such as soil pH and the susceptibility of the soil to compaction are dependent on the composition or constituents of the parent rock. But with the growth of plants and addition of fertilizer soil characteristics are being modify and alter its fertility. Desirable soil physical properties and the capacity of the soil to provide nutrients for growing crops are both soil quality indicators.

Parent rocks that contain high amounts of nutrient elements generally produce soils that are fertile during the early stage of soil development. On the other hand, rocks dominated by quartz and calcium carbonate produce soils that are low in nutrient content. Schachtschabel *et al.* (1992) reported that porous sedimentary rock enhances percolation and vertical water movement in the soil profile resulting in more horizon differentiation as well as the dissolution and movement of Fe and MnO_2. On the other hand, Asio, *et al.* (2006) observed that the soils in Punta, Baybay, Leyte that formed from limestone and marl had high $CaCO_3$ content, high pH, low nutrient status, and very variable soil development. In addition, they observed that the soils were poorly developed. Furthermore, Ohta, *et al.* (1992) reported that the characteristics of the highly weathered soils from sedimentary rocks under lowland dipterocarp forest in East Kalimantan Indonesia varied in characteristics depending on their location in the landscape. The authors found good correlation of several soil properties like clay content and Fe extracted by dithionite, clay content and exchangeable Al, clay content and effective CEC, clay content and P availability, total N and available N, and N and P contents. Asio (1991) found very low nutrient status of soils developed from conglomerate, limestone, shale and siltstone in Manjuyod, Negros Oriental. The soils also showed poor rootability, very low water availability but moderate to high erodibility. In another study, Asio, *et al.* (2006) found that the soils from limestone and marl in Punta, Baybay, Leyte were deficient in P, K, Fe, Mn, Zn and B. This was largely due to the high $CaCO_3$ content of the soils which was inherited from the parent material. They also noted that the fertility status of the soils was influenced by the variations in the parent material, slope position and anthropogenic influence in the landscape. Lastly, Asio *et al.*, (2015) reported that the nutrient status of the degraded land in Sta. Rita, Samar which is derived from a shale parent material is low. The soil has strongly acidic conditions, which are low in OM, total N, available P, and exchangeable bases contents. The low nutrient status of the soil is reflected by the low leaf concentration of the nutrients (N, P, K, Ca).

Very little information is available about the fertility and nutrient status of sedimentary soils in Samar. Thus, there is an urgent need for characterization studies to serve as basis for development of soil management strategies for sustainable crop production. Furthermore, the present study was conducted based on the hypothesis that the nutrient status of the soils from sedimentary rocks in Samar is primarily influenced by the parent material on the stage of development of soils.

Materials and methods

Selection of Study Area

The basic criteria in the selection of sampling sites were the presence of sedimentary rocks as parent material of the soil. The sites were selected through a preliminary survey around Samar Island (Fig. 1A). The study was conducted in five (5) municipalities of Samar Island, stretching from Eastern to Western Samar.

Soil Profile Characterization, Sampling and Preparation

A pit measuring approximately 1 m x 1 m with a depth of at least 1 m was excavated manually in each site to examine and sample the soil profile.

Alternatively, road cuts were cleared by removing about 20 to 30 cm thickness of surface soil to expose the fresh soil. Site and soil profile descriptions were done following the standard procedure of FAO (2006). Soil samples were collected from horizon of every soil profile following the quantitative procedure of Schlichting *et al.* (1995).

Samples were immediately brought to the screen house of the Department of Soil Science, VSU, Baybay City, Leyte for processing. Except those for bulk density determination, all soil samples were air-dried, pulverized using a wooden hammer and sieved in a 2-mm wire mesh to get the fine earth for the determination of most soil physical and chemical properties.

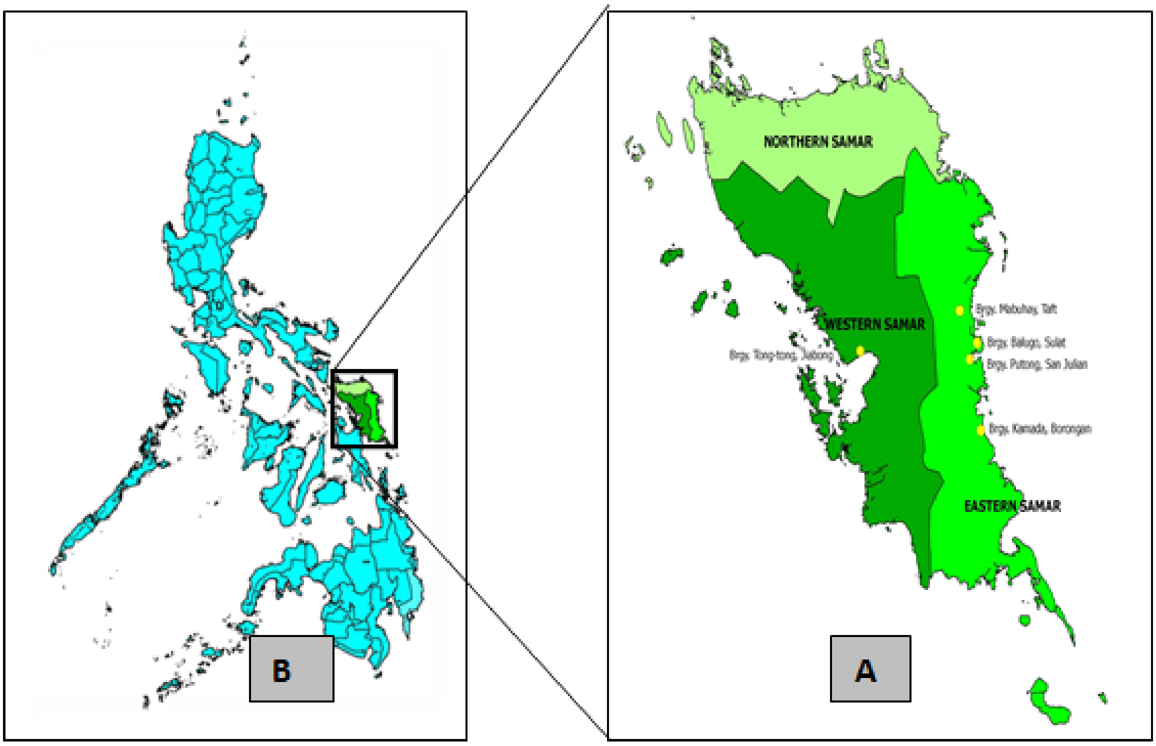

Fig. 1. The location of the study sites in Samar (A), Philippines (B).

Soil Physical and Chemical Analysis

The collected undisturbed bulk samples were analyzed for bulk density by the paraffin clod method (Blake and Hartge, 1986). Porosity was calculated from the determined bulk density value and a constant particle density of 2.65 g/cm^3. Particle size distribution was determined by the pipette method (ISRIC, 1995). An ultrasonic disintegrator (Hielscher UP100H) was used to completely disperse the soil separates after addition of sodium hexametaphosphate as dispersing agent.

The soil samples were also analyzed for pH_{H2O} and pH_{Cacl2} potentiometrically using a soil-soil solution ratio of 1:2.5 (ISRIC, 1995). Soil Organic Matter was analyzed following the Loss of Weight on Ignition method of Olsen and Sommers (1982). Extraction of available P was done according to the Olsen method (Olsen and Sommers, 1982) and absorbance was read using UV-vis (Cary 60) at 880 nm. Analysis of total N was done according to the micro-Kjeldahl method (ISRIC, 1995). Exchangeable bases were extracted by 1N NH_4OAc (pH 7.0) method according to ISRIC (1995). The quantification of exchangeable bases (K, Ca, Mg, Na) was achieved with the use of atomic absorption spectrophotometer (Varian Spectra 220 FS). Exchangeable acidity (Al^{3+} and H^+) was analyzed using 1N KCl as extractant and quantified by titrating the extract with 0.1 N NaOH (Thomas, 1982). Effective cation exchange capacity was calculated by summing up the amount of the exchangeable bases (k, Mg, Ca and Na) and total acidity (Al^{3+} and H^+). Extractable micronutrients were extracted using DPTA extraction and were determined using Atomic Absorption Spectroscopy method.

Analyses and Interpretation of Data

The fertility status of the soils were compared or matched with the optimum soil requirements for crop production.

Results and discussion

Soil Fertility Status of Soils Derived From Sedimentary Rocks In Samar

Fertility evaluation is based on examination and analysis of the morpho-physical and chemical characteristics obtained from sampled study sites. This is primarily done by matching the values of selected soil properties with published threshold of the same properties for crop growth or crop production (Landon, 1991; Schlichting *et al.*, 1995; Asio *et al.*, 2006). Moreover, Asio *et al.*, (2006) stressed that in this field; recognition of potential soil fertility constraints to the production of agricultural crops is achieved, therefore, providing essential information for the proposal of suitable soil management strategies for sustainable crop production. Furthermore, Lal (2000) stated that this practice must be in accordance with the idea that cautious assessment of soil constraints is one of the priorities to sustain agricultural production in the tropics.

Soil nutrient status

Tables 1a and 1b show the nutrient status of the studied soils, their rating, and sufficiency status of nutrients affecting agricultural production. Results reveal that all surface soils among all soil profiles are low in nutrient status like N, P and K. This is largely due to the inherent content of the parent material and anthropologic influence in the landscape. In this case, all soils are inapt for crop production due to the unavailability of most of the essential nutrients. On the other hand, most soils have high bulk density, which is unfavorable for better crop production, because it can limit crop rooting and anchorage. Presence of high amount of clay in most soil profiles having the same subangular blocky structure in most subsurface horizons but which turns hard upon drying is a limitation to crop growth during periods of dry seasons. The silty clayey and clay loam texture of soil profiles 3 and 4, respectively together with their friable granular and sub-angular blocky structure is also essential for proper diffusion of gases and water movement in the soil system. The clay content in soil profiles 1, 2 and 4 are primarily inherited from the mudstone parent material.

The potentiometric determination of soil pH (H_2O) revealed the acidic condition of the soils in the study site except soil profile 3. The low amount of available phosphorus in all soil profiles may limit soil productivity and crop production.

Table 1a. Soil nutrient status of soils from mudstones in Samar.

	Soil Profile				
	1	2	3	4	5
pH (H_2O)	5.23	5.85	8.06	5.29	6.07
CEC_{eff} (cmol kg^{-1} soil)	22.70	31.26	33.15	21.66	30.70
N %	0.12	0.10	0.09	0.13	0.13
P (mg/kg)	0.23	0.00	1.08	0.53	0.32
K (m.e/100 g)	0.001	0.001	0.001	0.001	0.002
Ca (m.e/100 g)	6.21	17.11	29.52	8.78	20.48
Mg (m.e/100 g)	11.30	13.61	3.60	8.83	10.19
Fe (mg/kg)	4.05	16.09	11.82	8.28	34.90
Mn (mg/kg)	9.23	11.49	3.58	2.56	30.11
Cu (mg/kg)	0.09	1.15	0.87	0.06	1.13
Zn (mg/kg)	0.15	0.40	0.35	0.12	0.84

Legend: 1 = Borongan, Eastern Samar; 2 = San Julian, Eastern Samar; 3 = Sulat, Eastern Samar; 4 = Taft, Eastern Samar; 5 = Jiabong, Western Samar.

Soil Suitability for Crops

The fertility status of the five profiles was evaluated by matching the values of selected soil properties with published threshold values of the same properties for crop growth or crop production (Landon, 1991; Schlichting, *et al.*, 1995).

This matching process enables one to identify potential soil fertility constraints to the production of agricultural crops, and thus provides valuable information for the design of appropriate soil management strategies for sustainable crop production, practically in problem soils.

Table 1b. Soil nutrient status of soils from mudstones in Samar.

	Soil Profile				
	1	2	3	4	5
pH (H_2O)	strongly acidic	moderately acidic	moderately alkaline	strongly acidic	slightly acidic
CEC_{eff} (cmol kg^{-1} soil)	medium	high	high	medium	high
N %	low	low	very low	low	low
P (mg/kg)	deficient	deficient	deficient	deficient	deficient
K (m.e/100 g)	deficient	deficient	deficient	deficient	deficient
Ca (m.e/100 g)	sufficient	sufficient	sufficient	sufficient	sufficient
Mg (m.e/100 g)	sufficient	sufficient	sufficient	sufficient	sufficient
Fe (mg/kg)	deficient	sufficient	sufficient	sufficient	sufficient
Mn (mg/kg)	sufficient	sufficient	sufficient	sufficient	sufficient
Cu (mg/kg)	deficient	sufficient	sufficient	deficient	sufficient
Zn (mg/kg)	deficient	deficient	deficient	deficient	sufficient

Legend: 1 = Borongan, Eastern Samar; 2 = San Julian, Eastern Samar; 3 = Sulat, Eastern Samar; 4 = Taft, Eastern Samar; 5 = Jiabong, Western Samar

Table 2 shows the soils in different profiles in the study sites vary in their fertility characteristics on the basis of the presence or absence of soil fertility constraints. All the soils possess majority of the soil fertility constraints to crop production. The clayey texture coupled by blocky structure in the subsurface horizons of all profiles that turns hard upon drying is a limitation for the soils in the entire profile. The sticky and plastic consistency of some soils poses an agricultural threat for farm operations during dry periods and in the rainy season. Specifically, profile 3 has a strongly alkaline condition, due to high $CaCO_3$ content, the pH level is also a constraint, in addition to the deficiency of the mineral nutrients P and N. Braschiet, al. (2003) reported that the precipitation of insoluble Ca-P phases is the predominant process that reduces P availability to plants for calcareous soils with a large reservoir of exchangeable Ca. Organic matter is also limited in the subsoil inhibiting microbial activities.

Table 2. Fertility and crop suitability of soils derived from sedimentary rocks in Samar.

Soil Property	Threshold value **	Soil Profile				
		1	2	3	4	5
Texture **	medium	-	-	-	-	-
Bulk density (g/cm^3)	< 1.45	+	+	+	-	-
Consistence	fr;np;ns	-	-	-	-	-
pH water	5.5-7.0	-	+	-	-	+
OM (%) **	> 3.0	-	-	-	-	-
Toatal N(%) **	> 0.2	-	-	-	-	-
Available P (mg/kg) **	> 8-11	-	-	-	-	-
Exch Ca (m.e/100 g)	> 0.40	+	+	+	+	+
Exch Mg (m.e/100 g)	> 0.50	+	+	+	+	+
Exch K (m.e/ 100 g)	>0.20	-	-	-	-	-
Avail Fe (mg/kg)	> 4.50	-	+	+	+	+
Avail Cu (mg/kg)	> 2.0	-	-	-	-	-
Avail Zn (mg/kg)	> 0.7	-	-	-	-	+

Plus sign (+) indicates that soil property is favorable for crop growth; minus sign (-), soil property is a constraint to crop growth/crop production; fr, friable; np, nonplastic; ns, nonsticky.

*It can also be called favorable value or condition.

**Based on Asio *et al*., (2006).

The results indicate that most of the fertility constraints of the soils studied is directly or indirectly related to the composition of the mudstone parent material. Mudstone soils also have physical fertility constraints aside from the nutrient imbalances coupled with the alkaline pH. Results of this study entail a more comprehensive agronomic and plant nutrition research, which will focus on all deficient mineral nutrients in sedimentary soils, in order to contribute to sustainable crop production in such soils. Soil management strategies should consider the physical and chemical characteristics and the site conditions.

Principally, the rated soil conditions and constraints are to some degree the effect of parent material and physiographic positions, which greatly control the hydrological and erosion and depositional processes. Similarly, the impacts of anthropologic activities like farming should be also considered on the degradation of soil resources. As a result, morphophysical and chemical characteristics of the soils should be considered for attempts on the provision of proper management practices. Craswell and Pushparajah (1989) emphasized that soil management should be based on a holistic approach to solve practical problems.

The inherent low fertility, acidity, and the occurrence of aluminum toxicity in most soils are a constraint to agricultural productivity. Hence, Duldado (2002) suggest application of lime, organic materials, and fertilizers would often lead to a successful crop production. In its entirety, most of the fertility constraints evaluated were found to be the combined effect of the different soil-forming factors with special focus on geomorphic positions as they affect nutrient and solute transport (Goovaerts, 2004).

Conclusions

Soils from sedimentary rocks in Samar are widespread and crop production is generally problematic in these areas apparently due to various soil constraints which may be traced primarily to the nature of parent material. This study evaluated the chemical, physical, and morphological properties of soils derived from sedimentary rocks in Samar; explain their origin, and determine their fertility status and suitability for crop production. Five soil profiles representing the dominant parent materials in the southeastern parts of Borongan-San Julain-Sulat-Taft in Eastern Samar including Jiabong, Western Samar were studied.

Results revealed that the soils studied varied in morpho-physical and chemical characteristics leading all soils to possess physical and chemical constraints to crop production. Nevertheless, the number of constraints present varied among the soils studied. All soil profiles possess a number of constraints as an indication unsuitable for crop production which is directly or indirectly influenced by their parent material; and therefore, soil management practices such as incorporation of organic matter into the soil would greatly improve the productivity of the soils.

The study revealed the dominant role of parent material in the characteristics and development of the soils derived from sedimentary rocks in Samar.

On the other hand, the results of the study would be useful for sustainable crop production and environmental conservation in the study sites. To alleviate the identified soil constraints, appropriate soil management strategies should be employed including: (a) Planting acid-tolerant crops (b) P fertilization through organic fertilization and; (c) Employing of organic soil management practices in minimizing soil compaction and increase soil organic matter content.

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